

australian cotton cooperative research centre



WEEDpak

a guide for integrated management
of weeds in cotton



Cover image:

Wide-leaf bladder ketmia
Hibiscus trionum var. *vesicarius*

DISCLAIMER

IT IS IMPORTANT TO READ THIS DISCLAIMER BEFORE USING THE MANUAL.

Australian Cotton Cooperative Research Centre, Cotton Research & Development Corporation, NSW Agriculture, University of New England, Commonwealth Scientific and Industrial Research Organisation, and Queensland Government Department of Primary Industries, by releasing and printing this manual and the information contained it, do not assume any liability for any crop loss, animal loss, public health impacts, safety or environmental hazards caused by the use of any part of the whole of this manual.

Whilst every attempt has been made to ensure the accuracy and integrity of the information and description sheets supplied in this manual, it should be understood that (due to new research information, new industry experiences, unpredictable weather and variations in the way individual growers set up equipment or have access to equipment) no warranty or guarantee is given or implied by the above organizations nor the people working for or contracted by those organisations to supply the information.

The manual does not claim to be complete and all-inclusive, but it aims to grow with the input of all who use and report on it.

Where trade names or products and equipment are used, no endorsement is intended nor is criticism implied of products not mentioned. Label information provided with chemicals regarding chemical use must be adhered to.

This manual does not contain a complete statement of all relevant legal obligations. You should seek your own legal advice as to both legislative and general legal obligations, in particular those legal obligations rising under environmental laws and the general laws of negligence.

No portion, in whole or part, of this manual may be reproduced without permission of the authors.



*Andrew and John Watson
(l to r) in a cotton crop on
their property 'Kilmarnock',
near Boggabri.*

FOREWORD

Foreword

At last! The publication of this weed management guide, 'WEEDpak', will meet a real need in the cotton industry. Many growers feel that weeds are becoming more expensive, and more difficult, to control. The weed spectrum seems to be changing for the worst and it is now appropriate that the many investigations of the weed scientists, and some grower experiences, are documented in the one publication as a practical management guide.

With this information there will still need to be a more disciplined approach to weed control to achieve growers' aims of reduced costs for weed-free cotton fields. This will entail better documentation of weeds in the previous crops in each field, planning for the control measures in the coming crop by using this guide, and a commitment to timeliness of operations.

WEEDpak covers quite a number of topics related to improving our knowledge and thus the control of our weeds. It highlights an integrated approach to weed control, stressing the need to use a range of management tools to achieve the cotton managers' aims in a modern cotton farming system. The main part of the book will deal with individual weeds, a 'best bet' management guide, the use of Roundup Ready cotton, and the potential development of resistant weeds by overuse of various herbicides including glyphosate.

Growers planning more rotations to control difficult weeds, or as a response to low cotton prices, will find sections containing weed lists, herbicide groups, plant back periods, and other important aspects of weed management.

The environmental risks of pollution by leaching and runoff will need to be understood by growers and allowed for on their farms. More structured scouting and counting of weed densities will help manage the need to reduce dependence on herbicides, particularly residuals with leaching potential.

As an important part of weed management, an identification guide will be published separately and is also available on the internet. This will complement the range of identification guides that already exist to provide one guide covering all weeds of significance to cotton. As with WEEDpak itself, further information can be incorporated when available. The format will allow new sections to be added where relevant. Needless to say the authors will welcome comments and new information.

I have been pleased to be associated with this project through the ACGRA with funding by the CRDC. The development of this publication has drawn on the considerable expertise of the weeds researchers with support from the National Cotton Extension Network.

Although cotton researchers may be contacted directly, there may be benefits to be gained by contacting your agronomist or your Cotton Industry Development Officer, to relate local knowledge and practices to this guide.

John Watson

ACGRA Weeds and Diseases Committee,
June 2002

INTRODUCING **WEED**pak

Weeds are a major problem in Australian cotton farming systems. Weeds directly impact on cotton production by competing for water, nutrients and light, they contaminate cotton fibre and cotton seed production, they act as hosts for both insects and pathogenic organisms that have adverse impacts on cotton production, they reduce the efficiency of various operations like picking and they may cause injury to field staff. The management of weeds imposes a significant cost burden on growers particularly as they aim for environmental sensitivity while reducing the risk of weeds developing herbicide resistance.

Integrated weed management (IWM) seeks to deal with these issues by combining a number of different approaches to achieve sustainable, cost effective and environmentally sensitive weed management. The WEEDpak manual has been designed to provide growers, agronomists, consultants and others with information on IWM, why IWM is so important and the tools that are available to implement an IWM strategy.

WEEDpak synthesizes the results of extensive research on IWM in Australian cotton farming systems from research over the past 13 years. The WEEDpak manual includes extensive reference material to help identify weeds, an important first step in IWM. WEEDpak then discusses a number of other issues involved with IWM including herbicide resistance, herbicides and their application, farm hygiene, the control of volunteer cotton, and weed control in rotation crops. Since the main thrust of IWM is management, WEEDpak contains sections on Roundup Ready cotton management, the management of specific problem weeds and a species-specific best bet management guide, sourced from industry consultation.

As further information becomes available, registered users of WEEDpak will receive updates, research reviews and other publications from the Australian Cotton Cooperative Research Centre's Technology Resource Centre. Sections in WEEDpak are complimentary and cross-referenced to other Australian Cotton CRC information packages such as ENTOpak, SPRAYpak, SOILpak and MACHINEpak. Growers and industry personnel are encouraged to register with the Australian Cotton CRC to ensure that they receive WEEDpak updates and other information packages.

A number of partners have sponsored the research contained in WEEDpak. These include the Cotton Research and Development Corporation (CRDC) and the Australian Cotton Cooperative Research Centre (CRC), NSW Agriculture, the University of New England (UNE), CSIRO Plant Industries and the Queensland Department of Primary Industries (DPI). This research continues as part of an on-going program to ensure that IWM continues to achieve sustainable cost-effective and environmentally responsible weed management outcomes.

Dr. Stephen Johnson
Coordinator

The following people have helped produce WEEDpak

WEEDpak Researchers:



Graham Charles,
NSW Agriculture,
Australian Cotton CRC,
Narrabri.

Graham.Charles@agric.nsw.gov.au



Stephen Johnson,
University of New England,
Australian Cotton CRC,
Narrabri.

StephenJ@mv.pi.csiro.au

Coordinator



Grant Roberts,
CSIRO Plant Industry,
Australian Cotton CRC,
Narrabri.

Grant.Roberts@csiro.au



Ian Taylor,
NSW Agriculture,
Australian Cotton CRC,
Narrabri.

Ian.Taylor@agric.nsw.gov.au

Cotton CRC WEEDpak Production Coordinator:



Leah MacKinnon

Cotton CRC WEEDpak Team:

Cathy Charles, Susan Hazlewood, Leanne Smith, Benita Inchbold, John Watson, David Larsen, Nicky Schick, Stewart Whiteside, Paul Grundy and Tracey Farrell.

Cotton CRC Extension Coordinator:

Ingrid Christiansen (QDPI, Toowoomba).

Cotton CRC Extension Team:

Mark Hickman (NSWAg Gunnedah), Leigh Jenkins (NSWAg Warren), David Kelly (QDPI Emerald), Sarah Kerlin (previously QDPI St. George), Julie O'Halloran (NSWAg Moree), Klara Schulze (NSWAg Narrabri), Annie Spora (NSWAg Narrabri), Anne Sullivan (QDPI, Goondiwindi).

Cotton Consultants & Growers in the

Macquarie, Namoi, Gwydir, Macintyre, St. George, Dawson/Callide and Emerald cotton growing areas.

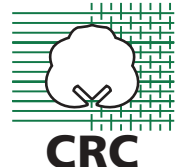
WEEDpak Reviewers:

Anne Tuart, John Watson, Lewis Wilson and Gary Fitt.

WEEDpak Layout and Production:

Visual Resources Unit, CSIRO Plant Industry

Cotton



Title	Chapter	Page
Weed Identification and Information Guide (see separate document)	A	1
Weed identification and information guide	A	2
Weed growth and development guide	A	3
Integrated Weed Management	B	1
Integrated weed management (IWM) guidelines for Australian cotton production	B	2
Managing weeds in cotton	B	3
Optimizing IWM using a weed control threshold	B	4
The critical period weed sampling sheet	B	4.1
Understanding the critical period for weed control concept	B	4.2
Applying the critical period for weed control in the field	B	4.3
Using the critical period for weed control in Roundup Ready Flex cotton	B	4.4
Using the critical period for weed control in the 2007/8 season	B	4.5
Managing weeds using the critical period for weed control	B	4.6
Sampling methods for the critical period for weed control	B	4.7
Herbicide Resistance	C	1
Managing herbicide resistance in cotton	C	2
Herbicide resistance and the crop management plan	C	3
Herbicides	D	1
Herbicides and formulation list	D	2
Spray guidelines	D	3
Roundup Ready Cotton®	E	1
Managing Roundup Ready Cotton®	E	2
Research results with Roundup Ready Cotton®	E	3
Farm Hygiene	F	1
Farm hygiene with integrated weed management	F	2
Managing weeds on roads, channels and water storages	F	3
Controlling volunteer cotton	F	4
Plant protection interactions with weeds	F	5
Best-Bet Management Guidelines	G	1
Best-bet management guidelines	G	2
Managing Problem Weeds	H	1
Managing cowvine in cotton	H	2
Managing nutgrass in cotton	H	3

Managing polymerica (take-all) in cotton	H	4
Managing bellvine in cotton	H	5
Managing caustic weed in cotton	H	6
Managing mintweed in cotton	H	7
Managing lippia in the cotton farming system	H	8
Managing flaxleaf fleabane in cotton	H	9
Rotation Crops	I	1
Herbicides for pigeon pea trap crops	I	2
Managing weeds in vetch rotation crops	I	3
Managing lucerne strips in cotton	I	4
Herbicide Damage Identification and Information Guide (see separate document)	J	1
Contents summary	J	1.1
Detailed contents	J	1.3
Herbicide damage symptoms guide	J	2
Herbicide damage information	J	3
Chlorsulfuron	J	3.1
Imazapic	J	3.4
Metsulfuron-methyl	J	3.9
Atrazine	J	3.10
Bromoxynil	J	3.11
Simazine	J	3.12
Isoxaflutole	J	3.13
2,4-D	J	3.14
Dicamba	J	3.16
Fluroxypyr	J	3.17
MCPA	J	3.18
2,4-D plus picloram (Tordon® 75D)	J	3.20
MCPA plus picloram (Tordon® 242)	J	3.22
Triclopyr plus picloram (Grazon® DS)	J	3.23
2,4-D plus glyphosate	J	3.24
Paraquat plus diquat (Spray.Seed®)	J	3.25
Glyphosate	J	3.27
Glufosinate (Liberty®)	J	3.28
Appendices	Z	1
Regional weeds of cotton	Z	2
Weeds species lists	Z	3
Further reading	Z	4
Abbreviations	Z	5
Glossary	Z	6

WEED IDENTIFICATION AND INFORMATION GUIDE

Introduction

The cotton farm can be home to a wide range of weed species. Many of these weeds are native and were present before cotton was first grown in these areas. Many more weed species, however, are introduced and have successfully established in the farming system.

Some of these weeds are of little importance, but most compete with cotton and are routinely controlled on cotton farms. When these weeds are not controlled, they may act as hosts for pests and diseases, may reduce crop yields, may impede irrigation, cultivation and harvesting operations, and may contaminate or discolour cotton lint.

Commonly, around 60 to 70 different weed species are found in cotton fields, although the weed spectrum may vary from field to field. Over 200 weed species are currently considered to be weeds of significance on cotton farms.

Positive identification and an understanding of the life cycles of these weeds is an important step in their management. Positive identification is especially important when using an integrated weed management system that includes herbicides. It is essential that herbicides are matched to their target species, matching label information on the control of specific species with a clear understanding of the weed spectrum present in a field.

Traditionally, plants have been primarily identified from their floral structure. Identification of adult plants is well covered in a host of publications. However, positive identification of weed seedlings is particularly difficult and is not covered in most publications. The **Weed Identification and Information Guide** has been designed with this difficulty in mind. A range of photographs has been included for all weeds, including pictures of cotyledon and young seedling plants. In addition, descriptions of the plants are given. These descriptions will help clarify any difficulties with identification.

This document is not complete as yet. More weed species will be added to the list as these become available. The guide is also available on the internet at <http://www.cotton.crc.org.au> and may include additional material. Just follow the links through the cotton site to **WEEDpak** and the **Weed Identification and Information Guide**.

INDEX OF WEED NAMES

Graham Charles

(NSW Agriculture)

Weeds in the **Weed identification and Information Guide** have been listed in alphabetical order by their botanical name. Grasses and sedges are listed first, followed by the broad-leaf weeds, as shown below in the **Index of Botanical Names**.

To assist with finding a weed, these weeds are also listed by their preferred common name in the **Quick Index**. The preferred common names are generally those adopted by Shepherd *et. al.* (2001).

However, an alternative preferred common name has been adopted where a weed is widely known throughout the Australian cotton industry by a

name other than the listed preferred common name. A complete listing of the weeds in the **Weed identification and Information Guide**, listed by all their recognised common names follows in the **Index of Common Names**. The preferred common names are highlighted in bold in this index.

Unknown weeds may be identified from a collection of seedling and adult pictures, or by leafing through the collection. The seedling collection has been structured with seedlings with similar leaf shapes grouped together. The adult collection places weeds in the same order as they occur in the seedling collection.

Index of Botanical Names

Botanical name	Common name	May be confused with:
Grasses and sedges		
<i>Cyperus rotundus</i>	Nutgrass	Downs nutgrass
<i>Echinochloa colona</i>	Awnless barnyard grass	Barnyard grass, Prickly barnyard grass, Hairy millet
<i>Leptochloa fusca</i>	Brown beetle grass	
<i>Urochloa panicoides</i>	Liverseed grass	
Broad-leaf weeds		
<i>Abutilon theophrasti</i>	Velvetleaf	
<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	Dwarf amaranth	Boggabri weed
<i>Ammi majus</i>	Bishop's weed	
<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	Mexican poppy	
<i>Chamaesyce drummondii</i>	Caustic weed	Red caustic weed, Hairy caustic weed
<i>Cirsium vulgare</i>	Spear thistle	
<i>Citrullus lanatus</i> var. <i>lanatus</i>	Wild melon	Colocynth, Prickly paddy melon, Watermelon
<i>Convolvulus erubescens</i>	Australian bindweed	Field bindweed
<i>Crotalaria dissitiflora</i>	Grey rattlepod	
<i>Cullen cinereum</i>	Annual verbine	
<i>Datura ferox</i>	Fierce thornapple	Common thornapple, Downy thornapple, Hairy thornapple
<i>Euphorbia davidii</i>	David's spurge	
<i>Hibiscus trionum</i> var. <i>trionum</i>	Narrow-leaf bladder ketmia	Wide-leaf bladder ketmia
<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Wide-leaf bladder ketmia	Narrow-leaf bladder ketmia
<i>Ipomoea lonchophylla</i>	Cowvine	Bellvine, Common morning glory, Silky cowvine
<i>Lamium amplexicaule</i>	Deadnettle	
<i>Medicago polymorpha</i>	Burr medic	
<i>Physalis minima</i>	Wild gooseberry	Annual ground cherry, Perennial ground cherry
<i>Polygonum aviculare</i>	Wireweed	
<i>Polymeria longifolia</i>	Polymeria	Annual polymeria
<i>Polymeria pusilla</i>	Annual polymeria	Polymeria
<i>Portulaca oleracea</i>	Pigweed	Hairy pigweed
<i>Rhynchosia minima</i>	Rhynchosia	
<i>Salsola kali</i>	Soft roly poly	
<i>Salvia reflexa</i>	Mintweed	
<i>Sesbania cannabina</i>	Sesbania pea	Budda pea, Red sesbania
<i>Sida fibulifera</i>	Pin sida	
<i>Sonchus oleraceus</i>	Common sowthistle	Rough sowthistle
<i>Trianthema portulacastrum</i>	Giant pigweed	
<i>Tribulus micrococcus</i>	Spineless caltrop	Caltrop
<i>Verbesina encelioides</i>	Wild sunflower	
<i>Xanthium italicum</i>	Italian cocklebur	Californian cocklebur, Noogoora burr
<i>Xanthium occidentale</i>	Noogoora burr	Italian cocklebur, Californian cocklebur
<i>Xanthium spinosum</i>	Bathurst burr	

Quick Index

Common names	Botanical name	May be confused with:
Grasses and sedges		
Awnless barnyard grass	<i>Echinochloa colona</i>	Barnyard grass, Prickly barnyard grass, Hairy millet
Brown beetle grass	<i>Leptochloa fusca</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Nutgrass	<i>Cyperus rotundus</i>	Downs nutgrass
Broad-leaf weeds		
Annual polymeria	<i>Polymeria pusilla</i>	Polymeria
Annual verbine	<i>Cullen cinereum</i>	
Australian bindweed	<i>Convolvulus erubescens</i>	Field bindweed
Bathurst burr	<i>Xanthium spinosum</i>	
Bishop's weed	<i>Ammi majus</i>	
Bladder ketmia	<i>Hibiscus trionum</i>	Narrow-leaf bladder ketmia, Wide-leaf bladder ketmia
Burr medic	<i>Medicago polymorpha</i>	
Caustic weed	<i>Chamaesyce drummondii</i>	Red caustic weed, Hairy caustic weed
Common sowthistle	<i>Sonchus oleraceus</i>	Rough sowthistle
Cowvine	<i>Ipomoea lonchophylla</i>	Bellvine, Common morning glory, Silky cowvine
David's spurge	<i>Euphorbia davidii</i>	
Deadnettle	<i>Lamium amplexicaule</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	Boggabri weed
Fierce thornapple	<i>Datura ferox</i>	Common thornapple, Downy thornapple, Hairy thornapple
Giant pigweed	<i>Trianthema portulacastrum</i>	
Grey rattlepod	<i>Crotalaria dissitiflora</i>	
Italian cocklebur	<i>Xanthium italicum</i>	Californian cocklebur, Noogoora burr
Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Mintweed	<i>Salvia reflexa</i>	
Narrow-leaf bladder ketmia	<i>Hibiscus trionum</i> var. <i>trionum</i>	Bladder ketmia
Noogoora burr	<i>Xanthium occidentale</i>	Italian cocklebur, Californian cocklebur
Pigweed	<i>Portulaca oleracea</i>	Hairy pigweed
Pin sida	<i>Sida fibulifera</i>	
Polymeria	<i>Polymeria longifolia</i>	Annual polymeria
Rhynchosia	<i>Rhynchosia minima</i>	
Sesbania pea	<i>Sesbania cannabina</i>	Budda pea, Red sesbania
Soft roly poly	<i>Salsola kali</i>	
Spear thistle	<i>Cirsium vulgare</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	Caltrop
Velvetleaf	<i>Abutilon theophrasti</i>	
Wide-leaf bladder ketmia	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Narrow-leaf bladder ketmia
Wild gooseberry	<i>Physalis minima</i>	Annual ground cherry, Perennial ground cherry
Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	Colocynth, Prickly paddy melon, Watermelon
Wild sunflower	<i>Verbesina encelioides</i>	
Wireweed	<i>Polygonum aviculare</i>	

Index of Common Names

Common names	Preferred common name	Botanical name	May be confused with:
Grasses and sedges			
Awnless barnyard grass		<i>Echinochloa colona</i>	Barnyard grass, Prickly barnyard grass, Hairy millet
Brown beetle grass		<i>Leptochloa fusca</i>	
Jungle rice	Awnless barnyard grass	<i>Echinochloa colona</i>	
Liverseed grass		<i>Urochloa panicoides</i>	
Nutgrass		<i>Cyperus rotundus</i>	Downs nutgrass
Nutsedge	Nutgrass	<i>Cyperus rotundus</i>	
Pale beetle grass	Brown beetle grass	<i>Leptochloa fusca</i>	
Purple nutgrass	Nutgrass	<i>Cyperus rotundus</i>	
Purple nutsedge	Nutgrass	<i>Cyperus rotundus</i>	
River grass	Awnless barnyard grass	<i>Echinochloa colona</i>	
Silvertop	Brown beetle grass	<i>Leptochloa fusca</i>	
Small-flowered beetle grass	Brown beetle grass	<i>Leptochloa fusca</i>	
Swamp grass	Awnless barnyard grass	<i>Echinochloa colona</i>	
Urochloa grass	Liverseed grass	<i>Urochloa panicoides</i>	
Zebra grass	Awnless barnyard grass	<i>Echinochloa colona</i>	
Broad-leaf weeds			
Afghan melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
American dogweed	Wild sunflower	<i>Verbesina encelioides</i>	
American jute	Velvetleaf	<i>Abutilon theophrasti</i>	
Annual polymeria		<i>Polymeria pusilla</i>	Polymeria
Annual verbine		<i>Cullen cinereum</i>	

Common names	Preferred common name	Botanical name	May be confused with:
Australian bindweed		<i>Convolvulus erubescens</i>	Field bindweed
Bastard melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Bathurst burr		<i>Xanthium spinosum</i>	
Bishop's weed		<i>Ammi majus</i>	
Bitter apple	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Bitter melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Black pigweed	Giant pigweed	<i>Trianthema portulacastrum</i>	
Black thistle	Spear thistle	<i>Cirsium vulgare</i>	
Bladder ketmia		<i>Hibiscus trionum</i>	Narrow-leaf bladder ketmia, Wide-leaf bladder ketmia
Blushing bindweed	Australian bindweed	<i>Convolvulus erubescens</i>	
Boar thistle	Spear thistle	<i>Cirsium vulgare</i>	
Bull thistle	Spear thistle	<i>Cirsium vulgare</i>	
Bullwort	Bishop's weed	<i>Ammi majus</i>	
Burr medic		<i>Medicago polymorpha</i>	
Burr trefoil	Burr medic	<i>Medicago polymorpha</i>	
Burrweed		<i>Xanthium</i> sp.	Bathurst burr, Noogoora burr
Butter daisy	Wild sunflower	<i>Verbesina encelioides</i>	
Caustic creeper	Caustic weed	<i>Chamaesyce drummondii</i>	
Caustic weed		<i>Chamaesyce drummondii</i>	Red caustic weed , Hairy caustic weed
Camel melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Chinese hemp	Velvetleaf	<i>Abutilon theophrasti</i>	
Chinese jute	Velvetleaf	<i>Abutilon theophrasti</i>	
Chinese lantern	Wild gooseberry	<i>Physalis minima</i>	
Clotburr	Noogoora burr	<i>Xanthium occidentale</i>	
Clumped bindweed	Polymeria	<i>Polymeria longifolia</i>	
Cocklebur		<i>Xanthium</i> sp.	Californian cocklebur , Italian cocklebur, Noogoora burr
Common cocklebur	Bathurst burr	<i>Xanthium spinosum</i>	
Common cowvine	Cowvine	<i>Ipomoea lonchophylla</i>	
Common pigweed	Pigweed	<i>Portulaca oleracea</i>	
Common purslane	Pigweed	<i>Portulaca oleracea</i>	
Common sowthistle		<i>Sonchus oleraceus</i>	Rough sowthistle
Cowvine		<i>Ipomoea lonchophylla</i>	Bellvine, Common morning glory, Silky cowvine
Creeping spurge	Caustic weed	<i>Chamaesyce drummondii</i>	
Crownbeard	Wild sunflower	<i>Verbesina encelioides</i>	
Crotalaria take-all	Grey rattlepod	<i>Crotalaria dissitiflora</i>	
David's spurge		<i>Euphorbia davidii</i>	
Deadnettle		<i>Lamium amplexicaule</i>	
Desert amaranth	Dwarf amaranth	<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	
Devil's fig	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Dwarf amaranth		<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	Boggabri weed
Erect bindweed	Polymeria	<i>Polymeria longifolia</i>	
European cocklebur	Noogoora burr	<i>Xanthium occidentale</i>	
False castor oil	Fierce thornapple	<i>Datura ferox</i>	
Flat Spurge	Caustic weed	<i>Chamaesyce drummondii</i>	
Fierce thornapple		<i>Datura ferox</i>	Common thornapple, Downy thornapple, Hairy thornapple
Fuller's thistle	Spear thistle	<i>Cirsium vulgare</i>	
Gloden crownbeard	Wild sunflower	<i>Verbesina encelioides</i>	
Goldweed	Wild sunflower	<i>Verbesina encelioides</i>	
Golden thistle-of-Peru	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Giant pigweed		<i>Trianthema portulacastrum</i>	
Green thistle	Spear thistle	<i>Cirsium vulgare</i>	
Grey rattlepod		<i>Crotalaria dissitiflora</i>	
Henbit	Deadnettle	<i>Lamium amplexicaule</i>	
Hoary scurfpea	Annual verbine	<i>Cullen cinereum</i>	
Hogweed	Wireweed	<i>Polygonum aviculare</i>	
Hunter burr	Italian cocklebur	<i>Xanthium italicum</i>	
Indian mallow	Velvetleaf	<i>Abutilon theophrasti</i>	
Ironweed	Wireweed	<i>Polygonum aviculare</i>	
Italian cocklebur		<i>Xanthium italicum</i>	Californian cocklebur, Noogoora burr
Jam melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Knotweed	Wireweed	<i>Polygonum aviculare</i>	
Lace-leaf sage	Mintweed	<i>Salvia reflexa</i>	
Lanternflower	Velvetleaf	<i>Abutilon theophrasti</i>	
Large cocklebur	Noogoora burr	<i>Xanthium occidentale</i>	
Long-spined thornapple	Fierce thornapple	<i>Datura ferox</i>	

Common names	Preferred common name	Botanical name	May be confused with:
Mat spurge	Caustic weed	<i>Chamaesyce drummondii</i>	
Meadowsweet	Bishop's weed	<i>Ammi majus</i>	
Mexican poppy		<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Mexican thistle	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Mickey melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Milk thistle	Common sowthistle	<i>Sonchus oleraceus</i>	
Milkweed	Caustic weed	<i>Chamaesyce drummondii</i>	
Mintweed		<i>Salvia reflexa</i>	
Narrow-leaf bladder ketmia		<i>Hibiscus trionum</i> var. <i>trionum</i>	Bladder ketmia
Nardoo	Sesbania pea	<i>Sesbania cannabina</i>	
Narrow-leaf sage	Mintweed	<i>Salvia reflexa</i>	
Native rhynchosia	Rhynchosia	<i>Rhynchosia minima</i>	
Native rock trefoil	Rhynchosia	<i>Rhynchosia minima</i>	
Native trefoil	Burr medic	<i>Medicago polymorpha</i>	
Native yellow vine	Spineless caltrop	<i>Tribulus micrococcus</i>	
Neverdie	Pigweed	<i>Portulaca oleracea</i>	
Noogoora burr		<i>Xanthium occidentale</i>	Italian cocklebur, Californian cocklebur
Paddy melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Peabush	Sesbania pea	<i>Sesbania cannabina</i>	
Peachvine	Cowvine	<i>Ipomoea lonchophylla</i>	
Peak Downs curse	Polymeria	<i>Polymeria longifolia</i>	
Perennial gooseberry	Wild gooseberry	<i>Physalis minima</i>	
Perennial pigweed	Pigweed	<i>Portulaca oleracea</i>	
Pie melon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
Pigweed		<i>Portulaca oleracea</i>	Hairy pigweed
Pink bindweed	Australian bindweed	<i>Convolvulus erubescens</i>	
Pink weed	Deadnettle	<i>Lamium amplexicaule</i>	
Pin sida		<i>Sida fibulifera</i>	
Plains rattlepod	Grey rattlepod	<i>Crotalaria dissitiflora</i>	
Polymeria		<i>Polymeria longifolia</i>	Annual polymeria
Portulaca weed	Pigweed	<i>Portulaca oleracea</i>	
Prickly burrweed	Bathurst burr	<i>Xanthium spinosum</i>	
Prickly poppy	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Prostrate knotweed	Wireweed	<i>Polygonum aviculare</i>	
Purslane	Pigweed	<i>Portulaca oleracea</i>	
Queen Anne's lace	Bishop's weed	<i>Ammi majus</i>	
Red pigweed	Pigweed	<i>Portulaca oleracea</i>	
Rhynchosia		<i>Rhynchosia minima</i>	
Rough cocklebur	Noogoora burr	<i>Xanthium occidentale</i>	
Rough medic	Burr medic	<i>Medicago polymorpha</i>	
Ryncho	Rhynchosia	<i>Rhynchosia minima</i>	
Scotch thistle	Spear thistle	<i>Cirsium vulgare</i>	
Sesbania pea		<i>Sesbania cannabina</i>	Budda pea, Red sesbania
Sheep's burr	Noogoora burr	<i>Xanthium occidentale</i>	
Silver sida	Pin sida	<i>Sida fibulifera</i>	
Soft roly poly		<i>Salsola kali</i>	
South African daisy	Wild sunflower	<i>Verbesina encelioides</i>	
Sowthistle	Common sowthistle	<i>Sonchus oleraceus</i>	
Spear thistle		<i>Cirsium vulgare</i>	
Spineless caltrop		<i>Tribulus micrococcus</i>	Caltrop
Spiny clotbur	Bathurst burr	<i>Xanthium spinosum</i>	
Spiny cocklebur	Bathurst burr	<i>Xanthium spinosum</i>	
Spurgewort	Caustic weed	<i>Chamaesyce drummondii</i>	
Stingless nettle	Deadnettle	<i>Lamium amplexicaule</i>	
Swamp Chinese lantern	Velvetleaf	<i>Abutilon theophrasti</i>	
Take-all	Polymeria	<i>Polymeria longifolia</i>	
Toothed medic	Burr medic	<i>Medicago polymorpha</i>	
Trefoil clover	Burr medic	<i>Medicago polymorpha</i>	
Thornapple		<i>Datura</i> sp.	Common thornapple, Downy thornapple, Hairy thornapple
Velvetleaf		<i>Abutilon theophrasti</i>	
Watermelon	Wild melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	
White thistle	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Wide-leaf bladder ketmia		<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Narrow-leaf bladder ketmia
Wild gooseberry		<i>Physalis minima</i>	Annual ground cherry, Perennial ground cherry
Wild melon		<i>Citrullus lanatus</i> var. <i>lanatus</i>	Colocynth, Prickly paddy melon, Watermelon
Wild mint	Mintweed	<i>Salvia reflexa</i>	
Wild sunflower		<i>Verbesina encelioides</i>	
Wireweed		<i>Polygonum aviculare</i>	
Woodnep	Bishop's weed	<i>Ammi majus</i>	
Yellow peabush	Sesbania pea	<i>Sesbania cannabina</i>	
Yellow poppy	Mexican poppy	<i>Argemone ochroleuca</i> ssp. <i>ochroleuca</i>	
Yellow vine	Spineless caltrop	<i>Tribulus micrococcus</i>	

Index of Seedlings



Liverseed grass



Awnless barnyard grass



Nutgrass



Downs nutgrass



Brown beetle grass



Soft roly poly



Indian hedge mustard



Australian carrot



Wire weed



Bishops weed



Mexican poppy



Cowvine



Bathurst burr



Noogoora burr



Italian cocklebur



Maloga bean



Fierce thornapple



Burr medic



Sesbania pea



Dwarf amaranth



Giant pigweed



Pigweed



Spineless caltrop



Wild goosberry



Grey rattlepod



Wild melon



Spear thistle



Annual polymeria



Australian bind weed



Turnip weed



Polymeria



Bladder ketmia



Deadnettle



Pin sida



Velvetleaf



Mint weed



Ryncho



Annual verbine



Caustic weed



David's spurge



Wild sunflower



Common sowthistle

Index of Adults



Liverseed grass



Awnless barnyard grass



Nutgrass



Downs nutgrass



Brown beetle grass



Soft roly poly



Indian hedge mustard



Australian carrot



Wire weed



Bishops weed



Mexican poppy



Cowvine



Bathurst burr



Noogoora burr



Italian cocklebur



Malaga bean



Fierce thornapple



Burr medic



Sesbania pea



Dwarf amaranth



Giant pigweed



Pigweed



Spineless caltrop



Wild goosberry



Grey rattlepod



Wild melon



Spear thistle



Annual polymeria



Australian bind weed



Turnip weed



Polymeria



Bladder ketmia



Deadnettle



Pin sida



Velvetleaf



Mint weed



Ryncho



Annual verbine



Caustic weed



David's spurge



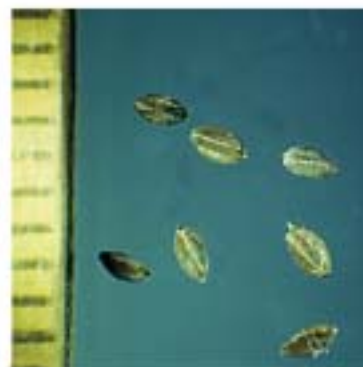
Wild sunflower



Common sowthistle

Cyperus rotundus L.

Nutgrass



Photographs: Graham Charles

Echinochloa colona (L.) Link

Awnless barnyard grass



Photographs: Graham Charles

Echinochloa colona

Family:

Poaceae (Grass family).

Common names:

Awnless barnyard grass, Barnyard grass, River grass, Swamp grass, Tiger millet, Zebra grass.

Confused with:

Barnyard grass (*Echinochloa crus-galli*), Prickly barnyard grass (*Echinochloa muricata* var. *microstachya*) and Hairy millet (*Echinochloa oryzoides*).

Description:

Seedlings - the seedling shoots are flattened and have a purple colouration at the base. Seedlings and adult plants do not have a ligule (a papery or hairy outgrowth at the leaf/stem junction) and this is a key identification point when comparing this species to other grasses.

Adult leaves - the adult leaves may have purple, red or black bands across the dull green surface. These stripes show variants within the species that are known as Tiger Millet or Zebra Grass. The leaves are hairless, 50 - 300 mm long and 3 - 10 mm wide, tapering to a fine point.

Mature plants - the plants either lay flat, or are semi-erect, tufted and 15 to 60 cm tall. The stems are slender and hairless, hollow, branched and may have a purple colouration at the base. The stems often root at the lower nodes with the nodes brown and thickened.

Seed heads - the seed head is pyramid-shaped, 40 - 150 mm long, 6 - 20 mm wide, with a number of racemes (smaller heads) that are each 7 - 40 mm long. This is in contrast to barnyard grass with racemes that are 100 mm long. The racemes of awnless barnyard grass become smaller towards the tips and the spikelets (a group of small flower heads) are formed in four irregular rows along one side of the raceme. The spikelets are 2 - 3 mm long.

Seeds - in contrast to barnyard grass, the seed covering does not have a stiff bristle-like hair (an awn) and the seed is white. The seed of barnyard grass is a pale brown.

Lifecycle/Biology:

Heavy rain, or flooding is required for germination.

An annual species that grows rapidly during the period spring to autumn.

Flowering occurs during summer and autumn, particularly in response to rain.

The seed is commonly spread in water.

Ecology:

The plant is common along stream banks, levees, irrigation channels, around waterholes and in gilgai country.

The species is found on a wide range of soils, particularly heavy grey and black soils that are periodically flooded.

The problem:

The plant grows rapidly following establishment and seeding is prolific.

The seeds are readily spread by irrigation or river water.

Awnless barnyard grass is often found growing along irrigation channels, storage banks and in cultivated fields.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. There is some debate as to whether the species is an Australian native or an introduced species.

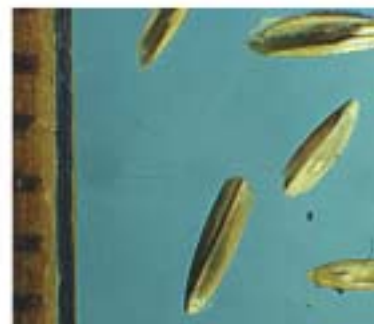
References:

Plants of Western New South Wales, p. 88 - 89, (incorrectly spelt as *Echinochloa colonum*).
Crop Weeds of Northern Australia, p. 8.

Susan Hazlewood and Stephen Johnson.

Leptochloa fusca (L.) Kunth

Brown beetle grass



Photographs: Graham Charles

Urochloa panicoides P. Beauv.

Liverseed grass



Photographs: Graham Charles

Urochloa panicoides

Family:

Poaceae (Grass family).

Common names:

Liverseed grass, Urochloa, Urochloa grass.

Confused with:

No other weeds.

Description:

Seedling leaves - the seedling leaves are yellow/green, very broad, 4 - 7 mm wide, with hairs on the leaf margins and sheaths.

Adult leaves - the adult leaves are light green to yellow/green, usually with long hairs that may be scattered or dense. The leaves are 20 - 200 mm long and 3 - 15 mm wide with crinkled or wavy leaf margins. The leaf blades expand at the point of attachment to the stem.

Mature plants - the stems either lie flat or bend upwards into an erect position, growing 15 - 80 cm high. The stems sometimes take root where the lower joints touch the ground. Plants may be tufted, or form a dense leafy mat.

Seed head - the seed head is about 10 cm long, has two to seven spikes (smaller heads) that arise off the main seed head stem. These spikes are 10 - 70 mm long. Seeds are produced in two rows along one side of each spike. The seed is produced in a spikelet (a group of small flower heads) that is 4 - 5 mm long.

Lifecycle/Biology:

An annual species that germinates in spring and summer.

Rapid growth and flowering occurs in summer.

Ecology:

The plant is found on a wide variety of soils varying from clays to sands.

The species is known to be a weed of disturbed ground, roadsides and cultivated areas.

The problem:

A troublesome weed to manage in irrigated summer crops, including cotton.

A large number of seeds are produced making management difficult.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Introduced species.

References:

Plants of Western New South Wales, p.152.
Crop Weeds of Northern Australia, p. 11.

Susan Hazlewood and Stephen Johnson.

Abutilon theophrasti Medik.

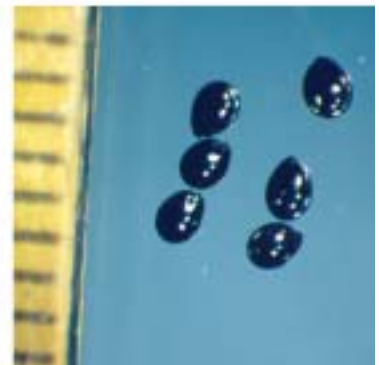
Velvetleaf



Photographs: Graham Charles

Amaranthus macrocarpus var. *pallidus* Benth.

Dwarf amaranth



Photographs: Graham Charles

Amaranthus macrocarpus

Family:

Amaranthaceae (Amaranth family).

Common names:

Dwarf amaranth, Amaranthus, Boggabri weed, Desert amaranth.

Confused with:

Boggabri Weed (*Amaranthus mitchellii*).

Description:

Seedlings - the green seedling leaves have purple leaf margins and veins.

These seedlings are more prostrate than other *Amaranthus* species, with the exception of native amaranth.

Adult leaves - these leaves are alternate, elongated oval-shaped, short and rounded but notched at the tip, 5 - 25 mm long, 4 - 13 mm wide, and have stalks 4 - 25 mm long.

Mature plants - mature plants either lie flat along the ground, or are semi-erect. The red/white stems are hairless and up to 30 cm long.

Flowers - the flowers are red/white and found in dense globular clusters in the upper leaf forks.

Seed heads - the seed head is a capsule, 3 - 5 mm long, pear-shaped, spongy and wrinkled, and either dark brown to almost black, or straw-coloured, when mature. Two varieties of this species occur in NSW, separated by the colour of the mature seed heads. Plants with black or dark brown seed heads are *Amaranthus macrocarpus* var. *macrocarpus*, while plants with straw-coloured seed heads are *Amaranthus macrocarpus* var. *pallidus*. Both varieties are commonly found throughout all cotton growing areas although *Amaranthus macrocarpus* var. *pallidus* has not been recorded in Southern NSW.

Lifecycle/Biology:

An annual species that germinates in spring and grows through summer and autumn.

Flowering commonly occurs in summer with mature seed heads formed in summer and autumn.

Ecology:

A common plant found on a wide range of soil types, particularly on clay soils but not restricted to them.

The plant is often found in depressions and in other wet areas.

The problem:

A common summer cropping weed, particularly in irrigated crops like cotton.

The weed is also common in summer fallows.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Australian native.

References:

Plants of Western New South Wales, p. 282 - 283.
Crop Weeds of Northern Australia, p. 113 - 118, (see page 118 for a comparison of *Amaranthus* seed heads).

Susan Hazlewood and Stephen Johnson.

Ammi majus L.

Bishop's weed



Photographs: Graham Charles

Argemone ochroleuca **Sweet ssp. ochroleuca**

Mexican poppy



Photographs: Graham Charles

Chamaesyce drummondii (Boiss.) D.C.Hassall

Caustic weed



Photographs: Graham Charles

Chamaesyce drummondii

Family:

Euphorbiaceae (Spurge family).

Common names:

Caustic weed, Caustic creeper, Creeping spurge, Flat spurge, Mat spurge, Milkweed, Spurgewort. Formerly named *Euphorbia drummondii*.

Confused with:

Red caustic creeper (*Chamaesyce prostrata*), and Hairy caustic weed (*Chamaesyce australis*).

Description:

Seedling leaves - dark blue/green, oblong to oval in shape with deep purple margins, 2 - 3 mm long and 2 mm wide.

Adult leaves - similar in shape but with a minute tooth near the tip, 2 - 10 mm long and 2 - 5 mm wide. The leaves are produced opposite each other on the stems. The leaves are almost stalkless.

Adult plants - hairless. The stems are red/purple and prostrate. When broken, the stems contain a white milky sap. These stems become woody at the base as they age. Plants may be produced from a thick or woody rhizome.

Flowers - the flowers are tiny, pink/white and are produced in the leaf forks.

Seed heads - the seed capsules are yellow/green, 2 - 3 mm across and have three lobes.

Lifecycle/Biology:

An annual or short-lived perennial species.

Germinates at any time of the year. Spring and summer are the main growth periods of the weed.

Plants grow up to 60 cm in diameter.

Flowering occurs in spring and summer.

Ecology:

The plant is found on a wide range of soil types and is known to be a weed of disturbed ground/cultivated fields.

The plant is drought tolerant.

The problem:

Caustic weed is difficult to control with herbicides or cultivation.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld and Central Qld. Australian native.

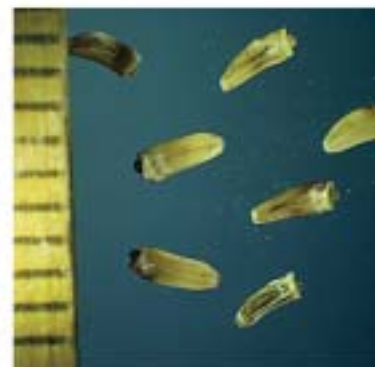
References:

Plants of Western New South Wales, p. 455 - 456.
Crop Weeds of Northern Australia, p. 93.

Stephen Johnson.

Cirsium vulgare (Savi) Ten.

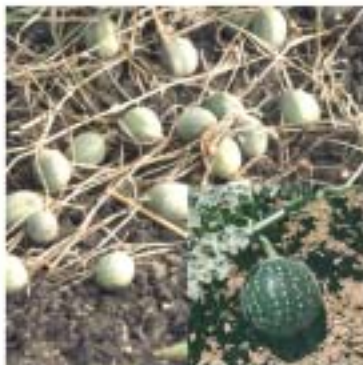
Spear thistle



Photographs: Graham Charles

Citrullus lanatus (Thunb.) Matsum. & Nakai var. *lanatus*

Wild melon



Photographs: Graham Charles

Citrullus lanatus var. *lanatus*

Family:

Cucurbitaceae (Cucumber/Melon family).

Common names:

Wild melon, Afghan melon, Bitter melon, Camel melon, Jam melon, Paddy melon, Pie melon, Watermelon.

Confused with:

Colocynth (*Citrullus colocynthis*) and Prickly paddy melon (*Cucumis myriocarpus*). The commonly cultivated watermelon is *Citrullus lanatus* var. *caffer*.

Description:

Seedling leaves - these leaves are oval shaped with a small notch at the leaf tip, 30 mm long and 20 mm wide, borne on a short stalk 3 mm long.

Early leaves - the first true leaf is roughly circular, has a long bristly stalk, wavy margins and pale veins. This leaf is notched at the base. The second true leaf is similar in shape but has three to five deep lobes.

Adult leaves - adult leaves have three to seven deep lobes, the middle lobe being the longest, the whole leaf deeply divided into crinkly lobes. The leaves are 20 - 200 mm long, 25 - 190 mm wide and are oval to heart-shaped. These leaves are generally hairless on the upper surface but have short hairs on the lower surface that make them rough to touch. There are long hairs on the leaf veins. The leaf stalk is also rough to touch, and is 20 - 120 cm long.

Mature plants - are prostrate vines, covered in long soft hairs with stems up to three metres in length that are woolly towards the tip. The long tendrils (thread-like structures at the tip of the stem) are often forked. The plant has a solid taproot with numerous lateral root branches.

Flowers - the plant produces yellow five-petalled male and female flowers, both on the same plant. The male flowers have petals that are 6 - 16 mm long, on stalks 10 - 80 mm long, while the female flowers petals are about 10 mm long on stalks 3 - 40 mm long. Both male and female flowers are 30 - 40 mm in diameter and tubular. The flowers are produced singly in the leaf axils.

Fruits - the fruits are melon-like, spherical to oblong, from 6 - 30 cm in diameter, smaller than cultivated melons, and bitter to taste. They are hairy, dark green, mottled with pale green or yellowish, long stripes, and contain a white flesh.

Seeds - initially the seeds are white but become brown with black stripes when mature. They are oval-shaped and flat, 9 - 10 mm long and 6 mm wide.

Lifecycle/Biology:

This annual weed germinates well during periods of warm weather and rainfall, often following spring and summer rains.

Growth is rapid as temperatures increase, particularly over summer. The plant dies off in autumn.

Flowers and fruits develop during summer and autumn.

The seeds are dispersed by a number of means. Dry fruit or seeds are blown by the wind or carried along in water. In addition, cultivation and other machinery disperse the seeds and fruit.

The deep taproot allows the plants to be extremely drought tolerant once established, with plants rarely dying without fruiting.

Ecology:

A common species in semi-arid areas, but also widespread throughout mainland Australia.

The plant is commonly found on sandy or flooded soils.

The weed grows along roadsides, neglected areas, watercourses, channels, and also in cultivated situations.

The density of the weed varies from year to year, probably depending on moisture availability.

The problem:

Commonly found in channels and other areas that retain soil moisture. The seeds are readily spread via irrigation water.

Dense stands will deplete the soil of water and nutrients.

The long dead stems may entangle fallow implements.

The seeds appear to remain dormant for several years.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld. Introduced species.

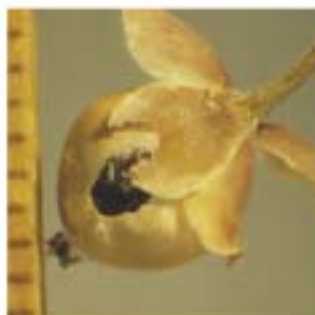
References:

Plants of Western New South Wales, p. 624 - 625.
Crop Weeds of Northern Australia, p. 145 - 146.

Stephen Johnson and Susan Hazlewood.

Convolvulus erubescens Sims

Australian bindweed



Photographs: Graham Charles & Stephen Johnson

Convolvulus erubescens

Family:

Convolvulaceae (Bindweed family).

Common names:

Australian bindweed, Australian dodder, Blushing bindweed, Pink bindweed, Morning glory.

Confused with:

Field Bindweed (*Convolvulus arvensis*).

Description:

Seedling leaves - the seedling leaves are almost square with a rounded base and a deeply notched tip, 7 mm long and 8 mm wide. This is in contrast to field bindweed, where only the seedling leaf tips are slightly notched.

Seedlings - the seedlings are initially erect, but become prostrate as they mature.

Early leaves - the first three to four true leaves are oblong, and have rounded or bluntly pointed tips.

Adult leaves - variable in shape, sometimes oblong to oval-shaped, but often shaped like an arrowhead with deeply divided lobes at the leaf base. These leaves are 15 - 55 mm long and 3 - 35 mm wide, and are borne on leaf stalks that are 5 - 30 mm long. The margins of the leaves are toothed.

Mature plants - the adult plants have hairy, prostrate, trailing or climbing stems that arise from a thick taproot. The stems may be more than one metre long and are grey to light green in colour.

Flowers - trumpet-shaped and pink or white, 12 - 18 mm in diameter and borne singly, or in groups of up to four, on slender stalks that are up to 45 mm long. The flowers are borne in the leaf forks.

Seed head - the seed head is an egg-shaped to spherical, papery capsule, 5 - 10 mm across containing four dark-brown angular seeds that are 4 mm long. The seeds may be warty, smooth, or covered in short hairs.

Lifecycle/Biology:

A perennial weed that has a thick taproot which allows it to persist during periods of low soil moisture.

Growth occurs mainly during the colder months.

The plant can flower throughout the year, but most flowering is from spring to autumn.

Seedlings emerge during spring and summer.

Ecology:

A weed of cultivated and wasteland areas, especially in high rainfall and irrigated areas. It grows on a wide variety of soil types.

The problem:

Mature plants are difficult to eradicate because they regrow from a deep tap root.

The weed also reproduces by seeds that aid in the spread of the weed to clean areas.

It is a common weed of channel banks and can become a problem in minimum tillage and dryland cotton.

Although the weed twines through the branches of surrounding cotton plants, this rarely results in difficulties for harvest machinery.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld and Central Qld. Native species.

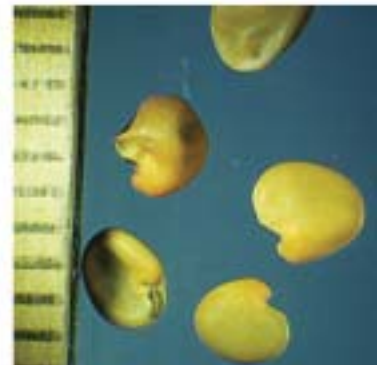
References:

Plants of Western New South Wales, p. 556.
Crop Weeds of Northern Australia, p. 126.

Annie Spora and Stephen Johnson.

Crotalaria dissitiflora Benth.

Grey rattlepod



Photographs: Graham Charles

Cullen cinereum (Lindl.) J.W. Grimes

Annual verbine



Photographs: Graham Charles

Datura ferox L.

Fierce thornapple



Photographs: Graham Charles

Datura ferox

Family:

Solanaceae (Tomato family).

Common names:

Fierce thornapple, Castor oil, False castor oil, Long-spined thornapple, Long-spurred thornapple, Thornapple.

Confused with:

Common Thornapple (*Datura stramonium*), Downy thornapple (*Datura innoxia*), and Hairy thornapple (*Datura wrightii*).

Description:

Seedling leaves - spear- or lance-shaped, 18 - 30 mm long and 4 mm wide, on stalks 2 - 4 mm long.

Seedlings - the stem is a purplish-black colour below the seedling leaves, in contrast to green stem of common thornapple.

Early leaves - the first two leaves are egg-shaped. Subsequent leaves are broadly oval, and angular to triangular in shape, with wavy, scalloped margins. These adult leaves are 8 - 17 cm long and 6 - 16 cm wide, dark green and have an unpleasant odour when crushed. The leaves tend to be borne near the branch tips.

Mature plants - grow up to two metres high and have smooth, repeatedly forked stems. These stems are green or purple towards the base and may have some hairs.

Flowers - are white to pink, trumpet shaped, up to 60 mm long. The flowers are borne singly, on short stalks in the forks of the branches.

Seed heads - are oval-shaped, 20 - 45 mm long and 15 - 35 mm in diameter. They grow upright and are covered with forty to sixty 15 - 35 mm long, sharp, stout spines. These seed heads are initially green but become brown as they mature.

Seed - the seed is black or grey and 4 - 5 mm long.

Lifecycle/Biology:

An annual summer growing species with a vigorous growth habit, particularly under wet conditions. Growth rates of two centimetres per day have been recorded.

Germination is predominantly in spring and summer.

Seeds may germinate at any time of the year from depths up to 7 - 8 cm given at least 10 mm of rainfall or irrigation.

Flowering occurs from late spring to autumn.

The seeds have a hard seed coat and considerable dormancy.

The seed is dispersed by machinery and irrigation water.

Although the plants die in the cooler months, dead plants bearing seed heads may remain standing during winter.

Natural hybrids between fierce and common thornapple occur.

Ecology:

A common weed of cultivation, particularly in summer crops and other disturbed areas.

The weed is common in regions of higher rainfall.

Widespread throughout many cotton-growing areas, but more common on lighter soils rather than heavy clays.

The problem:

A large weed that strongly competes with cotton for water, light and nutrients.

The weed can obstruct cultivation and harvesting machinery.

A common weed of fields, fallow and waste areas.

Mature plants produce allelochemicals that have an inhibitory affect on the germination and seedling growth of some crop plants.

This weed has been declared noxious in many states of Australia.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld and Central Qld. Introduced species.

References:

Plants of Western New South Wales, p. 585.
Crop Weeds of Northern Australia, p. 95 - 96.

Stephen Johnson and Annie Spora.

Euphorbia davidii Subils

David's spurge



Photographs: Graham Charles

Hibiscus trionum L. var. *trionum*

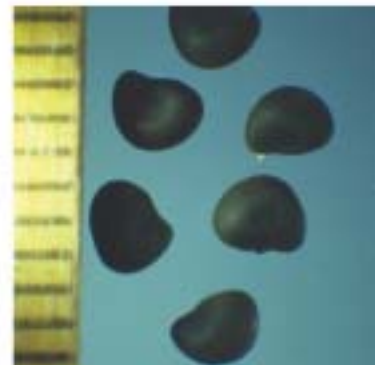
Narrow-leaf bladder ketmia



Photographs: Graham Charles

Hibiscus trionum var. *vesicarius* L.

Wide-leaf bladder ketmia



Photographs: Graham Charles

Ipomoea lonchophylla J.M.Black

Cowvine



Photographs: Graham Charles

Ipomoea lonchophylla

Family:

Convolvulaceae (Bindweed family).

Common names:

Cowvine, Common cowvine, Peachvine.

Confused with:

Bellvine (*Ipomoea plebeia*), Common morning glory (*Ipomoea purpurea*), and Silky cowvine (*Ipomoea polymorpha*).

Description:

Seedling leaves - long and v-shaped, 35 mm long by 30 mm wide.

Early leaves - the first true leaf is long and spear-shaped and subsequent leaves are triangular and have flat or notched bases and wavy margins.

Seedlings - the young stems may be purplish in colour.

Adult leaves - egg-shaped with notched bases, with margins that tend to fold inwards. This is in contrast to bellvine, that has leaf margins that do not fold inwards and a pronounced and regularly notched base. The adult leaves of cowvine are 30 - 100 mm long and 10 - 70 mm wide and are generally hairless or only slightly hairy. These leaves are borne on stalks 10 - 60 mm long.

Mature plants - have rough or smooth stems that may be up to 80 cm long and 20 cm high. The stems rarely twine, in contrast to bellvine.

Flowers - are white and trumpet-shaped, about 9 - 12 mm long. Single or paired flowers arise from the leaf forks on stalks that are 5 - 30 mm long.

Seed head - a spherical, papery capsule about 7 - 9 mm in diameter, containing three to four angular downy seeds that are 6 mm long.

Lifecycle/Biology:

A summer growing annual or biannual species.

Germination occurs all year round.

Plants can flower at only 5 cm in height.

Flowering occurs throughout the year.

Ecology:

Found on the heavy clay soils of floodplains and other cotton growing areas.

A common species throughout the coolibah woodlands and Mitchell grassland communities (some of which are now occupied by cotton growing areas).

Dense stands of the weed may occur following summer floods or heavy rains. This weed is ideally suited to irrigated fields.

The problem:

The weed is difficult to control with conventional management.

The weed reproduces by seeds and competes for light, soil water and nutrients.

A common weed of many summer growing crops including cotton.

Plants tangle in cultivation and harvesting equipment, and can block picker heads.

Distribution:

Northern NSW, Central NSW, Southern Qld and Central Qld. Native species.

References:

Plants of Western New South Wales, p. 558.
Crop Weeds of Northern Australia, p. 123 - 124.

Annie Spora and Stephen Johnson.

Lamium amplexicaule L.

Deadnettle



Photographs: Graham Charles

Medicago polymorpha L.

Burr medic



Photographs: Graham Charles

Physalis minima L.

Wild gooseberry



Photographs: Graham Charles

Physalis minima

Family:

Solanaceae (Tomato family).

Common names:

Wild gooseberry, Chinese lantern, Gooseberry, Ground cherry, Lantern, Native gooseberry.

Confused with:

Ground cherry/Annual ground cherry (*Physalis ixocarpa*), Perennial ground cherry (*Physalis virginiana*) and Apple-of-Peru (*Nicandra physalodes*).

Description:

Seedling leaves - egg-shaped and pale green, 8 mm long and 4.5 mm wide. These leaves have short stalks that are 1 mm long.

Early leaves - the first two leaves are oval, and subsequent leaves are egg-shaped with notched, wavy margins.

Adult leaves - oval with tapering tips with margins that are irregularly toothed. The leaves are 25 - 120 mm long and 12 - 60 mm wide.

Mature plants - erect, soft and pale green, 30 - 100 cm tall with spreading, bushy branches. Some small hairs may be present on the plant.

Flowers - creamy yellow with five large brown spots in the centre, cup-shaped, about 5 - 10 mm in diameter and borne singly in the forks of the leaves on stalks 15 - 25 mm long. This is in contrast to the shorter flower stalks of ground cherry that are 5 - 10 mm in length.

Seed head - the mature seed head has a yellow gooseberry-like berry, enclosed within a papery husk with ten ribs, five ribs more distinct than the other five. The papery husk is angular in cross-section, in contrast to ground cherry, that has a circular seed head in cross-section. The seed head of wild gooseberry is initially pale green, becoming pale brown to straw coloured when mature. The seed head is 22 - 30 mm long and borne on a stalk that is 12 - 25 mm long. Each seed head contains a berry.

Seed berry - 8 - 14 mm in diameter. The berries contain lense-shaped, yellow seeds.

Lifecycle/Biology:

An annual species that germinates predominantly during spring and summer and grows during summer.

Flowering occurs in summer.

Ecology:

Commonly found near rivers, growing quickly after flooding has occurred.

The problem:

The weed reproduces by seeds that aid in the spread of the weed to clean areas.

The plant removes soil water and nutrients.

Mature berries can contaminate and stain the cotton lint.

Distribution:

Northern NSW, Southern Qld, Central Qld.
Australian native.

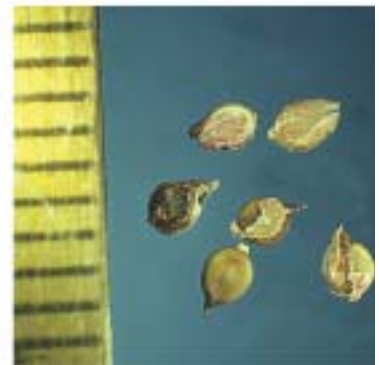
References:

Plants of Western New South Wales, p. 584 - 585 (a general section on the *Physalis* species).
Crop Weeds of Northern Australia, p. 121 - 122.

Annie Spora and Stephen Johnson.

Polygonum aviculare L.

Wireweed



Photographs: Graham Charles

Polymeria longifolia Lindl.

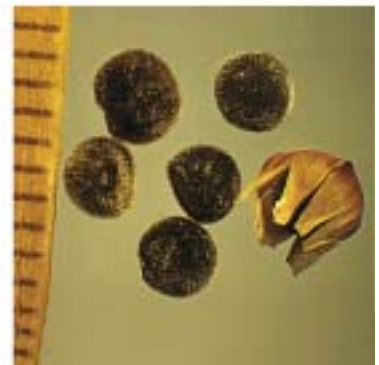
Polymeria



Photographs: Graham Charles & Stephen Johnson

Polymeria pusilla R.Br.

Annual polymeria



Photographs: Graham Charles

Polymeria pusilla

Family:

Convolvulaceae (Bindweed family).

Common names:

Annual polymeria, Polymeria.

Confused with:

Polymeria longifolia (Polymeria, Polymeria take-all, Peak Downs curse, Take-all).

Description:

Seedling leaves - the first two seedling leaves are roughly square-shaped, up to 10 mm square, but notched at the base and tip.

Early leaves - the first two true leaves are generally egg-shaped.

Adult leaves - subsequent leaves are oblong- to oval-shaped, and notched at the base, 10 - 30 mm long and 7 - 20 mm wide. The leaf stalks are 2 - 25 mm long.

Mature plants - are generally hairless. The stems run along the ground producing roots at the nodes. Adult plants rarely grow higher than 5 cm.

Flowers - are small and trumpet-shaped, 6 - 13 mm in diameter and produced over summer and autumn. The flowers are pale pink or mauve with yellow centres. Single flowers are borne on stems.

Seeds - are produced either above- or below-ground, in capsules that are 4 - 6 mm in diameter and borne on a short down-turned stem.

Lifecycle/Biology:

Although known as annual polymeria, it is a perennial species, growing all year round.

The weed grows in small circular patches, upwards in size from 20 cm in diameter.

The seed may have a considerable dormancy.

Ecology:

The plant is commonly found on the heavy clay soils that were open grassy woodland, and in areas that may be flooded seasonally.

The problem:

The weed is difficult to control with conventional management.

It reproduces by seeds that aid in the spread of the weed to clean areas.

The plant competes for soil water and nutrients.

Distribution:

Northern NSW, Southern Qld and Central Qld. Australian native.

References:

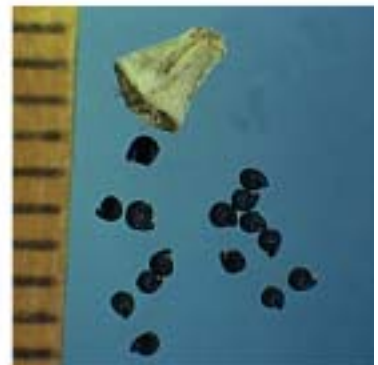
Plants of Western New South Wales, p. 558.

The *Polymeria* sp. (aff. *ambigua*) that they record as a weed of western NSW is in fact annual polymeria. Crop Weeds of Northern Australia, p. 91 - 92.

Stephen Johnson.

Portulaca oleracea L.

Pigweed



Photographs: Graham Charles

Portulaca oleracea

Family:

Portulacaceae (Portulaca family).

Common names:

Pigweed, Common pigweed, Common purslane, Neverdie, Perennial pigweed, Portulaca weed, Purslane, Red pigweed.

Confused with:

Hairy pigweed (*Portulaca pilosa*).

Description:

Seedling leaves - the seedling leaves are 6 mm long and 2 mm wide and have an elongated, oval shape and a short leaf stalk. Both the seedling and first true leaves are purple/green in colouration and have purple leaf margins.

Early leaves - the first true leaves are club shaped and waxy, 7 mm long and 4 mm wide.

Adult leaves - these leaves can be opposite each other, or alternate, and are often clustered towards the ends of the branches. Adult leaves are shiny, oblong-, wedge- or club-shaped, 5 - 25 mm long, 3 - 10 mm wide and borne on stalks 2 - 5 mm long.

Mature plants - mature plants have fleshy circular stems that lie along the ground and vary in colour from green/brown to red/brown. The stems are 30 - 40 cm long and are easily broken.

Flowers - the flowers are yellow, 8 mm across and have four to six petals that are around 4 - 7 mm long. Flowers are found in the leaf axils, are solitary, or in groups of between two and thirty flowers. The flowers remain open for only one day and then fall off to reveal a green cup that becomes the seed head capsule.

Seed head - the capsule is 3 - 6 mm long.

Seed - the red/brown or black seeds are released when the capsule top breaks off at maturity.

Lifecycle/Biology:

An annual, and sometimes perennial species that germinates in spring and summer.

Flowering occurs from August to May.

Mature seed is shed in autumn when the upper part of the seed capsule lifts off to release minute black seeds.

Dense mats of the species occur and tend to prevent the growth of other plants.

Small sections of the stem are easily broken off and transplanted elsewhere. Plants can establish and grow from these stem sections (vegetative reproduction).

Ecology:

The species has been found on a wide range of soil types and in most vegetation communities.

The problem:

A common weed in irrigated cropping, cultivated fields, along headlands, roads and channel banks.

A difficult weed to control, particularly due to the weeds vegetative reproduction.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld and Central Qld. Found throughout the world.

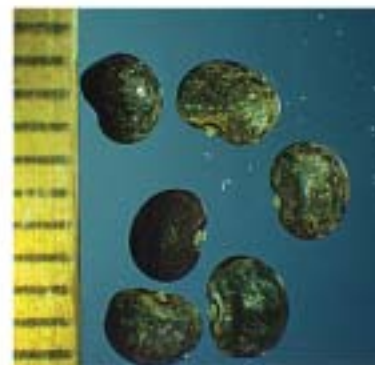
References:

Plants of Western New South Wales, p. 300.
Crop Weeds of Northern Australia, p. 70.

Susan Hazlewood and Stephen Johnson.

Rhynchosia minima (L.) DC.

Rynchosia



Photographs: Graham Charles

Salsola kali L.

Soft roly poly



Photographs: Graham Charles

Salvia reflexa Hornem.

Mintweed



Photographs: Graham Charles

Sesbania cannabina (Retz.) Pers. *Sesbania pea*



Photographs: Graham Charles

Sesbania cannabina

Family:

Fabaceae (Pea family).

Common names:

Sesbania pea, Danchi, Nardoo, Pea bush, Sesbania, Yellow pea-bush.

Confused with:

Budda pea (*Aeschynomene indica*) and Red sesbania (*Sesbania punicea*).

Some taxonomists name the species *Sesbania cannabina* as *Sesbania cannabina* var. *cannabina*.

Description:

Seedlings - the seedling leaves are oblong in shape, 10.5 - 25 mm long and 5 mm wide, borne on a very short stalk. In contrast, the seedling leaves of Budda pea are around 9 mm in length.

Early leaves - the first true leaf has an elongated oval-shape, is around 17 mm long and again borne on a very short stalk. The second true leaf has three pairs of leaflets (smaller leaves along the leaf stem). The number of leaflets increases on later leaves. The young stems and leaves often have spreading hairs. Both first true leaves of Budda pea have 5 - 6 pairs of leaflets.

Adult leaves - mature leaves are 50 - 200 mm long and are made up of a number of oblong, mostly hairy pairs of leaflets, often 12 - 30 pairs, but sometimes up to 45. Each leaflet is 5 - 20 mm long and 1.5 - 4 mm wide and has a small point on the rounded leaflet tip. In contrast, the leaflets of Budda pea are only 4 - 12 mm long.

Mature plants - the mature plant is erect, almost hairless and slender. The stems have a purple/green colouration and grow 1 - 3.5 metres tall. Adult plants have many branches, generally on the upper stem.

Flowers - the flowers are pea-like and yellow to yellow/orange, 10 - 15 mm long, with dark purplish streaks or spots on the back. The flowers occur in the leaf forks singly, or in groups of up to six, on stalks that are 5 - 40 mm long.

Seed head - the seed head is a long cylindrical pod, 120 - 200 mm long, around 2.5 - 4 mm wide, slender and drooping, olive-green to brown when ripe, with darker markings between the seeds. Each seed head or pod contains 20 - 35 smooth, oblong seeds that are 3 - 4 mm long.

Lifecycle/Biology:

An annual shrub that germinates in successive flushes in spring and summer.

Plants grow throughout summer, either as scattered individuals or in small to large stands.

Flowering occurs from late spring to early autumn.

Seeds are spread throughout fields in water and on machinery, especially on cotton pickers.

Because seeds are not produced until later in the season, timely control will prevent seed dispersal.

Dead plants often remain standing during winter, shedding seeds every time they are shaken.

Ecology:

Found most commonly on grey heavy clay soils in coolibah, black box and river gum communities on riverbanks, floodplains and in swamps.

The problem:

A common weed in the northern and central cotton growing areas, particularly on cultivated fields and in storages, channels and other wet areas.

The plant is difficult to control using current management techniques once it has attained at least 50 cm in height.

The weed has a rapid growth rate making timely control necessary.

The stems of the plant may become so thick that they need to be cut with an axe before the field can be picked.

Heavy infestations do occur in fields and may prevent picking altogether, or if not, are costly to control.

Distribution:

Northern NSW, Central NSW, Southern Qld, Central Qld. Australian native.

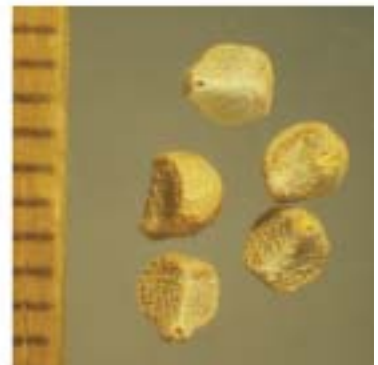
References:

Plants of Western New South Wales, p. 411 - 412.
Crop Weeds of Northern Australia, p. 75.

Stephen Johnson and Susan Hazlewood.

Sida fibulifera Lindl.

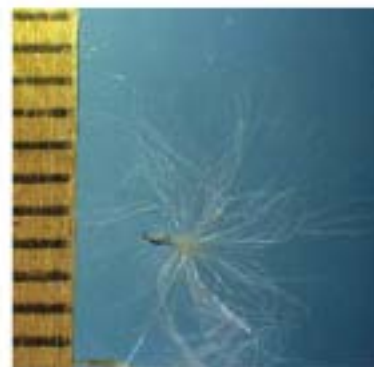
Pin sida



Photographs: Graham Charles

Sonchus oleraceus L.

Common sowthistle



Photographs: Graham Charles

Sonchus oleraceus

Family:

Asteraceae (Daisy family).

Common names:

Common sowthistle, Annual sowthistle, Common milk thistle, Milk thistle, Milkweed, Sowthistle, Thalaak.

Confused with:

Rough sowthistle/ Prickly sowthistle (*Sonchus asper* subsp. *glaucescens*)

Description:

Seedling leaves - round, 3 - 6 mm in diameter and bluish-green.

Early leaves - the first true leaf is wider than the seedling leaves, almost circular, and has a few spines on the leaf margin. The second true leaf has many backward-pointing spines.

Adult leaves - form a rosette with the lower stem leaves, similar to the rosette leaves, while the upper leaves clasp the stem and have tapering tips. The bluish-green to dark green leaves are 6 - 35 cm long and 3 - 12 cm wide. The adult leaves become increasingly lobed as they mature and are irregularly-toothed with small, soft spines. These leaves are thin and soft. The main difference between common sowthistle and prickly sowthistle is that the latter has stiffer, less divided leaves, with the spines on the leaf margins more pronounced. Intermediate forms between the two species may occur.

Mature plants - can grow up to 1.8 m. They arise from a deep taproot. When broken, both seedling and adult plants produce a milky sap.

Flowering stems - hollow, cylindrical or slightly angular, and have purple pigmentation.

Flower heads - borne on long stalks at the ends of branches. These branches arise from the upper leaf forks. These flower heads are about 5 - 18 mm long with swollen bases and a tuft of bright yellow florets at the top.

Seeds - about 2.5 - 4 mm long and 1 mm wide and brown. The seeds are light with white parachutes of silky hairs, 6 - 7 mm long.

Lifecycle/Biology:

An annual species that may grow and flower at anytime of the year. The plant is particularly abundant in winter and spring.

Flowering occurs mostly during spring.

The species reproduces by seed.

Ecology:

A common weed of cultivation that can be found on most soil types.

The problem:

This weed is an increasing problem in both irrigated cotton and dryland winter cropping systems.

Some populations of the weed collected from wheat fields around the Darling Downs, Macintyre and Gwydir valleys have resistance to herbicides containing chlorsulfuron.

Plants are more of a problem in zero-tillage fields and readily establish in retained, standing stubble.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Introduced species.

References:

Plants of Western New South Wales, p. 718.
Crop Weeds of Northern Australia, p. 53.

Annie Spora and Stephen Johnson.

Trianthema portulacastrum L.

Giant pigweed



Photographs: Graham Charles

Trianthema portulacastrum

Family:

Aizoaceae.

Common names:

Giant Pigweed, Black pigweed.

Confused with:

No other weeds.

Description:

Seedling leaves - the seedling leaves are fleshy and waxy, have an elongated oval shape and are 15 mm long by 5 mm wide.

Early leaves - the first true leaf is club-shaped, has purple margins and is borne on a short stalk about 1 mm long.

Adult leaves - are fleshy, borne opposite each other on the stem, are broadly oval-shaped, and are flattened or slightly notched at the tip. One of the pair of opposite leaves is smaller than the other, both in the seedlings and adult plants. The adult leaves have purple margins, are crinkly, 5 - 50 mm long and 5 - 45 mm wide. The leaf stalks vary in length from 2 - 35 mm and are swollen to form a cup at the base.

Mature plants - the yellow/purple stems are prostrate or ascending, are fleshy and are 50 cm or more in length. Young stems may be covered in very short hairs.

Flowers - the single pink, white or purple flowers occur in the cup-like structures in the leaf forks. The five flower lobes are each 2 - 5 mm long.

Seed head - The seed head is a capsule with an inverted-cone shape, 2 - 4 mm long. There are between 3 and 12 small round dull black seeds that are released from each capsule at maturity.

Lifecycle/Biology:

An annual plant that grows vigorously during spring and summer.

Flowering occurs in summer.

Very little else is known about the lifecycle of this plant.

Ecology:

Often found along rivers and in other damp areas.

The problem:

This weed forms dense mats in some areas, particularly during spring and summer.

A known weed of cultivation, and particularly cotton.

Distribution:

Northern NSW, Southern Qld and Central Qld. Introduced species.

References:

Crop Weeds of Northern Australia, p 71.

Susan Hazlewood and Stephen Johnson.

Tribulus micrococcus Domin

Spineless caltrop



Photographs: Graham Charles

Tribulus micrococcus

Family:

Zygophyllaceae.

Common names:

Spineless caltrop, Native yellow vine, Yellow vine.

Confused with:

Caltrop (*Tribulus terrestris*).

There has been some confusion between caltrop and spineless caltrop, and different varieties within spineless caltrop itself. Further research is required to sort out these differences.

Description:

Seedling leaves - the seedling leaves are oval-shaped, 8 mm long and 5 mm wide but have a flattened tip and are borne on stalks about 1 - 2 mm long. Seedlings grow prostrate along the ground.

Early leaves - the first and second true leaves have two and three pairs of leaflets (smaller leaves on a short stem) respectively. The number of leaflets increases on later leaves.

Adult leaves - leaves have 3 - 7 pairs of oblong-shaped leaflets that are 2 - 13 mm long and 1 - 6 mm wide. These leaves appear to shine and have hairs on the leaf margins.

Mature plants - the mature plants lie flat on the ground. The adult stems are red or purple/brown in colour and usually exceed one to two metres in length. The stem tips are covered in fine white hairs. A taproot aids in the survival of this species.

Flowers - the flowers occur singly and have five, pale yellow petals each 5 - 13 mm long. The flower diameter ranges from 11 - 25 mm.

Seed heads - the red/brown seed head is a globular burr, 7 - 10 mm wide with two short spines that spread near the tip and are 0.5 - 2.5 mm long. This is in contrast to the seed heads of caltrop that have four spines, the two divergent spines being 3 - 8 mm long.

Seeds - the five woody segments of the burr contain 1 - 3 seeds each.

Lifecycle/Biology:

An annual or perennial plant, which germinates after effective rainfall in the warmer months. There are a succession of germination events over the summer, particularly after rainfall or irrigation events.

Flowering and seed head production occurs from spring to autumn.

The burr segments protect the seeds and allow them to remain viable for many years before germinating.

Ecology:

A common plant found on clay and clay-loam soils, and a weed of disturbed situations.

The problem:

This species is less common in many cotton growing areas than caltrop and is generally easier to control.

The successive germination events of this weed make control a challenge however.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Native species.

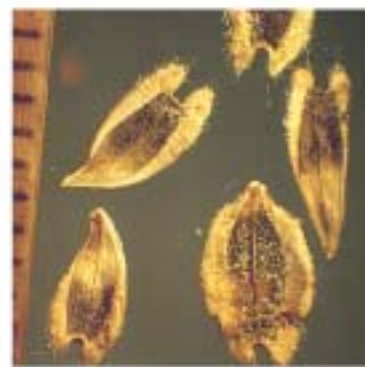
References:

Crop Weeds of Northern Australia, p. 74 (a one sentence comparison with caltrop only).

Susan Hazlewood and Stephen Johnson.

Verbesina encelioides (Cav.) A.Gray

Wild sunflower



Photographs: Graham Charles

Xanthium italicum Moretti

Italian cocklebur



Photographs: Graham Charles

Xanthium *italicum*

Family:

Asteraceae (Daisy family).

Common names:

Italian cocklebur, American cocklebur,
Cocklebur, Hunter burr.

Confused with:

Noogoora burr (*Xanthium occidentale*).

Some taxonomists recognize *Xanthium italicum* (Hunter burr), *Xanthium occidentale* (Noogoora burr), *Xanthium cavanillesii* (South American burr) and *Xanthium orientale* (Californian burr) as one variable species *Xanthium strumarium*. Many others separate the four species, as is the case here. Only the first two species occur in NSW cotton growing areas.

Description:

Seedling leaves - yellowish-green and are a narrow egg-shape, 6 - 33 mm long and 9.5 mm wide.

Early leaves - the first true leaves are egg-shaped and have toothed margins. These leaves gradually expand to become triangular in shape.

Adult leaves - very broadly egg shaped, 60 - 90 mm long, 60 - 120 mm wide, usually 3-lobed, and toothed, borne on 40 - 110 mm long stalks. The leaf lobes tend to be shallower than in Noogoora burr. Both leaf surfaces are rough to touch.

Mature plants - grow from 60 to 100 cm tall. The stems are also rough to touch.

Flower heads - the male flower head occur at the ends of branches, while the female flower heads occur in the lower parts of these branches.

Burrs - the female heads develop into hard woody, spiny burrs. These burrs are oval-shaped, brown, 20 - 30 mm long, and covered in hooked spines, around 5 mm long, with longer terminal spines, 7 mm long. These terminal spines spread apart (are divergent) and are curved in at the tips. Two seeds are produced in each burr. The burrs tend to be more densely spined than Noogoora burr. In addition the burrs of Italian cocklebur tend to be hairy. This is in contrast to the burrs of Noogoora burr, that are 7 - 20 mm long, often around 18 - 19 mm long, have spines that are only sparsely hairy, with the two terminal spines that are straight and either divergent or parallel.

Lifecycle/Biology:

An annual species that generally germinates from late winter to late summer.

Several flushes of germination may occur after rainfall and irrigation.

Flowering usually begins in February or March, regardless of plant size, continuing throughout autumn.

The burrs contain two seeds, one larger than the other. The larger seed has limited dormancy and usually germinates in the season it is produced or the following season. The smaller seed has a longer period of dormancy, and may germinate in the year following its production or later.

Hybrids between Italian cocklebur and Noogoora burr may occur.

Ecology:

A common weed of cultivation and abundant after flooding or summer rain.

The plant occurs on a wide range of soil types.

The problem:

A common weed of agricultural areas.

The weed reproduces by seeds contained in burrs that aid in the spread of the weed. These burrs float in water and care should be taken to remove plants that grow on irrigation channels and storages.

Because of the seed dormancy, the weed must be treated several times in a single season and for several seasons to achieve control.

A weed that competes strongly for light, soil water and nutrients.

The burrs of the weed can entangle the cotton lint and increase ginning costs.

Distribution:

Northern NSW, Central NSW, Southern NSW.
Introduced species.

References:

The Biology of Australian Weeds, pp. 241 - 302.

Stephen Johnson and Annie Spora.

Xanthium occidentale Bertol.

Noogoora burr



Photographs: Graham Charles

Xanthium occidentale

Family:

Asteraceae (Daisy family).

Common names:

Noogoora burr, Burrweed, Clotburr, Cockleburr, European cockleburr, Large cockleburr, Rough cockleburr, Sheep's burr.

Confused with:

Hunter burr (*Xanthium italicum*). Some taxonomists recognize *Xanthium occidentale* (Noogoora burr), *Xanthium italicum* (Italian cockleburr), *Xanthium cavanillesii* (South American Burr) and *Xanthium orientale* (Californian Burr) as one variable species *Xanthium strumarium*. Many others separate the four species, as is the case here. Only the first two species occur in NSW cotton growing areas. The species name *Xanthium pungens* and *Xanthium chinense* are less common names for *Xanthium occidentale*.

Description:

Seedling leaves - yellowish-green and a narrow egg-shape, 6 - 33 mm long and 9.5 mm wide.

Early leaves - the first true leaves are egg-shaped and have toothed margins. These leaves gradually expand to become triangular in shape.

Adult leaves - broadly egg shaped to roughly triangular and have wavy, toothed margins. These leaves are 50 - 150 mm in length and width, have irregular teeth or 3 - 5 lobes, and are borne on long purplish stalks 20 to 150 mm long. The upper leaf surface is a darker green than the lower surface. Both leaf surfaces are covered in short, rough bristles.

Mature plants - can grow to two metres or more in height. The stems are covered in rough hairs and are often tinged with purple patches or streaks. The plant has a deep taproot and an extensive lateral root system. The plants can be single- or multi-stemmed.

Flower heads - the male flower heads occur at the ends of branches while the female flower heads occur on the lower parts of these branches.

Burrs - the female flowers develop into hard, woody, spiny burrs. These burrs are oval-shaped, brown, 7 - 20 mm long, (most often around 18 - 19 mm long), 4 - 8 mm wide and covered in hooked spines, 3 - 4 mm long. There are two straight spines about 4 mm long at the end on each burr. These burrs may spread apart or be parallel. Two seeds are produced in each burr. The burr and spines are only sparsely hairy. This is in contrast to the burrs of Italian cockleburr, that are 20 - 30 mm long, have spines that tend to be hairy and have the two terminal spines that curve in at the tips.

Lifecycle/Biology:

An annual species that generally germinates from late winter to late summer. Plants can germinate from 150 mm in depth.

Several flushes of germination may occur after rainfall and irrigation.

Flowering usually begins in February or March, regardless of plant size, and continues throughout autumn.

The burrs contain two seeds, one larger than the other. The larger seed has limited dormancy, and usually germinates in the season that it is produced or the following season. The smaller seed has a longer period of dormancy, and may germinate in the year following its production, or later. Many burrs are retained on dead plants.

Hybrids between Noogoora burr and Italian cockleburr may occur.

Ecology:

A common weed of cultivated and fallow land, channels and waste areas.

The species commonly grows in low-lying areas that are subject to periodic flooding, such as rivers, creeks and alluvial floodplains. Masses of seedlings establish after flooding, forming extensive and dense stands.

The weed grows on a wide range of soil types.

The problem:

A common agricultural weed but difficult to control in many crops.

The weed reproduces by seeds. The burrs float so care should be taken to remove plants that grow on irrigation channels and water storages to minimise spread.

The weed must be treated several times in a single season and for several seasons to achieve control because of the dormancy of the seeds.

Noogoora burr competes strongly for light, soil water and nutrients.

The burrs of the weed can entangle the cotton lint and increase ginning costs.

The stems of this weed need to be chipped well below the ground, or the plants need to be pulled out, to prevent reshooting.

This weed has been declared noxious in all states of Australia.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Introduced species.

References:

Plants of Western New South Wales, p. 726 - 727.
Crop Weeds of Northern Australia, p. 138.
The Biology of Australian Weeds, pp. 241 - 302.

Stephen Johnson and Annie Spora.

Xanthium spinosum L.

Bathurst burr



Photographs: Graham Charles & Stephen Johnson

Xanthium spinosum

Family:

Asteraceae (Daisy family).

Common names:

Bathurst burr, Burrweed, Common cocklebur, Prickly burrweed, Spiny clotbur, Spiny cocklebur.

Confused with:

No other weeds.

Description:

Seedling leaves - the seedling leaves are dark green and have an elongated oval-shape, 15 - 40 mm long and 5 mm wide.

Early leaves - the first true leaves are egg-shaped, have notches on the lower part of the leaf margins and are covered in fine white hairs.

Adult leaves - have three to five irregular lobes, are dark green on the upper surface, 25 - 100 mm long and 6 - 30 mm wide, and are paler on the lower surface. These leaves are covered with fine white hairs and are borne on stalks that are up to 30 mm long. The leaves have sparse hairs and prominent white veins.

Mature plants - are compact with many branches, usually 60 to 100 cm tall. The stems of the mature plants have many yellow spines that have three branches on them. These spines are 7 - 25 mm long. One or two of these spines occur at the base of each leaf or branch. The plant has a deep taproot and an extensive lateral root system.

Flower heads - there are a few male flower heads, borne in clusters at the branch ends or in the forks of the upper leaves. Solitary female flower heads can be found in the leaf forks.

Burrs - the female heads develop into oval, brown, woody burrs, 8 -15 mm long and 4 - 5 mm wide. These burrs are covered in numerous hooked spines, to 3 mm long with two longer, straight, unequal spines at the tip of the burr.

Seeds - the two seeds are enclosed within the burrs. One of the seeds is slightly larger than the other.

Lifecycle/Biology:

An annual species with germination flushes during spring and summer after rainfall and irrigation.

Flowering and seed set generally occurs from January into autumn, although it may occur throughout the year.

Plants that emerge in late summer can produce burrs within several weeks.

Many seeds have a dormancy period of in excess of three years, longer than many other *Xanthium* species. Some freshly mature seeds have been shown to germinate immediately.

The smaller seed in the burr usually germinates in the first season after seedling while the larger seed will not germinate until several seasons later. This is in contrast to Noogoora burr.

Plants usually die in early winter. Many burrs are retained on dead plants.

Ecology:

A common weed of cultivated and fallow land, along roadsides, and in watercourse and river areas.

The plant is abundant in dense stands after flooding or summer rains and occurs on a wide range of soil types and particularly on high fertility soils.

This weed can extend further into drier areas than the other *Xanthium* species.

The problem:

A common weed but difficult to control in many leaf crops.

Because of the seed dormancy, the weed must be treated several times in a single season and for several seasons to achieve control. The burrs aid in the spread of the weed and float in water.

Bathurst burr competes strongly for light, soil water and nutrients.

The burrs of the weed can entangle the cotton lint and increase ginning costs.

Hand hoeing is an effective control measure for this weed. Plants with green seed heads should be removed from fields and burnt so that they do not contribute to the seed bank.

This weed has been declared noxious in all states of Australia.

Distribution:

Northern NSW, Central NSW, Southern NSW, Southern Qld, Central Qld. Introduced species.

References:

Plants of Western New South Wales, p. 727 - 728.
Crop Weeds of Northern Australia, p. 139.
The Biology of Australian Weeds, pp. 241 - 302.

Stephen Johnson and Anne Spora.

WEED GROWTH & DEVELOPMENT GUIDE

Graham Charles
(NSW Dept of Primary Industries)

Introduction

The data in this guide is a combination of growth cabinet, glasshouse and field observations on a range of weeds, recording characteristics such as growth rate, time to flowering and time to first mature seeds. The data set is not complete, but gives the best information currently available. Additional data will be added as it becomes available.

This data may be used as a guide to how quickly these weeds can grow and set seed in the field, giving an indication to the timing of weed management operations to prevent seed set. However, the data is a indication only, weeds may grow more or less quickly than shown in this guide, depending on environmental conditions such as temperature, soil moisture and soil nutrition. Generally, weeds will grow more slowly in cooler spring conditions and most quickly over mid-summer, provided soil moisture is not limiting. Also, weeds can be expected to grow more quickly in the northern-cotton areas and less quickly in the southern areas.

Differences in growth rate can be easily adjusted for by using the plant height as an indicator of growth stage. For example, in a field with a low density of anoda, the weed pressure might not be sufficient to require these weeds to be controlled (as indicated by the **Critical Period for Weed Control, WEEDpak section B4**). However, the information on the following page shows that the anoda is likely to start flowering about 25 days after emergence and will have mature seed around 16 days later. If the plants in the field are already around 20 - 30 cm high, then it is likely that they are already flowering and may have as many as 500 mature seeds per plant. They will need to be controlled as soon as possible. This estimation can be made even though the date of the anoda emergence is unknown and without considering the rate of growth.

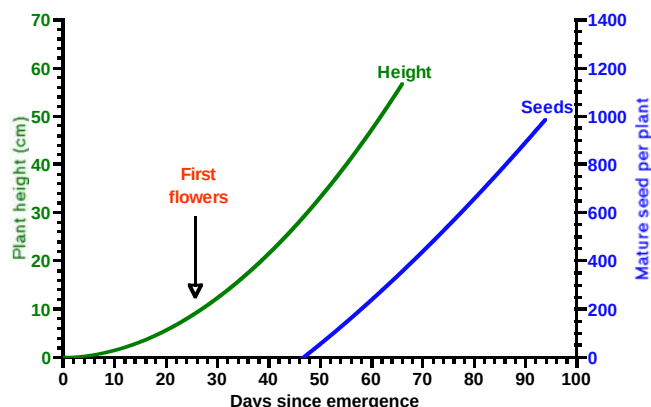
Plant height may often be a better indicator of weed maturity than the time since weed emergence. However, stressed weeds may flower and set seeds while much smaller than is indicated in this guide. If in doubt, check some plants to determine their stage of growth.

Acknowledgements

I gratefully acknowledge the input of Dr. Stephen Johnson (NSW DPI), whose research produced much of the data used to develop this guide. Thanks also go to Todd Green for the fleabane data.

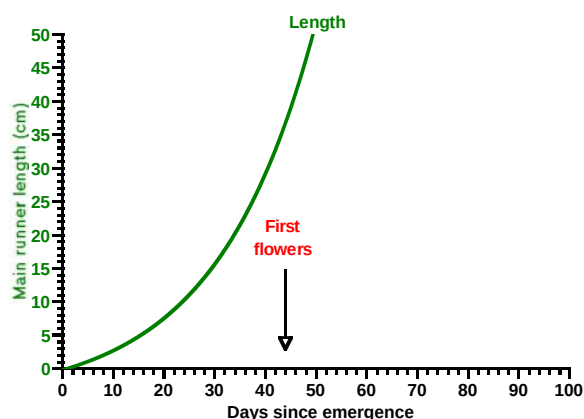
Contents	Page		
Anoda	A3.2	Cowvine	A3.5
Australian bindweed	A3.2	Dwarf amaranth	A3.5
Awnless barnyard grass	A3.2	Flaxleaf fleabane	A3.6
Bellvine	A3.3	Liverseed grass	A3.6
Blackberry nightshade	A3.3	Mintweed	A3.6
Black pigweed	A3.3	Sesbania	A3.7
Bladder ketmia – narrow leaf	A3.4	Tall fleabane	A3.7
Bladder ketmia – wide leaf	A3.4	Velvetleaf	A3.7
Budda pea	A3.4	Wild gooseberry	A3.8
Cobbler's pegs	A3.5	Yellow vine	A3.8

Anoda (*Anoda cristata*)



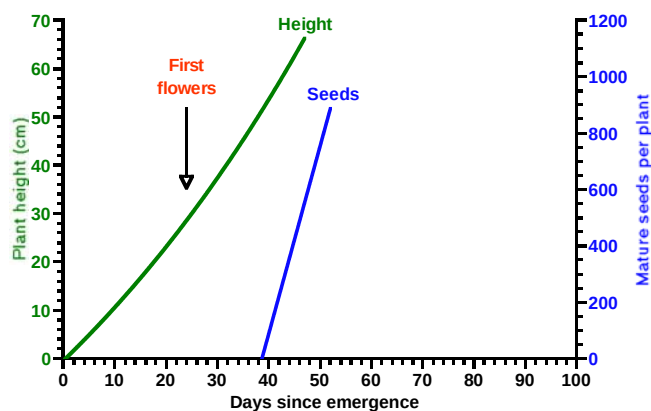
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		4 - 12
Typical emergence		20%
Depth of emergence		
First flowers		25 days
Mature pods		41 days
Seeds per pod		11 - 14
Seeds per medium plant		4000
Mature plant height		2 m
An introduced weed	☒	

Australian bindweed (*Convolvulus erubescens*)



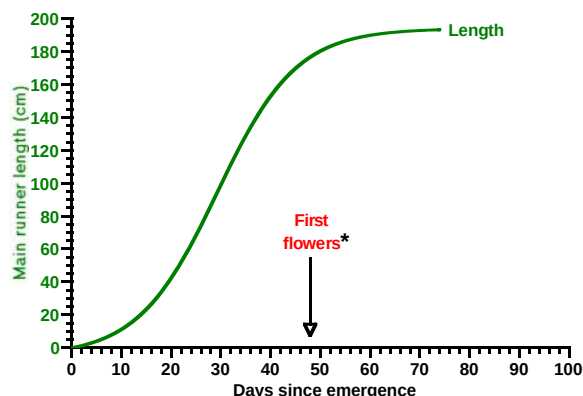
Perennial	☒	
Frost tolerant	☒	
Emergence		Autumn - spring
Days to emerge		4 - 9
Typical emergence		2%
Depth of emergence		
First flowers		44 days
Mature pods		
Seeds per pod		4
Seeds per medium plant		100
Mature plant diameter		2 m
A native plant	☒	

Awnless barnyard grass (*Echinochloa colona*)



Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		5 - 7
Typical emergence		20 - 30%
Depth of emergence		0 - 7 cm
First flowers		24 days
Mature seeds		39 days
Seeds per stem		75
Seeds per medium plant		
Mature plant height		0.6 m

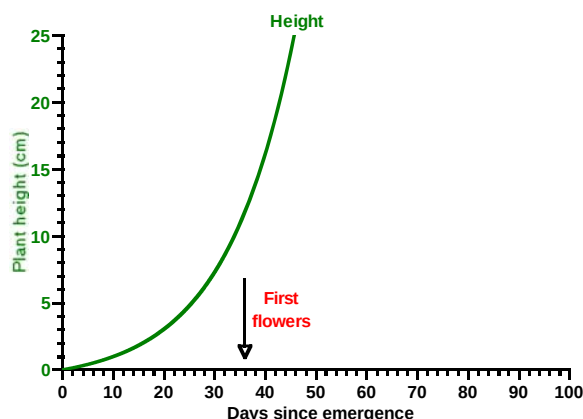
Bellvine (*Ipomoea plebeia*)



Annual	☒	
Frost sensitive	☒	
Emergence		Spring & summer
Days to emerge		4
Typical emergence		60 - 90%
Depth of emergence		2 - 4 cm
First flowers*		48 days*
Mature pods		
Seeds per pod		4
Seeds per medium plant		
Mature plant diameter		2 - 3 m
A native plant	☒	

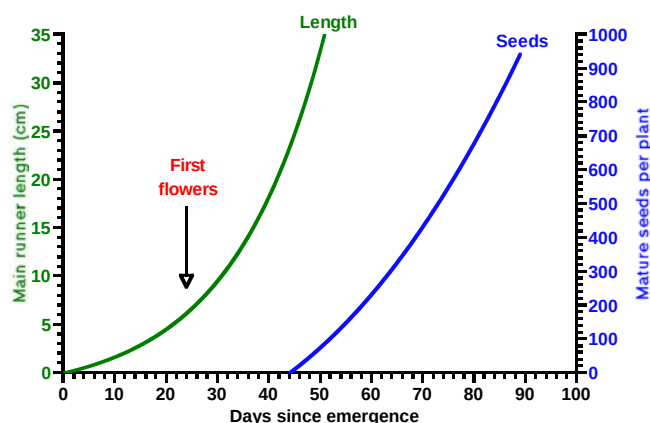
Note* Plants respond to day length and mostly flower in autumn, regardless of plant size.

Blackberry nightshade (*Solanum nigrum*)



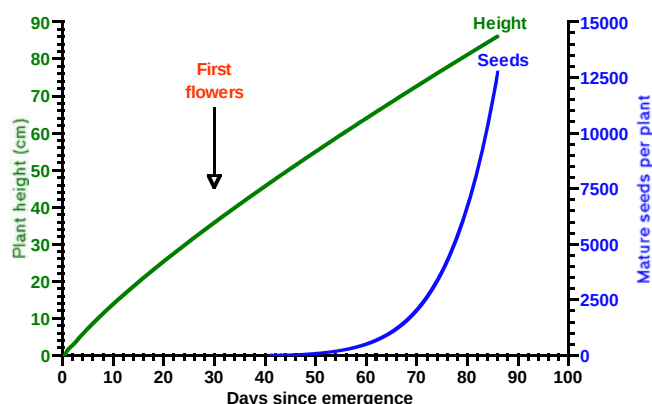
Annual	☒	or short-lived perennial	☒
Frost tolerant	☒		
Emergence			Winter - summer
Days to emerge			6 - 7
Typical emergence			30 - 90%
Depth of emergence			
First flowers			36 days
Mature pods			
Seeds per stem			
Seeds per medium plant			
Mature plant height			0.6 - 1.2 m
An introduced weed	☒		

Black pigweed (*Trianthema portulacastrum*)



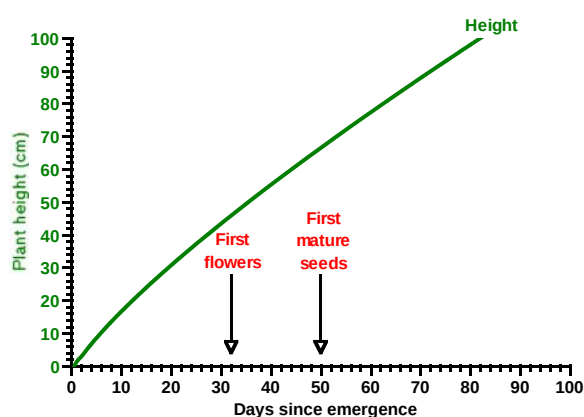
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - summer
Days to emerge		4 - 8
Typical emergence		30 - 50%
Depth of emergence		to 7 cm
First flowers		24 days
Mature pods		43 days
Seeds per pod		3 - 15
Seeds per medium plant		7000
Mature plant diameter		0.6 - 1 m
An introduced weed	☒	

Bladder ketmia – narrow leaf (*Hibiscus tridactylites*)



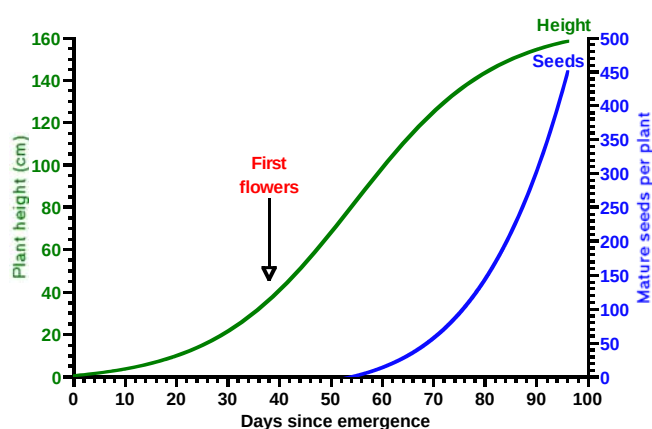
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		3 - 6
Typical emergence		1 - 10%
Depth of emergence		
First flowers		30 days
Mature seed pods		40 days
Seeds per pod		33
Seeds per medium plant		15 000
Mature plant height		1.3 m

Bladder ketmia – wide leaf (*Hibiscus verdcourtii*)



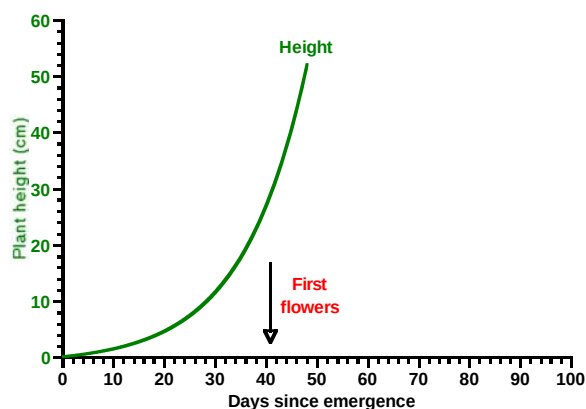
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		4 - 7
Typical emergence		1 - 10%
Depth of emergence		
First flowers		32 days
Mature seed pods		50 days
Seeds per pod		33
Seeds per medium plant		8000
Mature plant height		1.5 m

Budda pea (*Aeschynomene indica*)



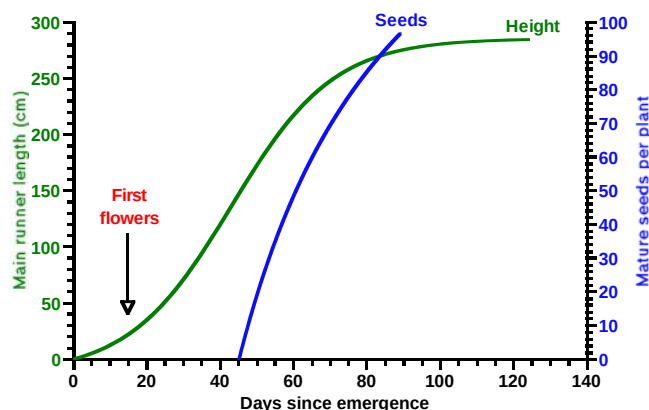
Annual	☒	or short-lived perennial	☒
Frost sensitive	☒		
Emergence			Spring & summer
Days to emerge			11
Typical emergence			20%
Depth of emergence			
First flowers			40 days
Mature seed pods			55 days
Seeds per pod			3 - 9
Seeds per medium plant			1000
Mature plant height			2 m
A native plant	☒		

Cobbler's pegs (*Bidens pilosa*)



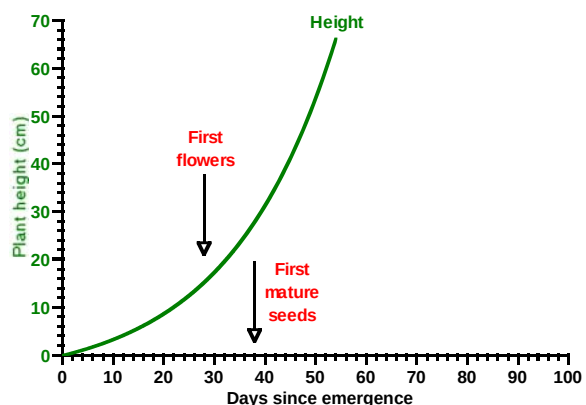
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		3 - 6
Typical emergence		70 %
Depth of emergence		
First flowers		41 days
Mature seeds		
Seeds per head		
Seeds per medium plant		
Mature plant height		1 m
An introduced weed	☒	

Cowvine - peachvine (*Ipomoea lonchophylla*)



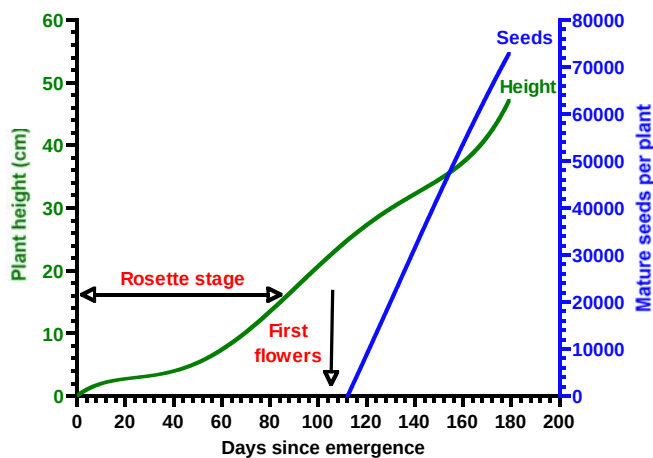
Annual	☒	or short-lived perennial	☒
Frost sensitive	☒		
Emergence			Spring - autumn
Days to emerge			4
Typical emergence			1 - 10%
Depth of emergence			5 cm
First flowers			16 days
Mature seed pods			50 days
Seeds per pod			3 - 4
Seeds per medium plant			1000
Mature plant diameter			2 - 3 m
A native plant	☒		

Dwarf amaranth (*Amaranthus macrocarpus*)



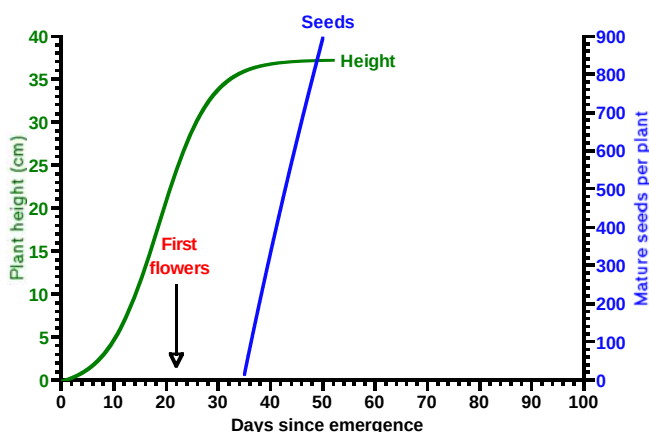
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		3 - 7
Typical emergence		10 - 50%
Depth of emergence		
First flowers		28 days
Mature seed pods		35 days
Seeds per pod		
Seeds per medium plant		
Mature plant height		0.3 m
A native plant	☒	

Flaxleaf fleabane (*Conyza bonariensis*)



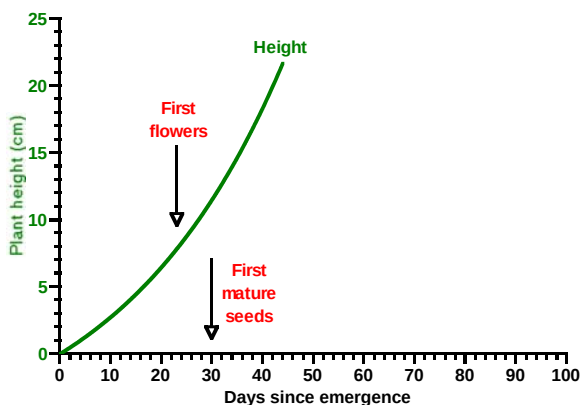
Annual	☒	
Frost tolerant	☒	
Emergence		Spring - autumn
Days to emerge		2 - 3
Typical emergence		10 - 60%
Depth of emergence		Surface only
First flowers		106 days
Mature seeds		124 days
Seeds per head		180 - 240
Seeds per medium plant		60 000 - 85 000
Mature plant height		0.4 - 1 m
Seedbank decay (50%)		3 - 9 months
An introduced weed	☒	

Liverseed grass (*Urochloa panicoides*)



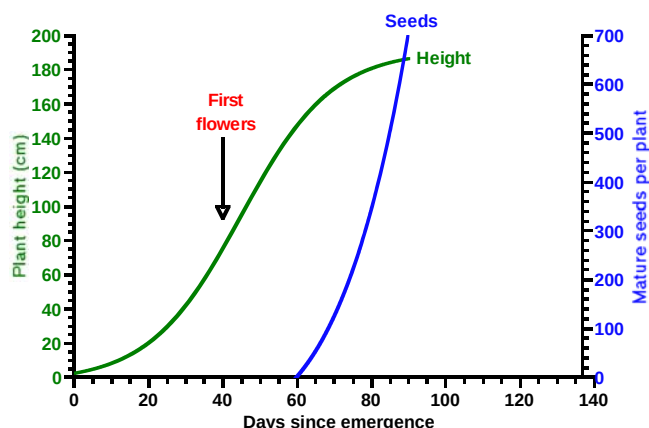
Annual	☒	
Frost sensitive	☒	
Emergence		Spring
Days to emerge		5 - 7
Typical emergence		1 - 40%
Depth of emergence		
First flowers		22 days
Mature seeds		38 days
Seeds per stem		20 - 30
Seeds per medium plant		
Mature plant height		0.6 m
An introduced grass	☒	

Mintweed (*Salvia reflexa*)



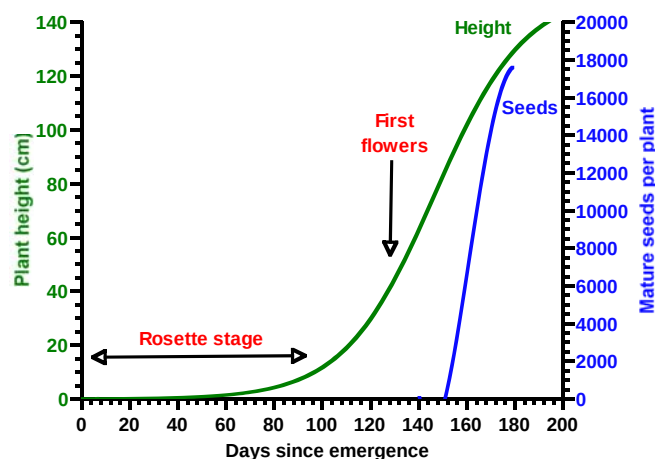
Annual	☒	
Frost tolerant	☒	
Emergence		Winter - summer
Days to emerge		7 - 15
Typical emergence		6%
Depth of emergence		
First flowers		23 days
Mature seed pods		30 days
Seeds per pod		2 - 4
Seeds per medium plant		
Mature plant height		0.7 m
An introduced weed	☒	

Sesbania (*Sesbania canabina*)



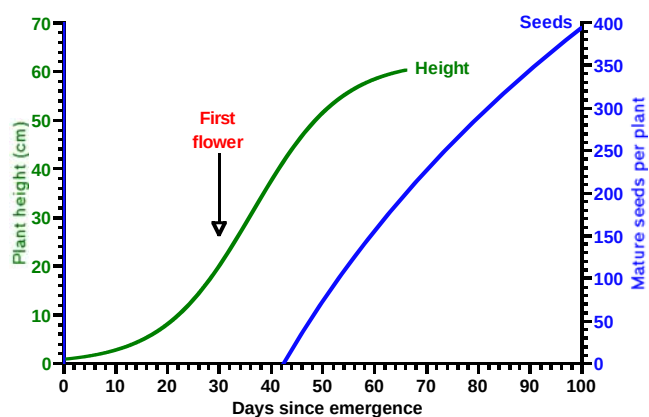
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		4 - 9
Typical emergence		5%
Depth of emergence		
First flowers		40 days
Mature seed pods		60 days
Seeds per pod		20 - 30
Seeds per medium plant		10 000 - 20 000
Mature plant height		2 - 3.5 m
A native plant	☒	

Tall fleabane (*Conyza sumatrensis*)



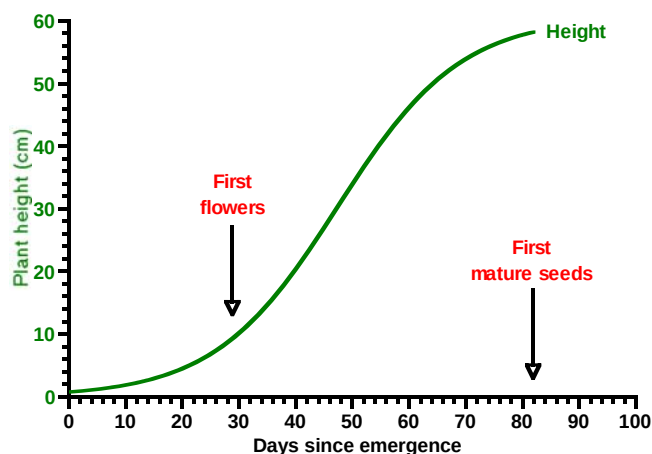
Annual	☒	or biennial	☒
Frost tolerant	☒		
Emergence			Spring - autumn
Days to emerge			2 - 3
Typical emergence			10 - 80%
Depth of emergence			Surface only
First flowers			129 days
Mature seed pods			148 days
Seeds per head			120 - 170
Seeds per medium plant			14 000 - 21 000
Mature plant height			1.2 - 2 m
Seedbank decay (50%)			3 - 8 months
An introduced weed	☒		

Velvet leaf (*Abutilon theophrasti*)



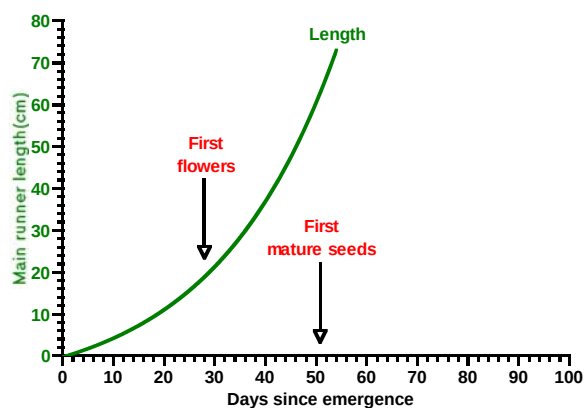
Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		3 - 7
Typical emergence		5%
Depth of emergence		
First flowers		30 days
Mature seed pods		45 days
Seeds per pod		2 - 3
Seeds per medium plant		1000 - 12 000
Mature plant height		1.4 m
An introduced weed	☒	

Wild gooseberry (*Physalis minima*)



Annual	☒	
Frost sensitive	☒	
Emergence		Spring - summer
Days to emerge		7
Typical emergence		50 - 90%
Depth of emergence		
First flowers		29 days
Mature seed pods		82 days
Seeds per pod		
Seeds per medium plant		
Mature plant height		05 - 0.8 m
A native plant	☒	

Yellow vine (*Tribulus micrococcus*)



Annual	☒	
Frost sensitive	☒	
Emergence		Spring - autumn
Days to emerge		4 - 5
Typical emergence		1 - 10%
Depth of emergence		
First flowers		28 days
Mature seed pods		51 days
Seeds per pod		10
Seeds per medium plant		10 000 - 15 000
Mature plant diameter		2 - 3 m
A native plant	☒	



INTEGRATED WEED MANAGEMENT

Introduction

The advent of insecticide resistance precipitated a radical change in insect management for Australian cotton growers. A major change was the adoption of an Integrated Pest Management (IPM) approach to managing insects. Similarly, an Integrated Weed Management (IWM) approach will need to be adopted if growers are to prevent herbicide resistance becoming a major issue in cotton. However, IWM is about more than just preventing herbicide resistance developing, it is about using multiple methods of weed control in synergy to achieve a superior outcome. The results of implementing IWM will be to reduce the reliance on herbicides, minimise the development of species shift and herbicide resistance, and reduce the impact of herbicides on the environment. An overriding theme throughout WEEDpak is the concept of IWM and how important this approach will be in the future.

The aim of this section is to introduce the concepts of IWM in detail and provide an overview of the weed management principles available for cotton production.

Contents:

B2. Integrated Weed management (IWM) Guidelines

B3 Managing Weeds in Cotton

B4 Optimising IWM Using a Weed Control Threshold

B4.1 The Critical Period Weed Sampling Sheet

B4.2 Understanding the Critical Period for Weed Control Concept

B4.3 Applying the Critical Period for Weed Control in the Field

B4.4 Using the Critical Period for Weed Control in Roundup Ready Flex® Cotton

B4.5 Using the Critical Period for Weed Control in the 2007/8 Season

B4.6 Managing Weeds Using the Critical Period for Weed Control

B4.7 Sampling Methods for the Critical Period for Weed Control

B2 Integrated Weed Management (IWM) Guidelines

This document introduces the concept of managing weeds in the cotton production system using an Integrated Weed Management (IWM) approach. It provides an understanding of why IWM will be important for the future management of weeds in Australian cotton and the importance of this concept with herbicide tolerant cotton. A summary table of weeds that have developed herbicide resistance is included, along with a table of the weeds that have developed resistance to the herbicide glyphosate. A description of the components of IWM is provided. This document will encourage cotton growers to evaluate their farm practices, review these practices in light of the IWM principles and adapt their systems to achieve improved outcomes.

B3 Managing Weeds in Cotton

A comprehensive overview of the management of weeds in cotton. This document describes the impact of weeds on the crop, common problems with weed identification and a description of the management tools that might be used for weeds in the Australian cotton system. There are summary tables on:

- Re-cropping intervals for many of the herbicides used in rotation crops,
- Residual herbicides and the weeds they control,
- Post-emergent grass herbicides, and
- Re-cropping intervals for the cotton herbicides.

A range of non-chemical management tools are also discussed. The article leads into the concept of herbicide resistance, while reiterating the importance of developing an integrated weed management system for cotton farms.

B4.1 The Critical Period Weed Sampling Sheet

This sampling sheet is used to estimate weed density in the field and determine the optimum timing of weed control using the weed control threshold developed from the critical period for weed control concept. The table of weed control thresholds and examples of weeds in the "large broad-leaf" group are shown on the reverse side. An explanation of how to use the sheet is given in section B4.7.

The assessment technique given in this sheet is due to be reviewed at the end of the 2008/9 season.

B4.2 Understanding the Critical Period for Weed Control

This document explains the theory behind the weed control threshold developed using the Critical Period for Weed control. It discusses the establishment of the economic threshold and the approach used to quantify the yield loss caused by the weeds.

A strength of the critical period for weed control concept is that it clearly defines the period during which weed control is required, and conversely, the periods during which weeds cause insufficient yield loss to justify their control. However, weeds might still need to be controlled to avoid seed production, harvesting difficulties and weed problems in later seasons.

This information is especially important for the management of relatively clean fields where weed control decisions can be difficult to make, as it may be unclear whether a weed density is sufficient to justify control.

B4.3 Applying the Critical Period for Weed Control in the Field

The critical period for weed control is a concept that relates the yield reduction caused by weed competition to an economic threshold. It establishes a period at the start of the season when weeds do not need to be controlled as they cause no economic loss, and a period at the end of the season when weeds again cause no economic loss. These periods define the middle, critical period for weed control, in which weeds must be controlled to reduce yield losses.

The relationships which define the critical period are affected by weed species, weed density and the economic threshold chosen.

This document develops this concept in the field, using real data and establishes a preliminary weed control threshold for cotton. It goes on to discuss the need to ensure that all weed control management inputs are focussed not only on maximizing crop yields but also on avoiding species shift and herbicide resistance.

B4.4 Using the Critical Period for Weed Control in Roundup Ready Flex[®] Cotton

The weed control threshold developed using the critical period for weed control approach were tested on relative dirty cotton fields at Narrabri using climatic data from the 2004/5, 2005/6 and 2006/7 seasons, using both fully irrigated and dryland scenarios. The findings from this analysis were:

- Applying the CPWC and controlling weeds within a few days of germination will minimize yield losses from weeds, while not leading to excessive herbicide use.
- Weeds that emerge after the CPWC still have to be controlled, but timing is not critical provided they are controlled before they set seed.
- Fields that have significant populations of troublesome weeds should always be treated with residual herbicides before or at planting.
- Alternative weed management tools such as inter-row cultivation and chipping can reduce the pressure on Roundup applications.
- Include a directed layby residual herbicide, incorporated with inter-row cultivation in the system.
- Consider an early layby herbicide application if seasonal conditions lead to excessive early season weed pressure.

B4.5 Using the Critical Period for Weed Control in the 2007/8 Season

The weed control threshold developed using the critical period for weed control approach were tested on clean, average and dirty cotton fields at Narrabri in the 2007/8 season, using fully irrigated and dryland scenarios. The conclusions from this analysis were:

- Using Roundup Ready Flex cotton without pre- or at-planting residual herbicides can be a sound weed management strategy in low weed pressure fields.
- Including alternative weed management tools in the system, such as inter-row cultivation, can reduce the pressure on Roundup applications.
- Including a directed layby residual herbicide, incorporated with inter-row cultivation, in the system can assist with the management of later emerging weeds and reduce the risk of species shift and herbicide resistance.
- If seasonal conditions lead to excessive early season weed pressure, an early layby herbicide application may be a valuable investment for reducing the pressure on glyphosate.
- Fields with significant populations of glyphosate tolerant or hard-to-control weeds should always be treated with residual herbicides before or at planting.

B4.6 Managing Weeds Using the Critical Period for Weed Control

This document explores the same data set as the previous document, but with an updated threshold. The threshold was changed in response to a large jump in herbicide and fuel costs during the season, necessitating the adoption of a higher economic threshold.

Data from the 2007/8 season was used to test the practicality of applying the critical period for weed control for irrigated (higher yielding) and dryland (lower yielding) cotton crops. The critical period was applied to weedy, average and clean Roundup Ready Flex[®] fields.

Applying the spraying threshold required that weed control began soon after crop emergence, while weeds were still small. A lighter herbicide rate would be appropriate for these weeds. The threshold was reached later in the dryland crop. The duration of the critical period depended on the density of weeds present.

All weed flushes were controlled using Roundup during the critical period within the constraints of the Roundup Ready Herbicide label, with an inter-row cultivation or early layby available as an additional management tool.

The results show that ensuring weeds are controlled soon after emergence is a practical approach to weed control which will help maximize crop yields. The approach can be equally applied to irrigated and dryland crops using Roundup Ready Flex, Liberty Link[®] or conventional cotton varieties.

B4.7 Sampling Methods for the Critical Period for Weed Control

A sampling method to estimate the weed population in a field is described and the system for using the sampling sheet is explained. In summary, the system is:

- Use a drive-by survey to identify patches of heavier weeds in the field
- Assess weeds in 3 - 5 of the more weedy areas (depending on field size)
- Estimate the weed type and density on a 250 m strip into the field at each assessment point
- Use these assessments to determine the Critical Period for Weed Control for this crop.
- Organise to control weeds as soon as practical if the weed flush is within the Critical Period
- If not, monitor the weeds and control them before they set seed.

INTEGRATED WEED MANAGEMENT (IWM)

Guidelines for Australian Cotton Production

Grant Roberts and Graham Charles

(CSIRO & NSW Agriculture)

Contents	Page
The impact of weeds	B2.1
What is integrated weed management (IWM)?	B2.2
Why use IWM ?	B2.3
Herbicide resistant weeds	B2.3
Why we don't have herbicide resistant weeds in Australian cotton fields	B2.4
Components of IWM in cotton	B2.4
1. Scouting	B2.4
2. Field records	B2.4
3. Accurate weed identification	B2.4
4. Closely follow herbicide recommendations	B2.4
5. Timeliness of operations	B2.4
6. Herbicide combinations and rotations	B2.4
7. Rotating herbicide groups	B2.4
8. Reducing herbicide use	B2.5
9. Herbicide tolerant cotton varieties	B2.5
10. Cultivation	B2.5
11. Shielded spraying	B2.5
12. Hand chipping	B2.5
13. Spot spraying	B2.5
14. Cropping rotations	B2.5
15. Field hygiene	B2.5
16. Cotton variety selection	B2.6
17. Planting time	B2.6
18. Irrigation management	B2.6
19. Crop competition	B2.6
20. Canopy closure	B2.6
21. Defoliation	B2.6
22. Consider the weed management system	B2.6
Herbicide tolerant crops – WARNING	B2.6
Summary	B2.7
Table 3. Integrated weed management for back-to-back cotton	B2.8
Table 4. Integrated weed management calendar for cotton/rotation farming system	B2.9

IWM is best practice in weed management

The impact of weeds

Weeds adversely impact cotton in many ways. Primarily, weeds compete for available nutrients, water and light. They can also directly impact cotton quality through contamination of cotton fibre or seed. Weeds may act as sources of pests or diseases that affect cotton, they may reduce irrigation, cultivation and harvesting efficiency, and they may cause physical injury to operators in cotton fields, such as bug checkers, machinery operators and irrigation staff.

Even a single weed, such as a large thornapple (*Datura ferox*) can compete strongly with cotton. The economic threshold for control by hand-chipping is approximately one thornapple per 73 m of cotton row, based purely on cotton yield reductions through competition. In addition, thornapples can host *Heliothis*, mites and verticillium wilt, they can block cultivation and harvesting equipment, and they can cause serious injury to field workers. Thornapple seeds may also contaminate cotton seed.

Weeds also impact cotton production indirectly, as the tools used to manage weeds are expensive and may adversely affect cotton to some extent. All the currently used herbicides can cause some degree of leaf or root damage to cotton. Many of the more commonly used herbicides can and on occasions do kill cotton plants if they are incorrectly applied, or if adverse weather conditions occur soon after application.

What is integrated weed management (IWM)?

IWM is about **NOT** relying on only one or two methods of weed control alone, and particularly not relying on herbicides alone. An IWM program uses a range of methods of weed control in combination so that all weeds are controlled by at least one component of the weed management system.

Ultimately, the aim of IWM is to prevent weeds setting seeds, or vegetatively reproducing, so that the weed population is reduced over time, reducing weed competition and improving crop productivity.

Weed management approaches that rely on a limited number of strategies often end up with uncontrolled weeds. The most common example of this is the repeated reliance on one or two groups of herbicides to control a target weed population. Within a weed population there is likely to be individual plants that are naturally resistant to any single herbicide. The frequency of these resistant individuals in the population is usually very low. Repeated exposure of the weed

population to a limited range of herbicides results in these resistant individuals being selected out, so that eventually a large proportion of the population is resistant to the herbicides. Eventually herbicide resistance develops such that the herbicide no longer controls the target weed.

As well as selecting for herbicide resistant weeds, the repeated use of a small number of weed management tools causes a species shift in the weed population. Weed species that are not controlled by these management tools will soon dominate the weed population, and the weed spectrum will shift towards these weeds. This species shift can result in new weed problems, with weed species that are much more difficult to control than were the original weeds.

The risk of developing these problems can be greatly reduced by using an IWM program. An IWM program may be conceptualised as shown below (Figure 1). All the individual components of the system contribute to a total weed management system.

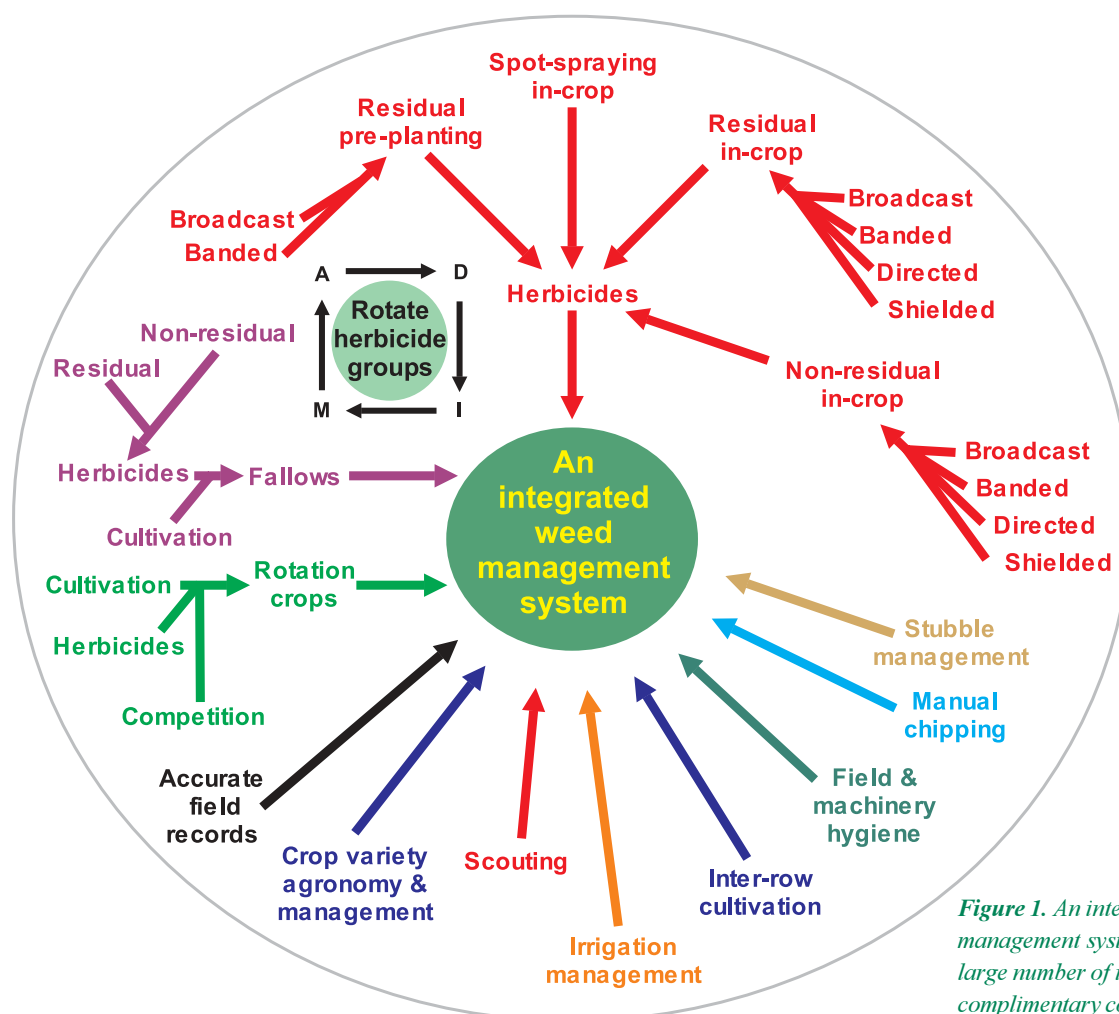


Figure 1. An integrated weed management system uses a large number of interrelated, complimentary components.

Why Use IWM?

Using an IWM program throughout the entire cotton rotation, including rotation crops and fallows, will:

- reduce the reliance on herbicides,
- reduce the risk of herbicide resistance developing in the weed spectrum and prolong the usefulness of the available herbicides,
- reduce the rate of shift in the weed spectrum towards more herbicide tolerant weeds,
- reduce the risk of herbicides accumulating in the soil and riverine systems, and
- reduce the total weed control costs in the future by reducing the weed seed bank (the number of weed seeds in the soil).

Although all these outcomes are important, the evolution of herbicide resistant weeds is a threat that has already had a major deleterious impact on many other cropping systems in Australia and elsewhere.

Herbicide resistant weeds

Currently, there are 156 weed species and 257 biotypes that have developed resistance to herbicides worldwide. Resistant species occur in 53 different countries.

A total of 37 weed species have developed resistance to a range of herbicides in Australia, some of which are shown in Table 1. Many of these weeds are cross-resistant to a range of herbicides. Cross-resistance occurs when a weed develops a mechanism of resistance to one herbicide that makes it resistant to other herbicides within the same or a different herbicide group.

Some weeds also have multiple resistance, with a single plant containing more than one resistance mechanism, making it resistant to more than one herbicide. Weeds with multiple resistance can be very difficult to control with herbicides.

Four weed species have developed resistance to glyphosate as shown in Table 2. More weeds can be expected to develop resistance to glyphosate if it becomes the primary method of weed control in a farming system.

Table 1. Important weeds that have developed resistance to herbicides in Australia.

Weed	Species	Herbicide mode of action	Herbicide Group	Examples ¹
Wild oats	<i>Avena fatua</i> and <i>sterilis</i>	Inhibitors of acetyl coA carboxylase	A	Hoegrass
Wild turnip	<i>Brassica tournefortii</i>	Inhibitors of acetolactate synthase	B	Glean
Brome grass	<i>Bromus diandrus</i>	Inhibitors of acetyl coA carboxylase	A	Nugrass
Dirty dora	<i>Cyperus difformis</i>	Inhibitors of acetolactate synthase	B	Londax
Paterson's curse	<i>Echium plantagineum</i>	Inhibitors of acetolactate synthase	B	Logran
Black bindweed	<i>Fallopia convolvulus</i>	Inhibitors of acetolactate synthase	B	Glean
Fumitory	<i>Fumaria convolvulus</i>	Inhibitors of tubulin formation	D	trifluralin
Prickly lettuce	<i>Lactuca serriola</i>	Inhibitors of acetolactate synthase	B	Ally
Wimmera ryegrass	<i>Lolium rigidum</i>	Inhibitors of acetyl coA carboxylase	A	Glean
		Inhibitors of acetolactate synthase	B	diuron
		Inhibitors of photosystem II	C	trifluralin
		Inhibitors of tubulin formation	D	amitrole
		Inhibitors of carotenoid biosynthesis	F	glyphosate
		Inhibitors of EPSP synthase	M	Fusilade
Paradoxa grass	<i>Phalaris paradoxa</i>	Inhibitors of acetyl coA carboxylase	A	Verdict
Wild radish	<i>Raphanus raphanistrum</i>	Inhibitors of acetolactate synthase	B	Ally
		Inhibitors of photosystem II	C	atrazine
		Inhibitors of carotenoid biosynthesis	F	amitrole
Turnip weed	<i>Rapistrum rugosum</i>	Inhibitors of acetolactate synthase	B	Ally
Charlock	<i>Sinapis arvensis</i>	Inhibitors of acetolactate synthase	B	Glean
Indian hedge mustard	<i>Sisymbrium orientale</i>	Inhibitors of acetolactate synthase	B	Glean
Sowthistle	<i>Sonchus oleraceus</i>	Inhibitors of acetolactate synthase	B	Glean
Liverseed grass	<i>Urochloa panicoides</i>	Inhibitors of photosystem II	C	atrazine

(List compiled from Chris Preston, Weeds CRC, Adelaide and Ian Heap, USA 2002 www.weedscience.org)

Note¹. A complete list of product trade names is listed in the 'Herbicide and formulation list', section D1 in WEEDpak.

Table 2. Weeds that are resistant to glyphosate (Group M).

Weed	Species	Country
Annual ryegrass	<i>Lolium rigidum</i>	Australia (NSW, VIC, SA and WA), USA (California), & South Africa
Italian ryegrass	<i>Lolium multiflorum</i>	Chile
Goosegrass (crowsfoot grass)	<i>Eleusine indica</i>	Malaysia
Horseweed (Fleabanes in Australia)	<i>Conyza canadensis</i>	USA (Delaware)

(Adapted from: Ian Heap 2002 www.weedscience.org)

Why we don't have herbicide resistant weeds in Australian cotton fields

The use of a combination of different weed control methods in Australian cotton fields (IWM) has up to this point prevented the appearance of resistant weed populations. Cultivation and particularly hand hoeing have been excellent practices for preventing herbicide resistant survivors from setting seed and so preventing herbicide resistance building up. Complacency and over reliance on one type of weed control method could quickly change this situation.

Components of Integrated Weed Management in cotton:

1. Scouting

Regularly check fields (cotton and rotations), roadways, channels, irrigation storages and unused land (grazing area, areas around sheds etc.) for weeds. Ensure that areas where herbicides are used are checked soon after application. Weeds which are not controlled by a herbicide must be controlled by some other method before they are able to set seed. Weeds may need to be closely examined, as some are capable of setting seed while the weeds are still very small.

Identify and closely monitor areas where machinery such as pickers and headers breakdown, as weed seeds are often inadvertently released when panels are removed from machines during repairs.

2. Field records

Maintain records of crops and weed control methods, and effectiveness after each operation in each field, each year. This allows field rotations and the effectiveness of methods of weed control to be compared. In addition, fields with low weed pressure can be identified. Herbicide rates may be able to be reduced on these fields, and some herbicides may not be needed. Remember that glyphosate will be ineffective for controlling volunteer Roundup Ready® cotton seedlings that may emerge on fallows, roadways, etc.

3. Accurate weed identification

Ensure that weeds are correctly identified. Always be on the lookout for new weeds and if necessary seek help to get these positively identified.

4. Closely follow herbicide recommendations

No herbicide controls every weed. Ensure that the herbicide you use will control the target weeds at the rates you are using. Ensure that the appropriate wetters, correct nozzles, nozzle pressure and water volumes are used. Always consider weather conditions and never spray when there is a risk of the herbicide moving off-target.

5. Timeliness of operations

Often the timeliness of a weed control operation has the largest single influence on the effectiveness of the operation. Herbicides are far more effective on rapidly growing weeds, and may be quite ineffective in controlling stressed weeds. Weeds must always be controlled before they set seed. Cultivation may be a more cost effective option than herbicides for controlling stressed weeds.

6. Herbicide combinations and rotations

Regular use of a small range of herbicides will result in a species shift to those weeds tolerant of the herbicides used. Using several herbicides in combination, or in rotation, can be an effective way of increasing the spectrum of weeds controlled. Always adjust herbicide rates when using combinations to reflect the overall amount of herbicide used. Always ensure that the herbicides are compatible before tank-mixing.

7. Rotating herbicide groups

All herbicides are classified into groups, ranging from A to N, based on their mode of action in killing weeds. The ratings are on the label and outside of each herbicide container. Weeds repeatedly exposed to herbicide groups A and B are at high risk of developing herbicide resistance. Groups C to K have a moderate risk

level and groups L to N are low risk, although resistant weeds already exist for some of these herbicides. Rotate herbicide groups whenever possible to avoid repeated resistance selection. If this is unavoidable, then other methods of weed control must be used in combination with the herbicides. Refer to **Managing Herbicide Resistance in Cotton**, section C2 in **WEEDpak** for more information.

8. Reducing herbicide use

Select fields with low weed pressure and reduce herbicide rates or remove some herbicide applications on these fields. Reducing the exposure of weeds to herbicides is one method of reducing the selection pressure on potential herbicide resistant weeds. Limiting the use of residual herbicides will reduce the number of successive weed generations controlled by the same herbicide. Identify major weed species and use the herbicides most appropriate for these target weeds. Avoid blanket approaches without thinking about the weeds you are trying to control.

9. Herbicide tolerant cotton varieties

Consider herbicide tolerant cotton varieties to reduce the need for some residual herbicides. Substituting post-emergent herbicides for some residual herbicides allows weed management to be more responsive, only controlling weeds when they are present. Follow the label crop management guidelines for herbicide tolerant cotton, ensuring that if weed escapes are detected, these weeds are controlled before setting seed. **Herbicide resistance MUST be prevented.** Detailed information on the use of Roundup tolerant, Roundup Ready cotton, is given in Monsanto's "**Roundup Ready® Cotton technical Manual**" and in **Managing Roundup Ready Cotton**, section E2 in **WEEDpak**.

10. Cultivation

Complete broad-acre cultivation is an effective non-herbicide weed control strategy in fallows. Ensure all weed escapes are controlled. Tactically use in-crop inter-row cultivation to control furrow weeds. Tractor guidance systems can improve the accuracy of cultivation next to the plant line. Cultivating when the soil is drying out is the most successful strategy for killing weeds and will reduce the damage caused by tractor compaction and soil smearing from tillage implements. Aggressive cultivation of dry soils can be effective for controlling perennial weeds.

11. Shielded spraying

Utilise shielded sprayers with non-selective herbicides such as glyphosate and Spray.Seed® (a mixture of paraquat+diquat) to control herbicide tolerant weeds and reduce the

need for chipping and blanket herbicide applications. Weed detecting sprayers are available that can improve spray selectivity and can greatly reduce overall herbicide usage and cost, as well as reducing the risk of spray damage to the crop. This same technology can be used to great advantage in fallow spraying, making the strategic use of very high rates of two and three way herbicide mixes efficient and cost effective.

12. Hand chipping

Hand chipping is one of the most effective weed management tools for preventing the development of herbicide resistant weeds. Hand chipping is ideally suited to dealing with low densities of weeds, especially those that occur within the crop row. However, it can be prohibitively expensive if used as a main form of weed control, and is normally used to supplement inter-row cultivation or spraying. Hand chipping may be delayed until late in the season (before canopy closure) to reduce costs. This strategy relies on good scouting to ensure that weed escapes do not set seed before they are controlled.

13. Spot spraying

Spot sprayers may be used as a cheaper alternative to hand hoeing for controlling low densities of weeds in crop. Ideally, weeds should be sprayed with a relatively high rate of a herbicide from a different herbicide group to the herbicides previously used to ensure that any herbicide resistant and herbicide tolerant weeds are still controlled.

14. Cropping rotations

Strategically use rotations to help control weeds by selecting crops and/or fallows that enhance weed control in cotton. It may be useful to pick crops that allow different herbicides or methods of weed control.

Fallows provide opportunities to use different herbicide groups and non-herbicide methods of control.

15. Farm hygiene

Minimise new weeds entering fields. Clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers are worthy of special attention. Eradicate any new weeds that appear while they are still in small patches; monitor frequently for new weeds. Weed patches should be monitored over a number of seasons, as weed seeds may remain dormant in the soil for many years.

Refer to **Managing Weeds with Farm Hygiene** in **WEEDpak** for additional information.

16. Cotton variety selection

Established cotton competes strongly with weeds, shading the soil surface and extracting water and nutrients from deeper in the soil profile than is available to emerging weeds. More vigorous, taller cotton varieties are better able to compete with weeds and better suited to weedy fields.

17. Planting time

Cotton seedlings grow slowly in cool spring conditions and do not compete well with weeds at this stage. Delaying planting on weedy fields until last, gives more opportunity to control weeds that emerge prior to planting and better conditions for cotton emergence and early growth.

18. Irrigation management

Weed emergence is often stimulated by rainfall and irrigation events. Irrigation should be planned to reduce the impact of weeds by coordinating irrigation with planting, cultivation and herbicide events. Pre-irrigation allows a flush of weeds to emerge and be controlled before cotton emergence. Irrigation during the season will cause another weed flush which will need to be controlled, but will also reduce moisture stress for existing weeds, making these more easily controlled by herbicide applications.

Irrigation must be sufficiently delayed after in-crop cultivation to allow all weeds to be killed by the cultivation, but should occur soon after cultivation to reduce stress to the crop.

19. Crop competition

An evenly established, vigorously growing cotton crop can compete strongly with weeds. Factors such as uneven establishment (gappy stands) and seedling diseases reduce crop vigour, and increase the susceptibility of the crop to competition from weeds. Close attention to crop agronomy will increase crop yields and can help reduce weed problems.

20. Canopy closure

Row closure in irrigated cotton is important to maximise light interception for optimum cotton yield but also provides a very important method of minimising light for weeds growing below the crop canopy. Many weeds will fail to germinate once row closure occurs, and many small weeds will not receive enough light to compete with cotton plants.

21. Defoliation

Additional opportunities for weed control can exist at defoliation where small numbers of large weeds, such as Noogoora burrs, emerge above the crop plants later in the season. If

uncontrolled, these weeds can damage or block pickers and can reduce lint quality and contribute large numbers of seeds to the soil seed-bank. Hand removal of large weeds may be worthwhile. Alternatively, weeds can be controlled at defoliation with glyphosate (non-Roundup Ready varieties only) or Spray.Seed (ground-rig application only). Drop-Ultra can also assist with defoliation and subsequent weed control.

22. Consider the total management system

Most inputs into cotton production have some impact on weed management and should be considered as part of the IWM program. Inputs such as fertilizer applications (type, amount, position and timing), stubble retention, and even insecticide applications all impact on weed growth and management. Remember, weeds and cotton are both plants.

All inputs that affect cotton also affect weeds.

Inputs such as in-furrow insecticides, fungicides and fertilizer placement can have a large impact on the early season vigour of cotton, which in turn affects its ability to compete with weeds.

Herbicide Tolerant Crops – WARNING!

A range of herbicide tolerant crops is being developed throughout the world. Australia will see many of these crops over the next decade. Triazine and imazapic + imazapyr tolerant canola (Clearfield®) are already widely grown in Australia. There are also plans to introduce imazapic + imazapyr tolerant wheat varieties and both glyphosate and glufosinate tolerant canola varieties into Australia.

The introduction of glyphosate tolerant cotton (Roundup Ready® cotton) brings herbicide tolerance technology to cotton fields and offers both advantages and potential problems. Roundup tolerance can be a very useful tool when incorporated into an IWM program, but will lead to problems if the technology is used to replace IWM. Reliance solely on the use of glyphosate in any system will inevitably lead to a species shift and may lead to the development of glyphosate resistant weeds.

Always utilise the IWM principles when growing Roundup Ready® cotton.

Always ensure weeds that survive an application of glyphosate do **not** set seed.

It is essential that Roundup Ready® crops be scouted soon after the last Roundup application to assess whether any weeds have survived the Roundup applications (**scouting**). This must occur

before new weeds have had a chance to emerge. It is then essential that any survivors be controlled using a method other than a glyphosate application before they set seed. Survivors can be controlled by a different herbicide, cultivation or chipping (**response**).

This approach (**scouting and response**) is the most effective resistance management plan possible and should prevent the build-up of herbicide resistant weeds. It will work equally well in conventional crops, and results in a more effective and responsive weed management system.

Tables 3 and 4 are examples of the range of IWM options that should be considered with back to back plantings or cotton/rotation crop plantings.

Summary

Integrated Weed Management (IWM) is about managing weed problems now and reducing problems for the future.

The main principle behind IWM is to manage weeds by integrating different management techniques together such that each technique compliments the other. In short, it is the principle of **NOT** relying on one method of weed control alone, particularly herbicides.

The three steps involved in implementing IWM are:

- **Education.** Understanding the principles of IWM, the range of control options available, and how to use them in an appropriate combination.
- **Evaluation.** Knowing the weed spectrum on each field and developing targeted economic and sustainable management strategies
- **Implementation.** Implementing an appropriate IWM strategy.

Preventing seed set and vegetative propagation is the most effective long-term method of managing and reducing weed problems. To develop an IWM program you need to think strategically about how you as a cotton grower can best utilise all available weed control methods in combination to give the best overall result, both in-crop and in rotations and fallows. Always avoid relying on one or two methods alone. Complacency with IWM may appear to save you money in the short term but will inevitably lead to expensive problems such as herbicide resistant weeds.

IWM is best practice in weed management

Table 3. Integrated weed management calendar for back-to-back cotton. The timing of operations will vary between seasons and regions.

	Conventional or Roundup® Ready cotton								Fallow				Conventional or Roundup Ready® cotton							
Pre-emergent herbicides									eg. Trifluralin, diuron Cotogard, Stomp											
Selective post-emergent herbicides			eg. Staple, Fusilade, Verdict, Select										eg. Staple, Fusilade, Verdict, Select							
Broadacre cultivation																				
Fallow herbicides									eg. Glyphosate, Spray.Seed, 2,4-D											
At-planting herbicides	eg. Dual, Stomp Cotoran												eg. Dual, Stomp Cotoran							
Inter-row cultivation																				
In-crop directed herbicides (layby)			eg. diuron, Gesagard Roundup to flowering										eg. diuron, Gesagard Roundup to flowering							
Shielded spraying of non-selective herbicides			eg. Roundup, Spray.Seed												eg. Roundup, Spray.Seed					
Non-selective post-emergent herbicides (Roundup Ready cotton only)	Roundup (to 4 leaf only)												Roundup (to 4 leaf only)							
Hand chipping																				
Spot spraying - non-selective herbicides			eg. Roundup, SpraySeed												eg. Roundup, SpraySeed					
Cotton canopy closure																				
Defoliation (glyphosate on conventional cotton only)									eg. Roundup											
Scouting (key times)																				
Field hygiene (key times for equipment)	Planting equipment		Cultivation equipment				Transport equipment		Cultivation equipment				Planting equipment		Cultivation equipment				Transport equipment	
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Non-herbicide options Herbicide options																				

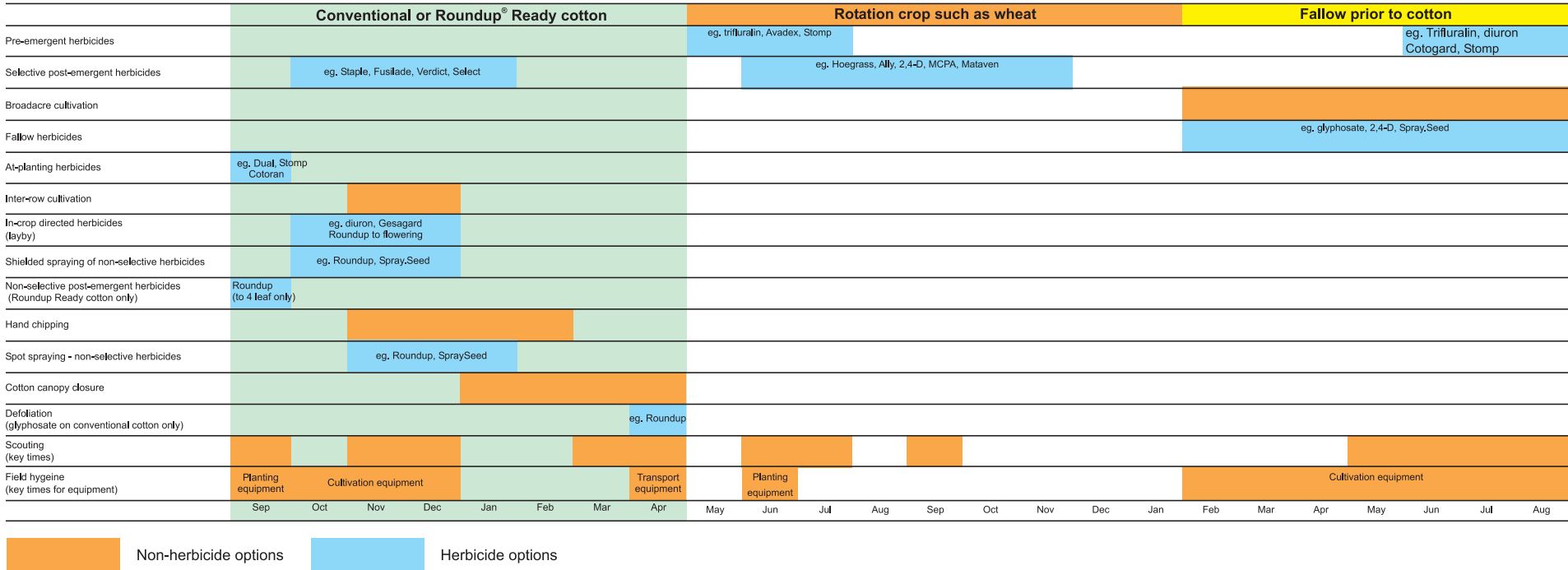


Non-herbicide options



Herbicide options

Table 4: Integrated weed management calendar for a cotton/rotation crop farming system. The timing of operations will vary between seasons and regions.



MANAGING WEEDS IN COTTON

Graham Charles
(NSW Agriculture)

Contents	Page
Introduction	B3.1
Direct impact of weeds	B3.1
Weed competition	B3.2
Other effects of weeds	B3.3
Weed identification	B3.3
Weed management tools	B3.4
Weed management in fallows	B3.5
Weed management in rotation crops	B3.5
Herbicides for fallows and rotation crops	B3.7
Pre-planting residual herbicides	B3.7
Residual grass herbicides	B3.10
Residual broad-leaf herbicides	B3.11
Residual herbicides for dryland cotton	B3.12
Pre-emergence, post-irrigation herbicides	B3.14
Post-emergence, non-residual herbicides	B3.14
Post-emergence and lay-by herbicides	B3.15
Shielded herbicide applications	B3.15
Spot-spraying	B3.15
Herbicide guide	B3.16
Crop agronomy and management	B3.16
Transgenic cotton varieties	B3.16
Irrigation management	B3.17
Inter-row cultivation	B3.17
Flame and other weeders	B3.18
Hand chipping	B3.18
Machinery hygiene	B3.18
Managing weeds on non-cropping areas	B3.19
Ultra-narrow row cotton	B3.19
Susceptibility of weeds to herbicides	B3.19
Herbicide resistance	B3.20
Modes of action of herbicides	B3.20
Development of herbicide resistance	B3.20
Rotation of herbicide groups	B3.21
Developing an integrated weed management system	B3.21
Re-cropping interval after cotton	B3.22
Summary	B3.22

Introduction

A successful cotton farm is a complex enterprise, integrating a wide range of competing needs into a sustainable, dynamic system. Insects, water, diseases, weeds, soil, environment, economic and social demands must all be juggled in a system that is sustainable in the short and long term. The needs of each area must be met and balanced so that conflicting demands are directed into a dynamic equilibrium in a functioning farm system.

A sustainable system for cotton production will necessarily include a well-developed weed management program. Weed management is an important issue for Australian cotton production, and requires a dedicated and long-term approach. The principles of management remain the same over time, over fields and over environments. However, the selection of weed management tools must be made on a week-by-week and field-by-field basis. Decisions made at any one time will affect outcomes in future seasons.

A sustainable weed management system must embrace a farming systems approach. To achieve this, a cotton grower must manage weeds on his roads, irrigation channels, fence lines, non-cotton areas, and rotation crops, as well as managing weeds in cotton crops. The costs of effective weed control may initially be high, but the benefits accrue over subsequent years.

Direct impact of weeds

Weeds adversely affect cotton in many ways. Weeds primarily compete for available nutrients, water and light. They can also directly impact cotton quality through contamination of cotton fibre or through contamination of cotton seed. Contamination of cotton fibre may necessitate additional processing at the cotton gin or may result in downgrading of fibre quality. Weeds may also act as sources of pests or diseases that affect cotton, they may reduce irrigation, cultivation and harvesting efficiency, and they may cause physical injury to operators in cotton fields, such as bug checkers, machinery operators and irrigation staff.

Even a single weed, such as a large fierce thornapple (*Datura ferox*) can compete strongly with cotton. The economic threshold for control by hand-chipping is approximately 1 thornapple

per 73 m of cotton row, based purely on cotton yield reductions through competition. In addition, thornapples can host heliothis, mites and verticillium wilt, can block cultivation and harvesting equipment, and can cause serious injury to field workers. Thornapple seeds may also contaminate cotton seed.

Weeds impact cotton production indirectly, as the tools used to manage weeds are expensive and may adversely affect cotton to some extent. All the herbicides currently used in cotton can cause some degree of leaf or root damage. Many of the more commonly used herbicides can, and on occasions do, kill cotton plants if they are incorrectly applied, or if adverse weather conditions occur soon after application.

Weed competition

Cotton seedlings have relatively poor vigour and compete poorly against weeds early in the cotton season. Even moderate weed infestations can reduce cotton yields.

Cotton seedlings are slow to emerge from the soil and grow slowly in cool spring conditions. This slow growth leaves a wide window for weed competition. Most weeds that emerge with the cotton grow more quickly than the crop, enabling them to shade the shorter cotton seedlings, and to better exploit water and nutrients from deeper in the soil than is available to the crop plants. This is especially a problem for dryland (non-irrigated) cotton production, where a lack of soil moisture near the soil surface can limit the growth of cotton seedlings.

All seedlings exploit water and nutrients from the moment they emerge from the soil, although in the cooler, southern areas, seedlings initially have very small requirements. Resource use rapidly increases as the seedlings grow. There has been no measurable reduction in cotton yield when weeds were removed within 4 weeks of emergence. However, yield reductions have been recorded when weeds were allowed to remain for longer than 4 weeks after emergence. The precise length of this critical period of competition of approximately 4 weeks depends on the growth rate of the weeds and scarcity of resources. Ideally, weeds should be controlled within 4 weeks of emergence, before they become well established and begin to compete strongly with the cotton crop.

Weed control needs to be maintained for at least 10 to 14 weeks after cotton emergence to achieve maximum cotton yields. Older, well-grown cotton plants have a large leaf canopy and a deep, extensive root system, enabling them to be very competitive, shading the soil surface and exploiting soil resources to depth. Consequently, weeds that emerge late in the season have no impact on cotton yield, although they may still cause problems with defoliation, can interfere with picking, can contaminate lint, can cause staining on the lint and can produce large amounts of seed, causing problems in later years.

In situations of limited soil moisture, cotton plants older than 14 weeks may still be small and not sufficiently well developed to be able to compete strongly with weeds. Consequently, weeds that emerge from summer rains may still have an impact through competition for soil moisture.

In skip-row cotton, weeds that emerge in the non-planted skips require long-term control. As there is no cotton planted in these rows, these weeds do not compete directly with the cotton crop early in the season and so may be tolerated for longer than weeds growing in the cotton rows. However, as these weeds grow, they begin to utilise the resources required by cotton later in the season, and so compete directly with the crop. Mid- and late-season control of these weeds is important.



Cotton seedlings emerge slowly from spring planting and compete poorly with weeds.



Weeds can compete strongly with cotton. Weeds can reduce yields, reduce lint quality, obstruct harvesting operations, and injure workers. This cotton crop will be low yielding and difficult to harvest due to the heavy weed infestation.



Best yields are achieved from well-managed cotton, free from weed competition.

Other effects of weeds

Weeds impact on cotton production in other ways. Weeds can act as hosts of cotton pests and diseases, and volunteer cotton can itself be a 'weed' in cotton. This is particularly important in managing Ingard® cotton crops, where heliothis caterpillars can grow and develop on weeds such as bladder ketmia, pigweed, the senecios or 'conventional' cotton, and then migrate onto Ingard® cotton.

Weeds and volunteer cotton can also be hosts to aphids that are implicated with bunchy top in cotton.

Cotton diseases may carry over on weeds, but many weeds in fallows are also hosts for VAM, which are beneficial soil microorganisms. Management of weeds on fields infested with fusarium wilt is an important issue as weeds may be symptomless hosts of fusarium.

Weeds may also adversely impact on cotton harvestability and lint quality. Large weeds such as thornapple, noogoora burr and sesbania pea can obstruct or damage cotton picker heads, leading to expensive breakdowns and down time. Vines such as cow vine, bell vine and yellow vine can tangle in picker heads, leading to significant down time as heads are cleaned.

All weeds have the potential to discolour or contaminate cotton lint. Grass weeds such as nutgrass which grow in the cotton row, or blow-away grass which can be blown into the cotton row from non-cotton areas, are a particular problem as grass fibres are difficult to remove from lint. Consequently, weeds that emerge late in the season may still need to be controlled, as they impact on cotton harvestability and lint quality, even though they do not affect cotton yield directly.

Weed identification

Common names for weeds vary from area to area, often creating confusion when discussing control options.

Correct weed identification is an essential component of weed management. While inter-row cultivation does not discriminate between different weeds, herbicides have better activity against some weeds than others. Accurate weed identification is essential for correct herbicide selection and for selection of the appropriate chemical rate. While plants are most readily identified from their flowers, identification of plants at earlier growth stages is critical for efficient weed management. Generally, small weeds can be identified after finding larger examples in the field or surrounding areas.

The **Weed Identification and Information Guide** at the front of **WEEDpak** is the first step for identification of weeds in cotton. This guide gives detailed information of a range of the weeds often found in the cotton system, with many photographs of each weed including seeds, seedlings, small plants and flowering stages.

Assistance with identification is available through extension officers in NSW Agriculture and the Queensland Department of Primary Industries, cotton consultants, and chemical company representatives. Alternatively, positive identification of flowering plants can be obtained from the herbariums located in the Botanical Gardens in each state.

Table 1. Some weeds that are easily confused, or have more than one commonly used name.

The common names listed here and accepted elsewhere in **WEEDpak** are those accepted by Shepherd, Richardson and Richardson (2001), in *Plants of Importance to Australia, A Checklist*.

Accepted common name	Botanical name	Other names
bellvine	<i>Ipomoea plebeia</i>	morning glory
cowvine	<i>Ipomoea lonchophylla</i>	peachvine
black bindweed	<i>Fallopia convolvulus</i>	climbing buckwheat
bladder ketmia	<i>Hibiscus trionum</i>	wild cotton
caltrop	<i>Tribulus terrestris</i>	cathead, bullhead
spineless caltrop	<i>Tribulus micrococcus</i>	yellow vine
caustic weed	<i>Chamaesyce drummondii</i>	caustic creeper, flat spurge
ground cherry	<i>Physalis ixocarpa</i>	annual ground cherry, Chinese lantern, physalis, gooseberry, wild tomato
wild gooseberry	<i>Physalis minima</i>	Chinese lantern, gooseberry, physalis
jute	<i>Corchorus olitorius</i>	native jute
legumes:		
• emu-foot	<i>Cullen tenax</i>	native lucerne, wild lucerne
• rhynchosia	<i>Rhynchosia minima</i>	ryncho
• sesbania pea	<i>Sesbania cannabina</i>	yellow pea bush, sesbania
liverseed grass	<i>Urochloa panicoides</i>	urochloa
melons:		
• wild melon	<i>Citrullus lanatus</i>	Afghan melon, camel melon, paddy melon, pie melon
• prickly paddy melon	<i>Cucumis myriocarpus</i>	paddy melon
polymeria	<i>Polymeria longifolia</i>	peak downs curse, polymeria takeall
annual polymeria	<i>Polymeria pusilla</i>	takeall, run-a-mile, inch weed
small-flowered mallow	<i>Malva parviflora</i>	marshmallow
common sowthistle	<i>Sonchus oleraceus</i>	sowthistle, milk thistle

In order to avoid misinterpretation in this document, the recommended common names used by Shepherd *et al.* are given precedence over other common names. Some of the more commonly confused local names are shown in Table 1.

Weed management tools

Weed can be managed using a combination of the following tools:

- management of fallows
- crop rotations
- herbicides
 - in-fallow
 - pre-planting
 - post-planting
 - over-the-top
 - directed sprays
 - shielded sprays
 - lay-by sprays
 - spot-spraying
 - pre-harvest, and
 - post-harvest
- crop agronomy and management
- irrigation management
- transgenic, herbicide tolerant cotton varieties
- cultivation and inter-row cultivation

- hand weeding (chipping)
- flame weeding
- field hygiene of
 - machinery
 - seed and other inputs
 - vehicles and water
- weed management on
 - rotobucks
 - roads
 - irrigation structures
 - fence lines
 - non-cropping areas

Selection of the ideal combination of weed management tools must be made on a year-by-year and field-by-field basis. Field history and expected weed pressure and diversity, expected cotton price and yield, available machinery and labour, available soil moisture and irrigation, and planting configuration all affect weed management decisions. The cotton grower must weigh up the need for weed control against the cost of control, both in terms of the actual cost of the control measures, and in terms of the cost of damage resulting from control measures. He must also consider the potential increase in the weed pressure in following seasons as a consequence of not controlling weeds and allowing them to set seed.

All control measures have the potential to cause some damage to cotton. Inter-row cultivation, for example, prunes some surface cotton roots and

damages the cotton. Many herbicides also cause some damage to cotton and will delay crop maturity to some extent. This effect is minimised when management tools are used correctly. The yield impact from the tools is normally much smaller than the impact of the weeds if they were not controlled. In all cases, the key to effective weed control is timeliness of application and the use of well set up equipment. Crop, soil and weather conditions must also be taken into consideration.

Ideally, a weed management program includes some residual herbicides, supplemented with non-residual herbicides as needed. Cultivation, shielded sprayers and spot sprayers are valuable for removing weeds from the inter-row area. Hand chipping and spot sprayers are particularly valuable tools for managing low densities of larger weeds.

Weed management in fallows

Where a field to be planted to cotton is fallowed prior to cotton, opportunity exists to control weeds. Often these weeds are most easily and cost effectively controlled in the fallow. Although many weeds produce dormant seeds that may survive in the soil for a number of years, the vast majority of the weed seed-bank can be run down simply by maintaining a weed free fallow.

When fallows are maintained using herbicides, this strategy has the added advantage of retaining stubble cover and maximising the retention of soil moisture. Maintaining stubble cover is an essential strategy for minimising soil loss through erosion on fields with slope, and fields prone to flooding and water movement.



Weed control can be difficult in broad-leaf rotation crops. This lablab crop failed due to poor establishment and poor weed control

Weed management in rotation crops

Rotation crops can also be valuable for managing weeds, as they often involve farming systems that differ from the typical cotton system. Winter and summer crops both have the advantage of drying out the soil profile, allowing strategic cultivation to manage soil and weed problems. In addition, a wider range of herbicides is available for use in rotation crops compared with cotton. Some weeds that are difficult to manage in cotton can be more easily managed with alternative herbicides in a rotation crop.

This is particularly the case with cereal crops, where most broad-leaf weeds can be readily controlled. Broad-leaf weed control remains a problem in most broad-leaf crops, including cotton.

Table 2. A guide to re-cropping intervals for the herbicides commonly used in rotation crops. Plant back periods for many of these herbicides will be much longer under dry conditions. Always check the label.

Product	Active ingredient	Applied rate per hectare	Re-cropping interval to cotton
2,4-D amine (various names)	500 g/L 2,4-D amine	up to 0.7 L 0.7 - 1.4 L above 1.4 L	10 days after a minimum of 15 mm rainfall 14 days after a minimum of 15 mm rainfall 21 days after a minimum of 15 mm rainfall
Tillmaster®	180 g/L 2,4-D amine + 90 g/L glyphosate	up to 2.0 L 2.0 - 4.0 L 4.0 - 6.0 L	10 days after a minimum of 15 mm rainfall 14 days after a minimum of 15 mm rainfall 21 days after a minimum of 15 mm rainfall
atrazine (various names)	500 g/L atrazine	2.5 L 2.5 - 6 L	6 months 18 months
chlorsulfuron (various names)	750 g/kg chlorsulfuron	15 - 20 g	18 months with a minimum of 700 mm rainfall where soil pH is 6.6 - 7.5. Where soil pH is 7.5 - 8.5, grow cotton only if a field test strip of cotton has been successfully grown through to maturity in the previous season. Do not use where soil pH is above 8.5.
clopyralid (various names)	300 g/L clopyralid	Up to 0.3 L 0.3 - 0.5 L Above 0.5 L	9 months 12 months 2 years
dicamba (various names)	500 g/L dicamba	up to 0.2 L 0.28 - 0.56 L	7 days after a minimum of 15 mm rainfall 21 days after a minimum of 15 mm rainfall
Sandoban®	60 g/L dicamba + 150 g/L glyphosate	up to 2.0 L above 2.0 L	7 days after a minimum of 15 mm rainfall 21 days after a minimum of 15 mm rainfall
2,4-D ester (various names)	800 g/L 2,4-D ester	up to 0.35 L 0.35 - 0.7 L above 0.7 L	10 days after a minimum of 15 mm rainfall 14 days after a minimum of 15 mm rainfall 21 days after a minimum of 15 mm rainfall
fluroxypyr (various names)	300 g/L fluroxypyr	up to 0.75 L 0.75 - 1.5 L	14 days 28 days
metsulfuron (various names)	600 g/kg metsulfuron	5 - 7 g	Cotton should not be planted on land previously treated with Ally. Tolerance of cotton grown through to maturity should be determined on a small scale before sowing into larger areas.
Tordon 75-D®	75 g/L picloram + 300 g/L 2,4-D	0.3 - 1 L	12 months
Tordon 242®	26 g/L picloram + 420 g/L MCPA	1.0 L	12 months
triasulfuron (various names)	750 g/kg triasulfuron	10 - 35 g	15 months where soil pH is up to 7.5 with 700 mm of rain 18 months where soil pH is 8.5 with 700 mm of rain 24 months where soil pH is above 8.6 with 500 mm of rain
Amber Post®	20 g/kg triasulfuron + 600 /kg terbutryn	250 - 500 g	14 months
trichlopyr (various names)	600 g/L triclopyr	80 - 160 mL	14 days
Harmony M®	682 g/kg thifensulfuron + + 68 g/kg metsulfuron	40 g	Cotton should not be planted on land previously treated with Harmony M. Tolerance of cotton grown through to maturity should be determined on a small scale before sowing into larger areas.

Herbicides for fallows and rotation crops

The wider range of herbicides available for use in fallows and rotation crops provides an opportunity to control weeds which are difficult to control in cotton, and to rotate herbicide chemistry, reducing the risk of selecting herbicide tolerant and herbicide resistant weeds. However, potential herbicide drift problems and plant-back periods must be considered with those herbicides that are not safe for use in cotton. Always refer to the product label for current recommendations. Table 2 gives a guide to re-cropping intervals to cotton. Most herbicides are toxic to cotton and have the potential to kill or severely damage a following or neighbouring cotton crop. For example, 2,4-D amine applied to a sorghum crop under unsuitable weather conditions such as atmospheric inversion can, in a worst case scenario, cause severe damage to cotton many kilometres away.



Cotton can be damaged by herbicides used on rotation crops. This damage (distorted growth) was caused by 2,4-D herbicide.

The breakdown rates of herbicides in the soil can be quite variable and difficult to predict. Most herbicides need moist soils (significant rainfall or irrigation) to facilitate breakdown, particularly those broken down by microbial activity. These same herbicides break down very slowly or may not break down at all under dry conditions. If in doubt as to whether a herbicide has broken down sufficiently before cotton planting, cotton growers should delay planting the field for as long as possible, or avoid planting the field altogether.

Prior to planting a doubtful field, growers should plant a test strip of cotton, or plant seeds into pots containing soil removed from the field to check for visual symptoms of herbicide damage on the seedlings. A doubtful field should be pre-irrigated before planting, if possible. However, even after these precautions, damage to cotton seedlings

may still occur, or damage can occur later in the season as the roots of developing plants encounter a herbicide band in the soil. Herbicide damage may not be visually apparent, but may still occur and weaken or stunt cotton seedlings, predisposing them to attack from seedling diseases.



Chick pea and wheat rotation crops planted into cotton trash.

Pre-planting residual herbicides

A range of residual and non-residual herbicides is available for use in cotton, as shown in Tables 3, 4 and 5.

Pre-planting residual herbicides have the advantage that they can be applied anywhere from several weeks before planting, up to immediately prior to planting, and remain effective for weeks or months after application. They can be applied in anticipation of a weed problem and they control weeds before they emerge. They are generally less expensive than their non-residual alternatives, particularly when multiple non-residual applications are required to replace a single residual herbicide application.

However, residual herbicides have two major drawbacks. Firstly, they must be applied in anticipation of a weed problem, whether or not a problem actually occurs. In situations of low weed pressure, their use may result in damage to cotton plants without any real benefit. Secondly, most residual herbicides need to be incorporated into the soil for optimum activity. Adequate incorporation of some residual herbicides is achieved through rainfall or irrigation, but others require incorporation through cultivation which may conflict with other farming practices such as minimum tillage and stubble retention.

Residual herbicides also have the potential to contaminate the environment if they move out of the target area. This potential is greater than that of the non-residual herbicides simply because they persist for longer in the environment and so are exposed to more opportunities for off-site movement. Their subsequent affect is also likely to be more significant because of their persistence.

Herbicide movement may occur through leaching of the herbicide following irrigation or rainfall.

However, many residual herbicides are strongly attracted to soil particles and so have little potential to leach. These herbicides may still move off-site, carried on blown dust, or on suspended soil particles following irrigation or rainfall. This risk can be greatly reduced by good irrigation design, where run off and irrigation tail-water are captured and recirculated, remaining on-farm.

Table 3. A guide to the weeds controlled by soil residual herbicides.

Active ingredient	trifluralin	pendimethalin	metolachlor	fluometuron	prometryn	fluometuron + prometryn
Typical use rate	1.4-2.8 L/ha	3.5-4.5 L/ha	2 L/ha	4.5-6.0 L/ha	3.3-4.5 kg/ha	3.5-5 L/ha
Herbicide group	D	D	K	C	C	C
Grass weeds						
Annual grasses general	S	S	S	MS	MS	MS
Barnyard grass	S	S	S	MS	MS	MS
Liverseed grass	S	S	S	MS	MS	MS
Johnson grass from seed	S	MS	MS	PS	T	T
Volunteer cereals	MS	MS	MS	S	S	S
Volunteer sorghum	S	S	S	S	S	S
Nutgrass	T	T	T	T	T	T
Broad-leaf weeds						
Amaranthus	S	S	PS	S	S	S
Anoda weed	T	T	T	-	-	-
Australian bind weed	T	T	T	T	T	T
Bathurst burr *	T	T	T	S	S	S
Bellvine	T	T	T	MS	S	S
Blackberry nightshade	T	MS	PS	S	S	S
Black bindweed	MS	T	T	-	S	MS
Bladder ketmia	T	T	T	S	S	S
Caltrop	S	MS	PS	S	S	S
Caustic weed	T	T	T	S	S	S
Cowvine (peachvine)	T	T	T	MS	S	S
Deadnettle	MS	T	PS	S	S	S
Devils claw	T	T	T	T	MS	S
Emu-foot	T	T	T	T	T	T
Ground cherry	T	T	T	S	S	S
Jute	PS	-	PS	MS	MS	MS
Mintweed	MS	MS	MS	MS	S	S
Mung bean *	T	T	T	MS	T	MS
Native rosella	T	T	T	S	-	S
Native vigna	T	T	T	-	-	-
Noogoora burr *	T	T	T	S	S	S
Parthenium weed	T	T	T	S	S	S
Pigweed	S	S	T	S	S	S
Polymeria						
Prickly paddymelon	T	T	T	S	S	S
Raspweed	T	T	T	-	-	-
Rattlepod	T	T	T	S	S	S
Rynchosia	T	T	T	-	-	-
Sesbania	T	T	T	MS	MS	MS
Spineless caltrop	S	MS	PS	S	S	S
Small-flowered mallow	T	T	T	T	T	T
Common sowthistle	T	T	T	S	S	S
Sunflower *	T	T	T	S	MS	MS
Thornapples *	T	T	T	S	S	S
Wireweed	S	S	PS	-	S	MS
Wild gooseberry	T	T	T	S	S	S
Wild melon *	T	T	T	S	S	S
Wild turnip	T	T	T	-	S	-

S=Susceptible MS=Moderately susceptible T=Tolerant PS=Some activity - Not known

* Because of their large seed size, these weeds may germinate below the herbicide band, reducing the level of control.

Table 4. A guide to the weeds controlled by herbicides (continued).

Active ingredient Registered trade name Typical use rate Herbicide group	diuron various 1.8-3.5 L/ha C	norflurazon Zoliar [®] ** 2-4 Kg/ha F	Pyrithiobac sodium Staple [®] 30-120 g/ha B	MSMA various 1-2.8 L/ha K	glyphosate various*** 1-2 L/ha M
Grass weeds					
Annual grasses general	MS	MS	T	S	S
Barnyard grass	MS	MS	T	S	S
Johnson grass from seed	T	MS	T	MS	S
Liverseed grass	MS	MS	T	S	S
Volunteer Cereals	S	MS	T	-	S
Volunteer sorghum	MS	MS	S	MS	S
Nutgrass	T	MS	T	MS	MS
Broad-leaf weeds					
Amaranthus	S	T	S	T	S
Anoda weed	-	T	S	T	MS
Australian bind weed	-	T	T	T	MS
Bathurst burr	S*	T	S	S	S
Bellvine	MS	T	S	T	PS
Blackberry nightshade	S	T	-	T	MS
Bladder ketmia	MS	T	T	T	MS
Black bindweed	-	T	T	T	MS
Caltrop	MS	T	T	T	S
Caustic Weed	MS	T	T	T	S
Cowvine (peachvine)	T	T	S	T	MS
Deadnettle	S	T	T	T	S
Devil's claw	-	MS	T	T	S
Emu-foot	-	T	T	T	MS
Ground cherry	MS	T	S	T	S
Jute	PS	-	T	T	S
Mintweed	MS	T	T	T	S
Mung bean	MS	T	T	T	S
Native rosella	-	T	T	T	MS
Native vigna	-	T	T	T	S
Noogoora burr	S*	T	S	S	S
Parthenium weed	S	T	T	T	MS
Pigweed	S	T	T	T	S
Polymeria	T	T	T	T	PS
Prickly paddymelon	S	T	T	T	PS
Raspweed	-	T	T	T	PS
Rattlepod	S	T	T	T	MS
Rynchosia	-	T	T	T	MS
Sesbania pea	MS	T	S	T	MS
Small-flowered mallow	T	T	T	T	PS
Common sowthistle	S	T	T	T	S
Spineless caltrop	MS	S	S	T	S
Sunflower	MS	T	S	T	S
Thornapples	S*	T	S	T	S
Wireweed	MS	T	T	T	S
Wild gooseberry	MS	T	S	T	S
Wild melon	S	T	S	T	S
Wild turnip	S	T	T	T	S

S = Susceptible MS = Moderately susceptible T = Tolerant PS = Some activity - = Not known

* = These weeds have large seeds and may germinate below the herbicide band, reducing the level of control.

** = Zoliar[®] is a residual herbicide that requires thorough incorporation, and needs to be applied for 2 or 3 consecutive seasons for nutgrass control.

*** = Glyphosate is toxic to conventional (non-Roundup Ready[®]) cotton and can only be safely applied to conventional cotton post-emergence through a well-constructed shielded sprayer, under suitable operating conditions with regard to wind, nozzle pressure, shield design, ground speed etc. For more information, refer to the section on **Directed and shielded applications of Roundup in Managing Roundup Ready[®] Cotton in WEEDpak**.

Table 5. A guide to weeds controlled by the post-emergence, over-the-top, grass herbicides.

Active ingredient	butroxydim	clethodim	fluzifop-butyl	haloxyfop-ethoxy-ethyl	propaquizafop	sethoxydim
Registered trade name	Falcon®	Select®	Fusilade®	Verdict®	Correct®	Sertin®
Typical use rate (mL/ha)	120-180	250-375	750	1.0-1.5	0.2 – 0.9	120-180
Herbicide group	A	A	A	A	A	A
Grass weeds						
Annual grasses general	S	S	S	S	-	S
Barnyard grass	S	S	S	S	S	S
Johnson grass from seed	S	S	S	S	S	S
Liverseed grass	S	S	S	S	S	S
Volunteer cereals	S	MS	S	S	S	S

S = Susceptible

MS = Moderately susceptible

- = Not known

Residual grass herbicides

The most commonly used residual grass herbicide is trifluralin, applied as a pre-planting, soil-incorporated herbicide. It has activity on most grass weeds, and some broad-leaf weeds such as amaranthus, caltrop, and mintweed. Its application window is from 6 weeks pre-planting to immediately prior to planting. Trifluralin is relatively inexpensive, but may inhibit the development of surface roots of emerging cotton seedlings and requires thorough soil incorporation to be effective. Soil incorporation at, or immediately after application is necessary because trifluralin is degraded by sunlight and is slightly volatile, leading to significant losses if it is left on the soil surface. Trifluralin is degraded by microorganisms in the soil.

If trifluralin is not used prior to planting, pendimethalin or metolachlor will normally be applied at planting as an alternative. It is also common to apply a band of pendimethalin as a 'top-up' behind the planter, even when trifluralin has previously been applied. This most often occurs on fields that are pre-irrigated, where a layer of dry soil is skimmed off the top of the irrigation hill at planting to allow cotton seed to be planted into moist soil. The herbicide treated soil ends up in the furrow. A band of pendimethalin is then applied to the area disturbed by planting, to replace the trifluralin that has been removed.



Young cotton in a well-managed seedbed, free of weeds.

Pendimethalin and metolachlor have similar activity on grass and broad-leaf weeds when compared with trifluralin. The main advantages of these herbicides are that they don't need as much soil incorporation as trifluralin, can be applied at planting, and don't cause surface root pruning. However, they are more expensive than trifluralin, and although they don't inhibit surface root development, they can still cause serious injury to cotton seedlings if they are poorly applied or subject to adverse weather conditions after application. Damage is most commonly seen when rain occurs immediately after planting, washing herbicide into the cotton seed zone. Both herbicides require some incorporation, with finger harrows behind the planter, or either by rainfall or irrigation. Both herbicides have some volatility (metolachlor less than pendimethalin), and are degraded by sunlight (metolachlor more than pendimethalin).

Residual broad-leaf herbicides

The residual broad-leaf herbicides commonly used in cotton are diuron, fluometuron and prometryn singularly, and a 50:50 fluometuron/prometryn mixture. These herbicides can be applied pre-planting, at planting, or post-planting, and have pre-emergence and post-emergence activity on many broad-leaf and some grass weeds. They are most effective when incorporated into the soil, but are also effective when applied to the soil surface or sprayed on small weeds, with the addition of a wetting agent.

Application timing and technique is important with these herbicides. While they can, and often are applied before cotton emergence, with no adverse effects, these herbicides have the potential to kill or severely damage cotton seedlings, resulting in the need to re-plant the crop. Damage, when it does occur, generally follows rainfall soon after planting which washes the herbicide into the seed zone. This problem is most likely where the planter has left a furrow in the top of the hill. Rain can concentrate herbicide from the top of the hill into this furrow, and into the root or shoot zone of emerging cotton seedlings. Prometryn is not commonly applied prior to crop emergence, due to the risk of injury to cotton from this herbicide, although the prometryn-fluometuron mixture is often used. Injury from diuron, fluometuron, and the prometryn/fluometuron mixture can be widespread when rain occurs at planting. As these herbicides are water-activated, they are most effective under wet conditions, when weeds are most active.



Fluometuron damage on seedling cotton (yellowing of the inter-venial leaf area). Fluometuron was applied at planting but damage did not become obvious until this growth stage.

Although listed earlier as a negative characteristic, the tendency of trifluralin to prune the surface roots of cotton seedlings may add some additional degree of product safety when trifluralin is included with one of these products in a weed management program. While pruning of the surface roots reduces the cotton's ability to absorb nutrients and water from the soil surface (a negative aspect), it also reduces the likelihood of cotton seedlings absorbing high concentrations of other herbicides from the soil surface (a positive aspect). Consequently, injury to cotton seedlings from herbicides like diuron is less likely when trifluralin has been applied pre-planting.

Generally, cotton can be successfully re-established from re-sowing after cotton seedlings are killed by herbicides, as these herbicide have relatively short half-lives, and so break down relatively quickly.

Because they do have foliar activity, it is important that the residual broad-leaf herbicides are applied as directed sprays when used after cotton emergence (the spray nozzle positioned to direct herbicide away from cotton foliage). It is common to observe some leaf damage to cotton after a directed spray application even when these herbicides are correctly applied. The damage is seen as yellowing of the cotton leaf, but should not cause leaf death or a reduction in cotton yield.



Zoliar® applied to a severe nutgrass infestation. The white areas in the foreground were caused by Zoliar®, which affects photosynthesis.

An alternative to these herbicides is Zoliar®, a highly residual soil applied herbicide with activity against some broad-leaf and most grass weeds. Zoliar® is particularly useful in fields infested with nutgrass or anoda weed, but can be very expensive if required at the maximum use rates. It needs to be thoroughly incorporated into the soil,

and can be applied in autumn or winter before cotton planting. For nutgrass control, Zoliar® needs to be applied over several consecutive seasons and should be used in conjunction with other management tools such as inter-row spraying with glyphosate or Semptra®. Zoliar® is only active at high soil moisture contents. It acts on plant chlorophyll and membrane lipids, rapidly turning affected tissue white. This will kill the affected plant if the soil remains wet and the herbicide remains active for long enough. Frequently however, under Australian conditions, the soil dries and the affected plant recovers. In this situation, Zoliar® does give effective suppression of the weed but will not eliminate the problem.

Zoliar® has a major advantage in that it is highly active in wet conditions when it is most needed and has a long half-life in the soil. Its disadvantages include relatively high cost (at the rates required for use in nutgrass), a lack of activity under dry conditions, and toxicity to most rotation crops. High rates of Zoliar® should not be used with the last cotton crop before planting a rotation crop. Plant back periods should be carefully considered before choosing a rotation crop. Most rotation crops can't be safely grown for several seasons following high rates of Zoliar® applied to consecutive cotton crops.

Residual herbicides for dryland cotton

Problems can occur for growers of dryland cotton where residual herbicides are used early in the season. Residual herbicides can give more cost-effective weed control than many of the post-emergence options but for optimum performance they must be applied prior to or at planting. If a planting opportunity fails to eventuate, or the crop fails, residual herbicide already applied may preclude later planting of an alternate crop.



Dryland cotton sown in a skip-row configuration (two cotton rows 1 m apart, separated by a 2 m gap). The cotton is sown into sorghum stubble.

Trifluralin and diuron are examples of relatively inexpensive but effective herbicides often used with dryland cotton, but which greatly reduce the growers' planting options should cotton not be planted or should the crop fail to establish. Minimum re-cropping intervals for cotton herbicides are shown in Tables 6 and 7. Judicious use of soil residual herbicides enable growers to consider other crop options for a December-January planting such as sorghum, sunflower, and mung beans.

One possible strategy to avoid problems with pre-plant residual herbicides is to band the herbicide so that herbicide is applied to the cotton row, and a band of untreated soil remains in the inter-row area. Weeds that emerge in this area can be managed with cultivation and a residual herbicide may be applied later in the season. Should cotton establishment fail, an alternative crop can be safely planted in the untreated area. This strategy is ideally suited to cotton grown with permanent wheel tacks, where the cotton-row and inter-row areas are well defined, and is particularly suitable for skip-row cotton which has a wide inter-row area.

Another strategy is to use a Roundup Ready® cotton variety with no early-season residual herbicides. This strategy can be very cost effective in relatively clean fields, but the total number of glyphosate applications may be of concern over time. Reliance on glyphosate as the primary weed control tool will result in a shift in the weed spectrum to those weeds that are more tolerant of glyphosate and may ultimately lead to glyphosate resistant weeds. This strategy may fail in weedy fields, where weeds that emerge in the plant-line after the over-the-top Roundup application may be difficult and expensive to control.

Residual herbicides applied after planting may still cause problems in the event of the cotton crop failing or being hailed-out. All residual herbicides have the potential to cause problems for the crop following cotton, as indicated in Tables 6 and 7. These data have been developed in consultation with the agrochemical industry and are intended only as a guide.

ALWAYS CHECK THE PRODUCT LABEL.

The re-cropping intervals listed can be modified to suit local seasonal conditions and soil type variations.

Table 6. Minimum re-cropping interval (months) to rotation crops after residual herbicide application in cotton.
Products are sold under a variety of trade names.

	trifluralin	pendimethalin	metolachlor	prometryn	fluometuron
Barley	12	6	6	12	6
Canola	0	6	6	12	6
Chickpea	0	0	6	12	6
Cotton	0	0	0	0	0
Cowpea	0	0	6	12	6
Faba Bean	0	0	6	12	6
Lablab	0	-	6	12	6
Linseed	0	-	6	12	6
Lucerne	0	6	6	12	6
Maize	12	0*	0	12	6
Millet	12	12	6	12	6
Mung Bean	0	0	6	12	6
Oats	12	12	6	12	6
Sorghum	12	12	0**	12	6
Soybean	0	0	0	12	6
Sunflower	0	0	0	12	6
Triticale	12	6	6	12	6
Wheat	12	6	6	12	6

* = Maize can be re-sown immediately after use in a failed crop provided the seed is sown below the treated band of soil

** = Concept® treated sorghum seed

- = No information available

Table 7. Minimum re-cropping interval (months) to rotation crops after residual herbicide application in cotton.
Some products are sold under a variety of trade names.

	fluometuron + prometryn	diuron	norflurazon Zoliar®*	pyrithiobac Staple®**
Barley	6	12	30	5
Canola	6	12	-	-
Chickpea	6	12	9	-
Cotton	0	S	0	0
Cowpea	6	12	-	-
Faba Bean	6	12	30	-
Lablab	6	12	-	-
Linseed	6	12	9	-
Lucerne	6	12	-	-
Maize	6	S	27	22
Millet	6	12	-	-
Mung Bean	6	12	27	11
Oats	6	12	30	5
Sorghum	6	S	27	22
Soybean	6	12	9	22
Sunflower	6	12	27	22
Triticale	6	12	30	-
Wheat	6	12	30	5

* = Re-cropping interval relates to a single application. Longer intervals will be necessary following applications over more than one season.

** = Re-cropping intervals relate to no more than a total of 120 g/ha of Staple® applied in one season. A maximum of 240 g/ha may be applied in back-to-back cotton.

S = The spring following application in cotton

- = No information available.

Pre-emergence, post-irrigation herbicides

In irrigated cotton production, the crop is established either by irrigating before planting, planting cotton into a drying soil (pre-irrigation), or by irrigating after planting (watering-up). An additional light irrigation (termed 'flushing') may be necessary soon after planting pre-irrigated cotton if the surface soil dries too rapidly for the emerging cotton seedling.

Where pre-irrigation occurs, it is common to get a rapid emergence of weeds, particularly grasses, before the cotton seedlings emerge from the soil. When this happens, opportunity exists to apply a herbicide such as glyphosate to control these weeds without damaging the cotton. If no rain or irrigation occurs after this herbicide application, there may be no further weed emergence and the cotton will be able to establish in a relatively weed-free situation. This strategy can also be valuable for managing problem weeds that emerge before the cotton, and so can be controlled at this stage.

However, this strategy is not always reliable and should only be used in conjunction with other weed management tools, as wet or windy weather can prevent herbicide application in this narrow window between planting and crop emergence.



Inter-row cultivation is used through the season to control weeds in the inter-row area and to maintain irrigation hills. Herbicides and fertiliser may also be applied through the cultivation rig.

Post-emergence, non-residual herbicides

Residual herbicides have the advantage that they are present and are active from the time of application, but have the disadvantage that they may damage cotton, and they are normally applied in anticipation of a problem, and thus may not actually be necessary. Non-residual herbicides have the advantage that they can be applied as needed, but will only control weeds present at the time of application and so are unable to control weeds from later germinations. A range of non-residual grass herbicides is shown in Table 5. These herbicides can be safely applied over-the-top of cotton and are effective in controlling small, actively growing grass weeds. However, they have no effect on broad-leaf weeds and are much less effective on stressed grass weeds. They are also largely ineffective in controlling larger grass weeds that escape earlier treatment.

MSMA is another herbicide with activity against most grass weeds, as well as nutgrass and many broad-leaf weeds. It can be applied over-the-top of cotton, but can damage cotton and may result in significant reductions in yield, particularly with sequential applications. Consequently, MSMA should only be applied over-the-top of cotton in situations of heavy weed infestation, where the potential damage from the herbicide is far less than the potential damage from the weeds. MSMA should be applied as a directed spray where possible. MSMA is not commonly used, except for early-season control of nutgrass.

Staple® (Table 4) is a more recently registered herbicide that is active at relatively low rates. It controls a range of broad-leaf weeds and can be applied over-the-top of cotton, although it does cause some injury to cotton and may suppress cotton growth for up to 14 days. This growth suppression should not result in a yield reduction. Staple® is relatively expensive and is often applied in a band to reduce overall cost. While it has little residual activity against weeds, it can cause significant damage to following rotation crops. Re-cropping intervals are shown in Tables 6 and 7.

Unlike the older broad-leaf herbicides (diuron, fluometuron and prometryn), Staple® has activity against a very specific range of weeds and so accurate weed identification is very important when using this herbicide. For example, Staple® is effective in controlling spineless caltrop (*Tribulus micrococcus*) but will not control caltrop (*T. terrestris*); these two weeds are similar in appearance and often grow together. Similarly, Staple® is effective for controlling sesbania pea (*Sesbania cannabina*) but less effective on budda pea (*Aeschynomene indica*). These plants are difficult to distinguish in early growth.

A weed control program based on non-residual herbicides may need to be repeated at 4-weekly intervals. Such a program may be impractical due to high cost, time and labour constraints. A period of wet or windy weather could be a disaster for a weed control program based solely on non-residual herbicides.

Post-emergence and lay-by herbicides

The residual broad-leaf herbicides discussed earlier (diuron, fluometuron and prometryn) are commonly also applied post-emergence, often in combination with inter-row cultivation. They may be applied as 'lay-by' herbicides with the final inter-row cultivation, just prior to the crop closing over the inter-row area. When used in this way, they are normally sprayed in front of a cultivator, which is set to throw some of the herbicide treated soil up under the cotton plants. Consequently, the herbicide is incorporated into the soil and kept away from the cotton foliage, but some treated soil still ends up over-the-top of the hill. This herbicide application is intended to control weeds that germinate after it is no longer practical to cultivate or apply directed herbicides in the cotton crop.

Shielded herbicide applications

Some herbicides that can't be safely applied over-the-top of cotton can be used to control weeds in the inter-row area when applied through a well-constructed shielded sprayer that prevents herbicide making contact with the cotton foliage. These sprayers must be operated under suitable conditions. This strategy is commonly used in dryland cotton, where large inter-row strips are present, but where stubble destruction and soil moisture losses resulting from cultivation are undesirable.



A purpose-built, high clearance sprayer set up for shielded spraying.

The use of herbicides such as glyphosate through a shielded sprayer is relatively safe, but extensive crop damage can occur if the herbicide does make contact with cotton foliage. Damage is most likely to arise from herbicide drift from within the shield due to windy conditions, excessive ground speed, poor shield construction or set up, excessive nozzle pressure, or poorly positioned spray nozzles. Problems can be reduced by using appropriate nozzles, producing large droplets at low pressure, within well-constructed shields and ensuring that nozzles remain well positioned. It is also essential to ensure that there are no herbicide leaks from tanks or fittings. Due to the risk of damage to cotton, shielded sprayers should only be used where weeds can't easily or economically be controlled by other methods.

Spot-spraying

Spot-spraying is ideally suited to situations where large weeds are present at low densities. Herbicides such as glyphosate and MSMA may be applied to small areas of weed within a field, where the damage caused by the herbicide is confined to a small area and is negligible over the entire field. Alternatively, a more expensive herbicide such as Staple®, Semptra®, Zoliar® and the post-emergence grass herbicides may be spot-applied to greatly reduce the overall cost. Spot-spraying may involve a 'normal' boom spray, with the operator switching on boom-sections as required, but more commonly involves a purpose built, self-propelled, spot-spraying unit, designed to go

through cotton rows with a minimum of disturbance. These units have multiple operators, each of whom can spot-spray weeds in several rows in a single pass, using special applicators which limit spray drift.



Spot spraying and chipping are efficient and effective ways of controlling low densities of large weeds such as these velvetleaf plants.

Herbicide Guide

A guide to the weeds controlled by the herbicides most commonly used in cotton is provided in Tables 3, 4 and 5. This information is a general guide only. **SPECIFIC DIRECTIONS FOR PESTICIDE USE IS PROVIDED ON THE PRODUCT LABEL AND MUST BE COMPLIED WITH.** Further information on specific herbicides, application rates, and application details is provided in the Cotton Pest Management Guide, published each year.

Crop agronomy and management

A cotton grower aims to establish a strong, healthy cotton stand that produces a profitable cotton crop. To achieve this aim, the grower will try to produce a favourable seedbed with optimum levels of nutrients and water. Unfortunately these conditions are also ideal for weed establishment and growth, enabling weeds to out-grow and out-compete cotton seedlings. A dense population of weeds can easily out-compete and shade cotton, but the converse is also true, that a well established cotton crop can in time out-compete and shade most weeds.

The opportunities for weeds can be reduced and managed by attention to crop agronomy and management, making the crop more competitive. Once established, a well grown cotton plant will develop a thick leaf canopy, shading both the row and furrow area, and an extensive and deep root system, extracting water from the soil surface and deeper in the soil profile. In contrast, poor cotton

establishment may result in large gaps between cotton plants, allowing opportunities for weeds to establish and grow. Re-planting of 'gappy' cotton stands is essential in weedy fields. Poorly growing cotton can also be out-competed by weeds, with weeds growing more rapidly than cotton in spring, shading the cotton and competing strongly for nutrients and water.

For best results, cotton should be given the best chance for establishment and vigorous growth. Where a grower has both clean and weedy fields, the weedy fields should be planted last. If the opportunity arises, a herbicide such as glyphosate should be applied to weeds after cotton planting but before crop emergence. Operations such as cultivation, chipping, and side banding of fertilizer should be timed to give the crop the best chance to out-compete weeds. Taller cotton varieties, with good seedling vigour are best suited to weedy fields.

Transgenic cotton varieties



Small plots of transgenic, Roundup Ready® cotton sown amongst conventional cotton and sprayed with Roundup herbicide.

Transgenic, herbicide tolerant cotton varieties are becoming available. Roundup tolerant, Roundup Ready® cotton varieties are now commercially available. Herbicide tolerant varieties have been genetically modified to enhance their tolerance of specific herbicides. These herbicides can't normally be used with conventional cotton varieties. The use of transgenic varieties provides opportunities to use a new range of herbicides in cotton with improved crop safety. In many instances, this technology allows cotton growers to substitute non-residual herbicides for residual herbicides, reducing potential re-cropping problems. These herbicides may also be valuable for managing weeds that are difficult to control in conventional cotton.

Irrigation management

Irrigation management is an important aspect of crop agronomy. Weeds generally emerge after irrigation and rainfall events, so the timing of irrigation affects the emergence of weeds.

While cotton may be sown into soil moisture following rainfall, sowing generally occurs as the soil dries after pre-irrigation, or cotton is sown into a dry seedbed and then irrigated. Both practices result in a flush of weeds, but pre-watering is generally preferred in weedy fields as it allows a better opportunity for weed emergence and control with cultivation or herbicides before crop emergence.

Later in the season, irrigation, chipping, cultivation and herbicide applications must be coordinated to minimise stress to the cotton crop but maximise weed control and weed control opportunities.



Irrigation is often timed to follow inter-row cultivation, as in this field.

Irrigation water can be a source of weed infestation, with weed seeds carried in the water. While it is not practical to filter these seeds from the irrigation water, growers should always be on the lookout for new weeds that may have been introduced in irrigation water. Growers should give special consideration to water pumped during floods, as this water has the greatest potential to carry new seeds. If possible, flood water should be first pumped into storage to allow weed seeds to settle out of the water, reducing the risk of these seeds being carried into fields.

Inter-row cultivation

Inter-row cultivation is a relatively cheap and effective method of removing weeds from the inter-row area. In irrigated cotton, cultivation is also an important tool for re-delving and maintaining the irrigation furrow.

To be effective, inter-row cultivation should occur before weeds become too large, and be timed to occur as fields are drying. Cultivation should be delayed for a few days after rain or irrigation, as many weeds will not be killed but simply transplanted by cultivating in damp soil. Soil compaction is another undesirable outcome of cultivating wet soil. However, cultivating in dry conditions is expensive and may cause excessive damage to young cotton seedlings, particularly in a blocky or compacted soil. Inter-row cultivation can be timed to occur just prior to an irrigation, provided that the soil is easily friable, allowing sufficient time between cultivation and irrigation for weeds to be killed (approximately 1 day), but minimising the stress to cotton which may have been damaged during the cultivation pass.



Inter-row cultivation rig set up for one-pass cultivation and cold-flow nitrogen application.

Inter-row cultivation is particularly valuable for managing dryland, skip row cotton. However, some soil moisture is lost with every cultivation pass, and some pruning of cotton roots occurs, damaging the cotton. This root pruning may contribute to problems with fusarium wilt, where this disease is present. Inter-row cultivation also exposes the soil surface, leaving the soil more vulnerable to erosion. Ideally, cultivation should cause minimal surface soil disturbance, leaving surface residues largely undisturbed. This is particularly important on sloping, erosion prone fields.

Flame and other weeders



A homemade flame weeder for controlling weeds in the inter-row area.

Flame weeders, infra-red weeders, steam weeders and electro-static weeders have been developed as alternatives to cultivation and herbicides and are especially useful in organically grown cotton where herbicides can't be used. They are effective in controlling small annual weeds in the inter-crop area and can control small weeds in the cotton plant line in older cotton with minimal damage to the crop. They have the drawback that they require large inputs of energy and are therefore expensive to use.

Hand chipping

Manual weeding using hand chipping is a valuable tool for removing low densities of weeds from the cotton plant line. Chipping can also help prevent the build up of herbicide resistant weeds, removing any weeds that survive the other weed management practices.

However, hand chipping can be extremely expensive. Chipping should be used in conjunction with inter-row cultivation, so that the majority of weeds are removed by the cultivator, at much lower cost than chipping. Care should be taken to ensure that the cost of chipping does not become excessive.



Hand chipping is an important part of an integrated weed management program.

Machinery hygiene

Weeds are spread through a variety of mechanisms, but most commonly through the dispersion of seeds by wind and water. Most weeds produce large numbers of seeds, each of which is capable of producing a new plant. Some weeds are also capable of reproducing vegetatively, spreading through tubers, rhizomes or stolons, and some are capable of regrowing from a piece of leaf or stem.

Apart from the natural means of weed dispersion, one of the principle villains for spreading problem weeds is the cotton grower himself. This spread normally occurs on contaminated machinery such as cultivation equipment, pickers and farm vehicles. Good machinery hygiene is essential to avoid introducing new weeds and diseases from other contaminated fields, or other areas. Machinery from off-farm should always be thoroughly cleaned before use.

Managing weeds on non-cropping areas

Weeds present on areas surrounding cotton fields can contribute significant weed seed loads to cotton fields. If poorly managed, these areas can contribute large seed loads of many of the more difficult to control weeds such as noogoora and Bathurst burr, fierce thornapple, sesbania pea, and cowvine.

Roadways and irrigation structures can be particularly important in spreading weeds, as rain run-off from these areas often flows directly into irrigation channels and onto cotton fields. Weed seeds are readily transported in this water.

Weeds on irrigation channels and structures are most commonly managed using a combination of residual and knockdown herbicides and mechanical means. Diuron and glyphosate are the main herbicides used. Diuron is applied after the final irrigation in autumn and incorporated by rain. Channels may need to be flushed in spring to remove excess chemical if insufficient rainfall occurs over winter. Glyphosate is applied as needed to control established weeds.

Regular mechanical maintenance of irrigation structures also contributes to weed management, removing many of the more difficult to control weeds. Cotton growers who pump irrigation water from a river or whose land is flood susceptible, have little control over weed input from these sources, but the management of seeds from all sources within a growers control can make a big difference to the level of in-crop weed competition.



Weeds around channels, roads and water storages can contribute significant quantities of weed seeds to cotton fields.

Ultra-narrow row cotton

The ultra-narrow row planting configuration has become feasible in cotton due to new cotton picker head design, improved cotton varieties, and transgenic herbicide tolerant cotton. Irrigated, ultra-narrow row cotton is more competitive than conventional cotton, due to a much increased cotton plant density. However, the narrow-row configuration precludes normal in-crop, inter-row cultivation, and limits in-crop herbicide applications to those herbicides that can be applied over-the-top of the crop. Ultra-narrow row is best suited to transgenic herbicide tolerant cotton varieties and fields that are relatively free of weeds.

Susceptibility of weeds to herbicides

The weeds listed in Tables 3, 4 and 5 have been rated according to their susceptibility to the various herbicides under average to good conditions. Since the level of control is influenced by rainfall, seedbed soil conditions, and other environmental factors, there is no guarantee that a treatment will give the result indicated in the tables.

ALWAYS READ THE LABEL OF THE PRODUCT BEFORE USE.



Ultra-narrow row cotton. A range of planting configurations is being used.

The information supplied here is only a guide. Product registrations vary between states and label information must be complied with. Products labels supply additional information on product safety and use constraints, application rates and timing, the use of surfactants, soil incorporation, water rates, nozzle pressure and configuration, product compatibilities, and equipment decontamination, as well as other information pertaining to the product and its use.

Herbicide resistance

Information on the herbicide group to which the product belongs is included on the product label. This information is essential for developing an integrated weed management strategy which avoids developing herbicide resistant weeds. The herbicide groups are indicated by a lettering system, as shown in Tables 3, 4 and 5.

More detailed information on managing herbicide resistance is given in **Managing Herbicide Resistance in Cotton** in **WEEDpak**.

Modes of action of herbicides

There are many different modes of herbicidal action and a single herbicide may act on more than one plant process. Nevertheless, similar herbicides often have similar modes of action. For example, the post-emergence grass herbicides (Table 5) are all group **A** herbicides which act through inhibiting acetyl-coA carboxylase, leading to membrane disruption in the plant. Consequently, although five chemically distinct herbicides are listed in Table 5, they all act on the same plant pathway and a weed that develops resistance to one of these herbicides will probably be resistant to all five herbicides. However, apparently similar herbicides do not always have similar modes of action. Of the pre-emergent grass herbicides (Table 3), trifluralin and pendimethalin are both group **D** herbicides, which inhibit tubulin formation, effectively inhibiting plant growth, whereas metolachlor is a group **K** herbicide, with multiple modes of action inhibiting growth and root elongation.

Where herbicides with similar weed spectrums have different modes of action, opportunity exists to rotate herbicides, thereby reducing the risk of selecting weeds resistant to any one herbicidal mode of action.

Development of herbicide resistance

When applied correctly, a herbicide will effectively control its target weed. Nevertheless, within any weed population there will be weed species that are more tolerant of the herbicide, and within a species there may be individual plants that are more resistant to the herbicide than the remainder of the population.

Repeated use of a herbicide will have two effects. Firstly, the herbicide will select for the more tolerant weed species, probably resulting in a shift in favour of those tolerant species. That is, the density of the more herbicide susceptible species will decline, while there will be a relative increase in the density of the herbicide tolerant species. Secondly, the herbicide will select the more herbicide resistant individuals from within a species and the frequency of these individuals will increase within the population, leading to the development of herbicide resistance.

The rate at which these changes occur depends on a number of factors, including:

herbicide efficacy, the frequency of herbicide application, the degree of tolerance to the herbicide, the frequency of herbicide resistant individuals within the population, and the nature of the weed's reproductive mechanism,

- dilution of the population from external sources, and
- use of other management tools that reduce the population of tolerant and resistant individuals.

While all herbicides have the potential to cause a species shift in the weed population, they do not all have the same risk of developing a resistant weed population. Within the herbicide groups, there are three broad categories.

- herbicides with high risk (groups **A** and **B**). Repeated use of herbicides from groups **A** and **B** has a high risk of selecting out herbicide resistant weeds.
- herbicides with moderate risk (groups **C** to **H**).
- herbicides with low risk (groups **I** to **N**).

Nevertheless, these risks are relative. Repeated use of a single herbicide from any herbicide group may eventually lead to the development of herbicide resistance. That is, the selection from a previously susceptible population, of a new population that is resistant to the herbicide at the rates used. Once this happens, the herbicide is no longer of any use for controlling that weed.

Rotation of herbicide groups

One approach to reducing the likelihood of herbicide resistance developing is to rotate herbicides, using different herbicide groups over time, so that weeds are exposed to a range of different herbicidal actions. This strategy is difficult to implement in cotton, as many of the herbicides that could be readily substituted are from the same herbicide groups.

For example, as discussed earlier, although the post-emergence grass herbicides Falcon®, Fusilade®, Select®, Sertin®, and Verdict® are chemically different, they are all group **A** herbicides with similar modes of action. A weed that develops resistance to one of these herbicides may be cross-resistant to all of them, even though the weed had not been exposed to the other herbicides.

Similarly, the residual, broad-leaf herbicides most commonly used with cotton production (diuron, prometryn and fluometuron) are all group **C** herbicides, with similar modes of action.

However, the pre-emergent grass herbicides belong to groups **D** (trifluralin and pendimethalin), **K** (metolachlor) and **F** (Zoliar®). Use of these herbicides in rotation allows the opportunity to expose weeds to totally different herbicide groups, greatly reducing the risk of the development of herbicide resistance.

Overall, the most effective approach to reducing the development of herbicide resistance and a species shift to herbicide tolerant individuals, is to ensure that herbicides are used correctly and that an integrated approach to weed management using components from each of the weed management options is adopted. Special care needs to be taken when making repeated use of group **A** or group **B** herbicides.

Developing an integrated weed management system

Each of the weed management tools has advantages and disadvantages, and needs to be integrated with other tools to form an effective and efficient weed management system. The weed management system must be balanced with the needs of the other components of cotton production, such as insect management and disease control.

A weed management system must be flexible and able to respond to the changing needs of each field. One of the most significant factors affecting weed management is the prevailing seasonal conditions, and in particular, rainfall. An effective weed management system must be able to respond to a range of seasonal conditions. Rainfall affects both weed germination and herbicide efficacy. All plants need moisture to germinate and grow. Generally, weeds will germinate only after a rainfall or irrigation event, and are not normally much of a problem in dry seasons. However, all residual herbicides are water activated. They are relatively inactive in a dry soil and become active after rain or irrigation. In addition, most of the translocated, non-residual herbicides are much more effective on plants that are not moisture stressed. Residual herbicides should work well in a wet season, when maximum weed pressure will occur, but may not work well in a relatively dry season, when light rain may stimulate weed germination, but not sufficiently activate the herbicides. In this situation, non-residual herbicides and cultivation may be needed to supplement residual herbicides.



An integrated weed management approach is the simplest way to ensure that all weed management tools remain available into the future. Some weeds (such as the nutgrass in this photo) will be very difficult to manage if they develop resistance to herbicides.

Re-cropping interval after cotton

The minimum re-cropping intervals following herbicide applications in cotton are presented as a guide in Tables 6 and 7 to assist in planning crop rotations.

ALWAYS READ THE PRODUCT LABEL.

Planting a crop too soon after a previous crop in which residual herbicides were used is likely to result in crop failure, or crop damage, which may not be apparent in initial crop establishment.

Summary

Weeds can compete strongly with cotton, potentially reducing cotton lint yields and lint quality. Weeds can act as hosts for diseases and pests of cotton. Uncontrolled weeds can also produce large numbers of seeds, creating far bigger weed problem in future years.

A range of management tools is available for weed control in cotton. These tools are best used in combination, in an integrated weed management system. The management tools include residual and contact herbicides, cultivation, hand chipping, cropping rotations, transgenic, herbicide resistant cotton varieties and crop agronomy. Herbicides can be used in a variety of ways, including in fallows, pre-crop planting, post-planting, post-emergence, and as directed or spot applications. Even inputs such as irrigation, fertilizers, and crop variety selection have some impact on weed management.

These tools need to be integrated into a cost effective, sustainable management system that maximises crop yield and quality, while minimising the impact of the weeds. Attention to weed management in fallows and rotation crops, and on irrigation structures and roads is critical to the whole farm system. The potential plant-back periods from residual herbicides used in cotton and rotation crops must be considered in the whole system. Movement of weed seeds and residual herbicides in the irrigation system must also be taken into account.

The Critical Period Weed Sampling Sheet

Date:
Property:

Recorder:
Field:

Assessment:

Large broadleaf
weeds

Number per 50 m of row

<5 1	5 - 50 2	50 - 500 3	>500 4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Large broadleaf – Noogoora burrs,
thornapples, sesbania & budda pea
Medium broadleaf – all other
broadleaf weeds
Grasses – grasses and all grass like
weeds

Sum

—	—	—	—

Total

Medium broadleaf
weeds

<5 1	5 - 50 2	50 - 500 3	>500 4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Sum

—	—	—	—

Total

Grasses

<5 1	5 - 50 2	50 - 500 3	>500 4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Sum

—	—	—	—

Total

Assessment score

1	2	3	4	5

Large broadleaf

Medium broadleaf

Grasses

Assessment summary

1	2	3	4	5

Large broadleaf

Medium broadleaf

Grasses

Average

—
—
—

Assessment score	Weed density
1	0.006
2	0.008
3	0.010
4	0.013
5	0.016
6	0.020
7	0.025
8	0.032
9	0.040
10	0.05
11	0.063
12	0.079
13	0.10
14	0.13
15	0.16
16	0.20
17	0.25
18	0.32
19	0.40
20	0.5
21	0.63
22	0.79
23	1.00
24	1.26
25	1.58
26	1.99
27	2.51
28	3.15
29	3.97
30	5
31	6.29
32	7.92
33	10
34	12.6
35	15.8
36	19.9
37	25.1
38	31.5
39	39.7
40	50



Examples of Large Weeds



Noogoora burr complex:
Italian cocklebur, Californian burr
and Noogoora burr (L to R)



Thornapple complex:
common thornapple,
fierce thornapple, and
downy thornapple



Sesbania and budda pea



The Critical Period for Weed Control in cotton (day degrees since planting)												
Weed density (no./m ²)	High yielding cotton crops						Low yielding cotton crops					
	Broad-leaf weeds				Grasses		Broad-leaf weeds				Grasses	
	Large		Medium				Large		Medium			
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
0.1	145	189	145	172	-	-	-	-	-	-	-	-
0.2	144	275	144	244	-	-	254	229	-	-	-	-
0.5	143	447	143	387	-	-	251	368	-	-	-	-
1	141	600	141	514	-	-	246	498	246	319	-	-
2	139	738	139	627	-	-	238	620	238	421	-	-
5	131	862	131	729	129	174	215	735	215	537	-	-
10	121	915	121	771	127	248	184	785	184	595	152	206
20	106	944	106	795	125	357	142	812	142	631	147	290
50	87	962	87	810	119	531	93	830	93	654	134	431
Min. density	0.06		0.07		2.5		0.24		0.59		5.4	

UNDERSTANDING THE CRITICAL PERIOD FOR WEED CONTROL

Graham Charles and Ian Taylor
(NSW Dept of Primary Industries)

Contents	Page
Introduction	B4.2.1
A weed control threshold	B4.2.1
Determining the economic threshold for weed control	B4.2.2
Understanding the impact of weeds	B4.2.2
Determining the yield loss from weeds	B4.2.2
The critical period for weed control	B4.2.3
Beyond the critical period for weed control	B4.2.3
Timing of herbicide applications	B4.2.4
Preventing weed seed set	B4.2.4

Introduction

The last few years have brought new innovations in weed management in the Australian cotton industry. These include the transgenic herbicide tolerance options of Roundup Ready®, Roundup Ready Flex® and Liberty Link® cottons, the post-emergence, over-the-top herbicides Staple® and Envoke®, and more accurate inter-row cultivation, with additional options likely over the next decade.

These new options allow growers to develop more effective and flexible weed management programs, but the old dilemmas still remain.

Growers have to answer the questions; should I use multiple pre-emergent herbicide applications, with pre-planting as well as at-planting herbicides? Or maybe just one of the options, but if so, which herbicide/s and at what rates, broadcast or banded? When should I inter-row cultivate or chip, or should I just apply another herbicide? Should I use a layby?

Using more and more herbicides gives better weed control, but pre-emergence residual herbicides can contribute to establishment problems and additional post-emergence herbicides will not necessarily result in better yields, or improved returns. In fact, controlling weeds in a fairly clean field may just reduce profits. Conversely,

inadequate weed control can be costly to remedy, and can result in lost yield and weed problems for years to come. So the question is, what herbicide/ cultivation/ chipping combinations will give optimal weed control, and maximise yields and returns?

The answers are complex and vary from field to field and season to season.

A weed control threshold

Post-emergence herbicides, such as glyphosate, bring the advantage that they are applied to a known weed population. This allows the choice of herbicide, rate and application timing to be targeted to the weed population. These herbicides can substitute for pre-emergent residual herbicides, cultivation and chipping inputs to maximise weed control and minimise costs.

However, the application timing of post-emergent herbicides remains an issue. Growers must balance spraying too often, which provides good weed control, but increases cost and selection pressure for herbicide resistance and species shift, against spraying too little. Delaying control may save costs by reducing the number of applications needed over the season, but increases the risk of weed escapes that can be costly to control, and may lead to yield losses and a build up of weeds over time.

A weed control threshold is needed to help balance the pressures of spray efficacy and cost. The threshold must take into account the characteristics of the weeds, their density and the control options available, to provide guidelines on if and when a weed population should be controlled.

Determining the economic threshold for weed control

The decision to control a weed is influenced by crop growth stage, the availability of suitable herbicides, labor and equipment, the weather, and financial aspects such as lint price, expected yield, and the cost of weed control. The actual level of the economic threshold (the critical number of weeds that triggers a grower to control a weed infestation) is a personal choice reflecting how much loss a grower is willing to tolerate before deciding to control the weed.

For example, a grower may consider using a Roundup Ready Herbicide® application costing around \$23/ha, including application. The grower will probably not use the herbicide unless the weeds will cause at least a \$23 per ha yield loss, with additional benefit expected in harvest efficiency, lint quality and reduced weed problems in later years. At a bale price of \$380 and an expected yield of 8 bales per ha, this establishes an economic threshold for applying Roundup Ready Herbicide at around 0.8% yield loss. That is, **the economic threshold is the 0.8% level of yield loss.**

The economic threshold is easily established. The trick is in being able to quantify the yield loss caused by the weeds.

Understanding the impact of weeds

A weed control threshold must take into account the characteristics of the weeds, their density and the control options available. Competitive ability is one of the more important characteristics of a weed, but other features, such as the ability to host insect pests and diseases, seed production, and lint contamination potential are also important.

The competitive ability of a weed relates to its growth rate and architecture (height, shape, leaf size, branching characteristics, root structure, rooting depth, etc.), and varies with each weed species. Generally, smaller weeds are less competitive, and large weeds, such as noogoora burrs, are highly competitive.

The competitive impact on a crop is also affected by the time the weed emerges and the time of the weed's removal. Weeds that emerge late in the season may have little impact on the crop's yield, whereas even relatively uncompetitive weeds that emerge with the crop are likely to impact on yields if not controlled.

Determining the yield loss from weeds

The impact of weed competition on crop yield is demonstrated in Figure 1, generated from a field population of 4 thornapples per meter of cotton row.

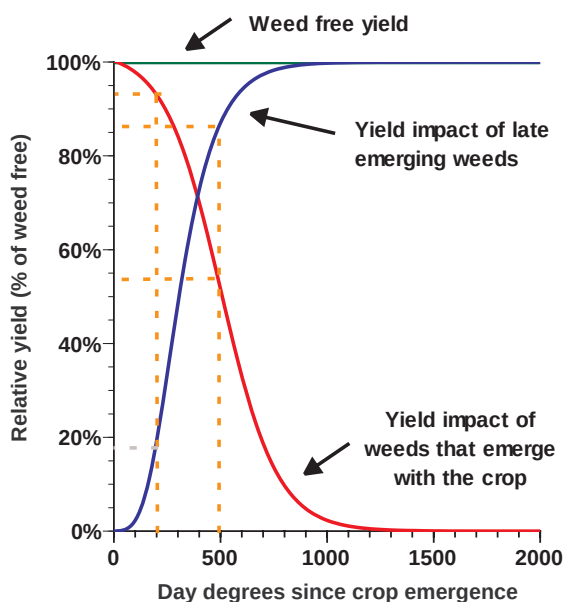


Figure 1. The impact of 4 thornapples/m on crop yield. The orange lines demonstrate the impact of control 200 and 500 day degrees after crop emergence.

In Figure 1, the green line across the top is the yield if there were no weeds in the field (the weed free yield).

The red line is the yield loss from a thornapple infestation where the weeds emerged with the crop and were removed some time after emergence. For example, if the thornapples were controlled at 200 day degrees, crop yield would be reduced to 93%, a 7% yield reduction (indicated by where the orange line at 200 day degrees hits the red line). If the thornapples were removed at 500 day degrees, the yield would be reduced to 54%, a 46% yield reduction (500 degrees days orange line). Yield would be reduced by 100% if the thornapples were not controlled before 1300 day degrees.

The blue line is the yield loss from a thornapple infestation where the weeds emerged after the crop and were not subsequently controlled. If, for example, thornapples emerged at 200 day degrees and were not controlled, yield would be reduced to 18%, an 82% yield reduction (where the orange line at 200 day degree hits the blue line). However, if the thornapples didn't emerge till 500 day degrees and were not controlled, the yield would only be reduced to 86%, a 14% yield loss.

WEEDpak

section B4.2

Although a single red line is shown for simplicity in Figure 1, there would actually be a family of red lines, representing thornapples that emerged after each weed control input (inter-row cultivation, herbicide etc.), as shown in Figure 2.

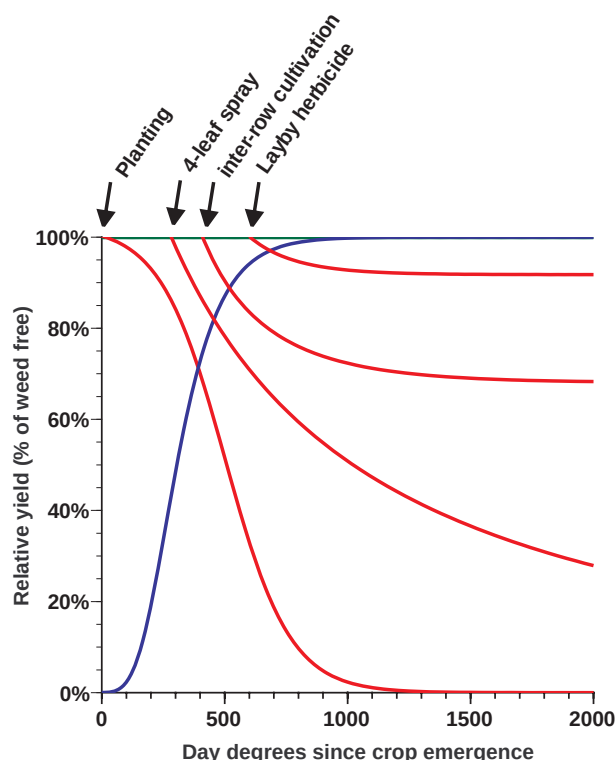


Figure 2. The impact of weed competition on crop yield following weed control inputs.

A further set of lines would be needed to show the impact of thornapples at another density, and still more sets of curves to show the impact of other weeds, as the curves are different for each species and density.

The critical period for weed control

A concept known as the 'critical period for weed control', can be derived from the interaction of these relationships with the economic threshold for weed control.

The critical period for weed control starts at the intersection of the first red line with the economic threshold (yellow line), and ends with the intersection of the blue line with the economic threshold, as shown in Figure 3. A new critical period for weed control is defined after each weed control input, beginning where each subsequent red line intersects with the economic threshold. The end of the critical period does not change.

The critical period for weed control is defined by the economic threshold chosen, the weed species and the weed density. In this example, the critical period for weed control for 4 thornapples/m of

cotton row is 166 to 621 day degrees at a 5% economic threshold. Thornapples not controlled during this period will cause economic yield loss.

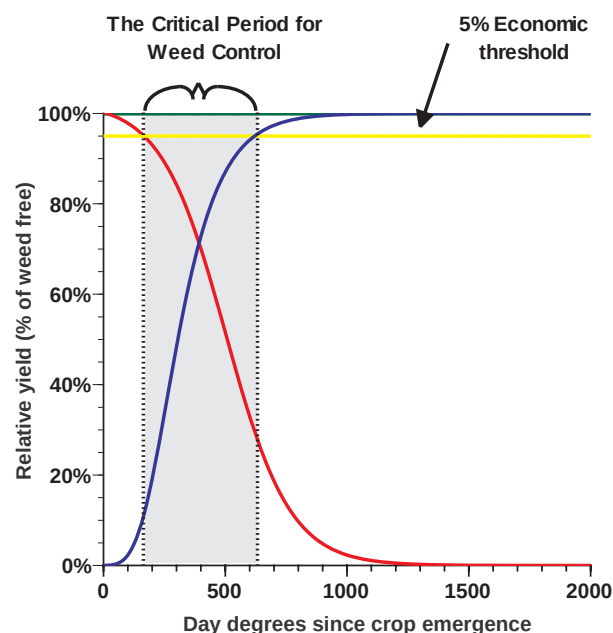


Figure 3. Deriving the critical period for weed control (the blue shaded area).

Beyond the critical period for weed control

A strength of the critical period for weed control concept is that it clearly defines the period during which weed control is required, and conversely, the periods during which weeds cause insufficient yield loss to justify their control. Figure 3, for example, shows that where thornapples emerged with the cotton crop at 4 plants/m, there is no justification for controlling them before 166 day degrees of crop development.

Conversely, if up to 4 thornapples/m establish after 621 day degrees, they would not cause an economic yield loss (using a 5% yield loss threshold). However, they might still need to be controlled to avoid seed production, harvesting difficulties and thornapple problems in later seasons.

This information is especially important for the management of relatively clean fields where weed control decisions can be difficult to make, as it may be unclear whether a weed density is sufficient to justify control.

However, the critical period for weed control concept has several weaknesses. It assumes that weeds are equally easily controlled at all growth stages, that the cotton grower has the capacity to control all weeds at the required time, and that the weeds have no negative impact except on crop

yield. Weed control decisions may also be justified for irrigation and harvesting efficiency, to reduce pest and disease carryover, to prevent lint contamination, and to prevent weed seed set, reducing future weed burdens.

Also, the critical period for weed control is affected by the economic threshold adopted. At a 1% yield loss (economic) threshold, compared to a 5% economic threshold, for example, the critical period in Figure 3 extends from 61 to 818 day degrees after crop emergence. At this threshold, the first-post-emergence treatment would occur while the crop was at the 1 node stage, and subsequent treatments would need to occur within a week or so of weed emergence to avoid reductions in crop yield.

Timing of herbicide applications

Application timing is critical to achieving good results with post-emergent herbicides. Herbicides should be applied when they will provide effective control and before weeds begin to reduce crop yield potential, ideally at the start of the critical period for weed control (Figure 3). Best control with herbicides is obtained when weeds are small, when there is adequate soil moisture and when temperatures are ideal.

However, the germination of weed seeds is mainly governed by temperature and soil moisture conditions, (it may also be influenced by seed dormancy). Consequently, there are normally a number of weed flushes throughout a season following rainfall and irrigation events. Cotton growers must take into account the likely number of germination events, the cost of weed control, the capacity to cover a number of fields with the application equipment available, and possible yield reductions due to weed pressure when making a weed control decision. Control of very small weeds prior to the weed removal time would be efficient in terms of herbicide, as lower rates are required to control smaller weeds, but may be very inefficient if subsequent germinations quickly replace the previous weed population, requiring repeated treatments.

Preventing weed seed set

The aim of weed management is to minimise economic loss in the current crop, but also to protect future crops by preventing weeds from setting seeds and adding to future weed problems. To achieve this, weed management strategies may need to continue beyond the critical period for weed control.

However, rather than focusing on controlling the weeds, emphasis needs to be placed on preventing those weeds from setting seed. This may be achieved using a lay-by herbicide, or with spray topping, where a sub-lethal dose of

herbicides is applied to cause weeds to abort seed or to set non-viable seed. Defoliant or Roundup applied at or prior to defoliation may also help to reduce seed set. Further research is needed to confirm the value of these options.

APPLYING THE CRITICAL PERIOD FOR WEED CONTROL IN THE FIELD

Graham Charles and Ian Taylor
(NSW Dept of Primary Industries)

Contents	Page
Introduction	B4.3.1
The critical period for weed control	B4.3.1
Predicting the critical period for weed control	B4.3.2
Using the 'critical period for weed control' data set	B4.3.2
Avoiding herbicide resistance and species shift	B4.3.3



Sunflowers in cotton at the start of November mimicking an infestation of large broad-leaf weeds.

Introduction

The critical period for weed control is a concept that relates the yield reduction caused by weed competition to an economic threshold. It establishes a period at the start of the season when weeds do not need to be controlled as they cause no economic loss, and a period at the end of the season when weeds again cause no economic loss. These periods define the middle, critical period for weed control, in which weeds must be controlled to reduce yield losses.

The relationships which define the critical period are affected by weed species, weed density and the economic threshold chosen.

The critical period for weed control

Experiments were conducted at the ACRI at Narrabri over the past 4 seasons to define the critical period for weed control for irrigated cotton in Australia. These experiments used sunflowers, mung beans and Japanese millet to mimic the competition from a large broad-leaf weed such as thornapple, a medium sized broad-leaf weed such as bladder ketmia and a grass weed such as barnyard grass.

Relationships for these weeds at two densities are shown in Figure 1. The curves show the competitive effects of weeds that emerge with the crop and are subsequently controlled (maroon line) and weeds that emerge after the crop and are not subsequently controlled (brown line).

At the densities shown, the large broad-leaf weeds had the greatest effect on the crop, suppressing yield by up to 100% when not controlled. The medium broad-leaf and grass weeds had less effect, with 79% yield reduction from season-long competition of 40 grass plants per metre of cotton row.



Japanese millet at 40/m row in cotton at the end of December mimicking a heavy infestation of a grass weed.

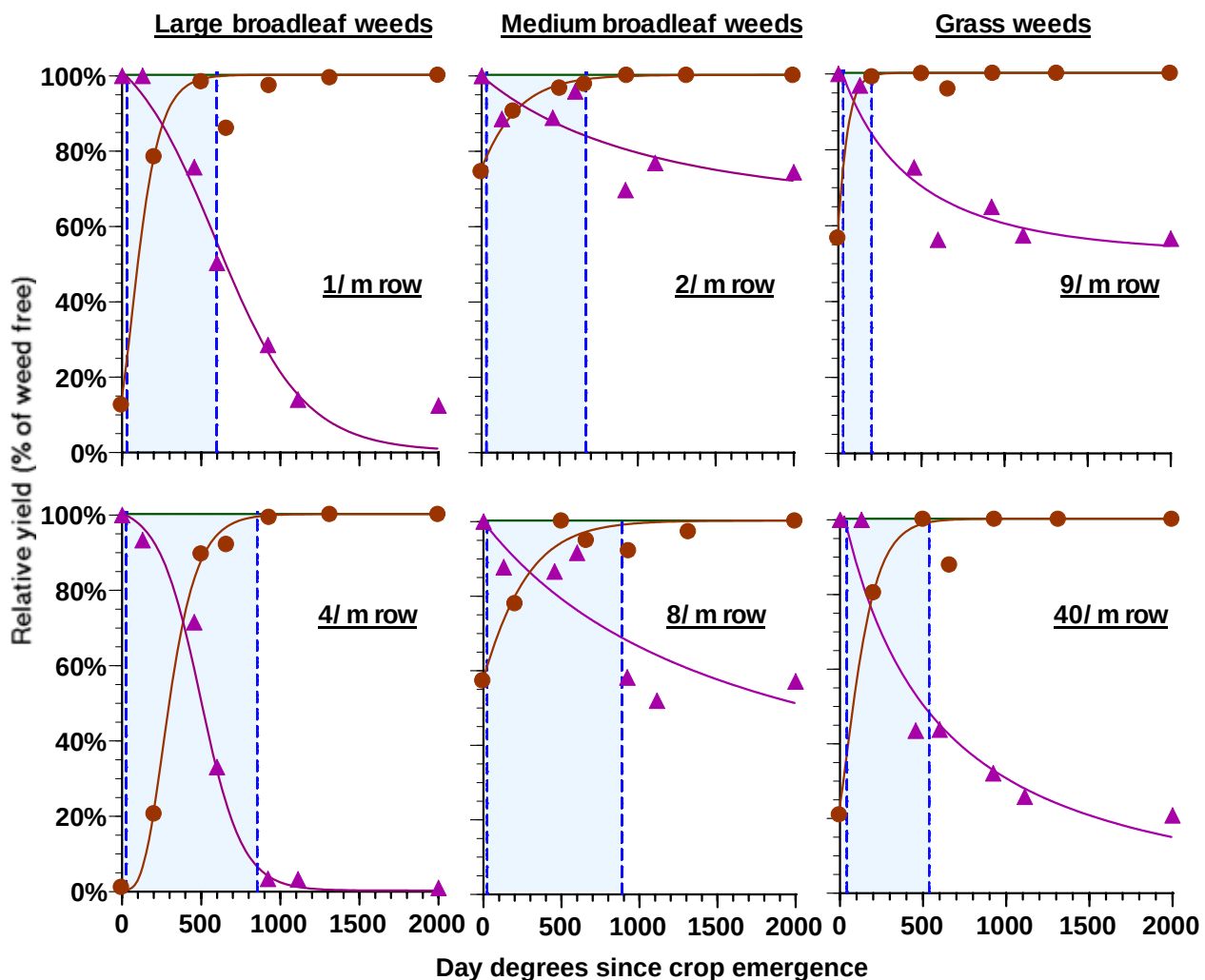


Figure 1. Yield relationships for weeds competing in irrigated cotton. Data for large and medium broadleaf and grass weeds are shown. Weed densities are indicated on each figure. The critical period for weed control at a 1% yield threshold is the shaded blue area in each figure. This area is determined by where the curves in each figure cut the chosen economic threshold, which in this example is at 1% yield loss (99% yield).

The critical periods for weed control defined by these weed competition relationships are dependant on the economic threshold chosen. As an example, results for a 1% yield threshold are indicated in Figure 1 by the shaded blue areas in each figure. These areas are defined by where the maroon and brown lines cut the economic threshold, and determine the start and end of the critical period in day degrees on the bottom axis.

Figure 1 shows that the critical period for weed control at a 1% economic threshold for one large broad-leaf weed/m row starts 30 day degrees after crop emergence and continues till 598 day degrees. In other words, at one large weed/m row, if weed control starts later than 30 day degrees after crop emergence, a yield loss of greater than 1% will occur. Conversely, large broadleaf weeds that emerge at up to 1/m row later than 598 day degrees after crop emergence cause less than a 1% reduction in crop yields. Consequently, controlling these weeds that emerge later than 598 day degrees after the crop can't be justified on the

basis of the yield reduction they will cause. They may still need to be controlled, however, as they may interfere with harvesting and may produce a seed load that leads to increased weed problems in later seasons. A layby application of a residual herbicide may be the best option at this point in the season.

The length of the critical period for weed control increases with increasing weed density, climbing from 598 day degrees after crop emergence for 1 large broad-leaf weed/m row to 854 day degrees for 4 weeds/m. The start of the critical period declines slowly as weed density increases, decreasing from 30 day degrees at 1 large broad-leaf weed/m to 26 day degrees for 4/m.

Predicting the critical period for weed control

These data were put together to produce relationships to predict the start and end of the critical period of weed control for any density of these weeds. The relationships predict that for any density of weeds, the maximum critical period is 996 day degrees post crop emergence (Table 1). Weeds that emerged later than 996 day degrees after crop emergence didn't cause more than 1% yield loss, regardless of their type or density.

The start of the critical period for weed control was fairly insensitive to weed density, declining from 43 day degrees at the lightest density of grass weeds.

The length of the critical period was much shorter for the grasses compared to the broad-leaf weeds at the same densities. Season long competition from fewer than 3 grass weeds/m causing less than 1% yield loss. Consequently, control of fewer than 3 grass weeds/m row can't be justified on the basis of yield loss alone. However, failure to control grasses at this density early in the season will lead to problems later in the season with harvesting difficulties and lint contamination. Not controlling grass weeds will result in seeds being added to the seed bank. This seed may germinate following the next rainfall or irrigation event, resulting in greatly increased weed problems later in the season or in subsequent seasons.

Table 1. The predicted start and the end of the critical period for weed control for a range of weed species and densities.

Weed density (weeds/m row)	Critical period (day degrees)	
	Start	End
Large broad-leaf weeds		
0.1	31	130
0.2	31	230
0.5	30	427
1	30	598
2	29	747
4	26	854
Medium broad-leaf weeds		
0.1	31	92
0.2	31	169
0.5	30	336
1	30	503
2	29	668
4	26	800
Grass weeds		
2	-	-
3	42	61
4	42	80
8	42	148
16	40	258
32	37	410

Other weeds, such as the vines, may have little impact on yield at low densities but can cause major difficulties for harvesting. Low densities of some weed species may also be problematic as they may harbour pests or diseases, or have the ability to rapidly spread if not controlled. Controlling a low density of small weeds may make a lot more sense than trying to control a heavy density of large weeds later in the season.



Using the 'critical period for weed control' data set

The critical period for weed control data will be a valuable tool for managing weeds in cotton into the future. However, the current data is very preliminary and should be viewed with caution. Other research has shown that the results of this type of research can be site and season specific, meaning that different results might be obtained in other seasons and in other cotton areas.

Future research in this project will cover a number of additional points, including developing data sets for mixed populations of real weeds, testing the findings in other regions and developing more robust weed competition assessment tools. Weed densities are never uniform in the real world, and staggered weed germinations can make for difficult decisions. Developing a weed management guide based on measurements such as weed and crop leaf area may give much more robust guidelines than the current findings simply based on weed density.

Nevertheless, these preliminary findings can be used to guide weed management decisions, especially in Roundup Ready Flex® and Liberty Link® cotton crops where over-the-top broad-spectrum herbicides are available. The results firstly indicate that weed control should be commencing early in the season, soon after weed emergence, when light rates of herbicide give good control on small, susceptible weeds. Weeds should not be allowed to grow unchecked in the hope of being able to control multiple weed germinations with a single, high rate herbicide application later in the season.

Secondly, the duration of the weed control period is influenced by weed species and density, but may extend until well into the season in dirtier fields. Weed control may have to be maintained until mid- to late-January, depending on the region and the season. Conversely, weed control with an over-the-top herbicide in relatively clean fields may be largely cosmetic and not justified on the grounds of competition alone. Controlling these weeds with inter-row cultivation or a lay-by herbicide later in the season would be a better option. This is especially the case in fields that are not going back to cotton.

Avoiding herbicide resistance and species shift

One of the biggest concerns with adopting a system which relies largely on a single weed control tool is the development of species shift and herbicide resistance. This is a potential issue for systems such as a Roundup Ready Flex cotton system where few other inputs might be used.

An obvious strategy might seem to be to limit the number of Roundup Ready applications, using maximum rates to control big weeds. This is not advisable for two reasons. Firstly, the critical period for weed control work shows that this strategy will lead to large yield losses. Secondly, using a lesser number of applications of a heavy herbicide rate will not necessarily reduce selection pressure compared to multiple applications of lighter rates on small weeds. The issue is not how many applications are made per season, but whether successive generations are exposed to the same selection pressure.

There are three keys to successfully adopting a low input weed control system. These are:

- Ensuring the herbicide will control all weeds at the rate used,
- Ensuring successive generations of weeds are not exposed to the same herbicide, and
- Ensuring all weed escapes are controlled using a different management tool **before they set seed.**

High yielding cotton crops can be grown for many years into the future if these strategies are adopted.

USING THE CRITICAL PERIOD FOR WEED CONTROL IN ROUNDUP READY FLEX[®] COTTON

Graham Charles, Ian Taylor and Tracey Farrell
(NSW Dept of Primary Industries)

Contents	Page
Introduction	B4.4.1
The critical period for weed control	B4.4.1
Model inputs	B4.4.2
The CPWC in 2004-5	B4.4.3
The CPWC in 2005-6	B4.4.4
The CPWC in 2006-7	B4.4.4
Observations from these simulations	B4.4.5
Resistance to Roundup	B4.4.5
Conclusions	B4.4.5
Summary	B4.4.6

Introduction

The Critical Period for Weed Control (CPWC) is a concept that relates the yield reduction caused by weed competition to an economic threshold. It establishes a period at the start of the season when weeds do not need to be controlled as they cause no economic loss, and a period towards the end of the season when weeds again cause no economic loss. These periods define the middle, CPWC, in which weeds must be controlled to reduce yield losses.

Work by NSW DPI staff at the Australian Cotton Research Institute (ACRI) at Narrabri has for the first time defined the CPWC in irrigated Australian cotton. Articles describing the work were published in the August-September 2007 edition of the Australian CottonGrower.

Still, the question remains, how can a cotton grower best use this information in a cotton crop?

The main aim of this article is to explore how applying the critical period concept might have worked out in grower's fields over the last three seasons.

The critical period for weed control

In practice, the critical period is defined by the type of weed present, the density of weeds, the potential crop yield, the cost of weed control and the economic threshold the cotton grower chooses.

The CPWC is defined in Table 1 using 1% and 3% weed control thresholds for fully irrigated cotton (1% threshold) and lower yielding or rain-fed crops (3% threshold). These control thresholds were determined from the point where the yield loss caused by the weeds exceeds the cost of control with Roundup Ready Herbicide. As well as reducing lint yield, uncontrolled weeds set seed



A cotton crop with a heavy infestation of grass weeds in the plant line. This was part of the experiments used to establish the CPWC in cotton.

leading to increasing weed problems over time, impede water flow and pesticide penetration, harbor pests and diseases, and cause harvesting difficulties and lint contamination.

To show how these thresholds might be used in the field, we applied them to Narrabri data for each of the last three seasons.

The simulations and discussion focus on management of a Roundup Ready Flex cotton crop because the critical period approach is most readily adapted to this system. However, the concept can be equally applied to conventional and Liberty Link[®] cotton crops.

Table 1. The predicted start and the end of the CPWC for a range of weed species and densities using 1% and 3% thresholds. The critical period is measured in day degrees from planting.

Weed density (weeds/m ² row)	Critical period			
	1%	Start 3% threshold	1%	End 3% threshold
Large broad-leaf weeds				
0.1	111	-	210	-
0.2	111	178	310	222
0.5	110	177	507	365
1	110	175	678	508
2	109	170	827	653
5	105	158	959	798
Medium broad-leaf weeds				
0.1	111	-	172	-
0.2	111	-	249	-
0.5	110	-	416	-
1	110	175	583	227
2	109	170	748	331
5	105	158	913	517
10	101	142	987	661
Grass weeds				
2	-	-	-	-
3	123	-	141	-
5	122	137	178	148
10	121	136	259	206
20	120	132	383	299
50	115	124	600	477

Model inputs

We tested the CPWC on a relatively dirty field with a mixed weed population of 1 large broadleaf weed/m² (eg. thornapple or noogoora burr), 5 medium sized broadleaf weeds/m² (eg. bladder ketmia) and 10 grass weeds/m² (eg. barnyard grass). Simulations were made for both fully irrigated and rain-fed crops in each season.

Weed germinations were related to rainfall and irrigation events. The simulations assumed most of the weeds emerged between 50 and 100 day degrees after rain (or irrigation), and all weeds were susceptible to Roundup Ready Herbicide.

The irrigated crop was pre-watered and planted on 5th Oct. each season. No residual herbicides were applied prior to or at planting. Roundup was applied before crop emergence to ensure a clean start to the season. Applying a 1% yield loss threshold, the CPWC extended from cotyledon to mid-flowering growth stages (105 to 913 day degrees) for the simulated weed population, as shown by the red lines in the figures.

The “rain-fed” simulations used similar assumptions, with no pre- or at-planting residual herbicides. Planting occurred on the first opportunity following rain after the 5th Oct., and Roundup was again applied before crop emergence to ensure a clean start to the season. Applying a 3% yield loss threshold, the CPWC extended from the 2 node stage to early squaring (136 to 517 day degrees).



A cotton crop showing the effect on crop height and biomass of a heavy weed infestation following a Roundup Ready application (foreground). Weeds have been uncontrolled since planting in the plot behind this. These plots are part of an experiment to test the CPWC in Roundup Ready Flex cotton.

The CPWC in 2004-5

Reasonable rainfall fell in the first half of the 2004-5 season at Narrabri, with a daily maximum of 138 mm recorded in Dec. Multiple weed germination events were triggered by early season rainfall and irrigation later in the season (Figure 1).

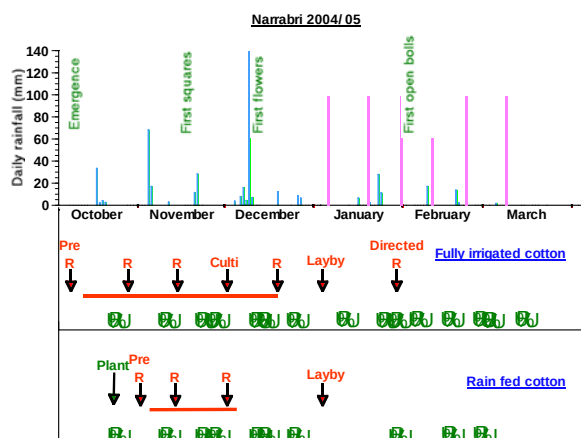


Figure 1. A simulation of how the CPWC might have been applied in the 2004-5 season at Narrabri (ACRI). Simulations are for both fully irrigated and rain fed crops. Symbols are: blue bars, daily rainfall (mm); pink bars, irrigations; red lines, the CPWC; red arrows, weed control inputs (R = Roundup Ready® Herbicide, Pre R = a pre-crop emergence Roundup, Culti = inter-row cultivation, Layby = a residual layby herbicide); and green arrow, planting. Periods of peak weed emergence are indicated by .

With no pre-planting or at-planting residual herbicides used, post-emergence weed control was required following weed emergence on four occasions during the critical period, at 6 nodes, first squares, first flowers and mid-flowering (310, 511, 719 and 946 day degrees). Ideally, weeds need to be controlled within 105 day degrees of their germination, which will be only a few days after seedling emergence. Roundup Ready Herbicide could be used on three of these occasions, with inter-row cultivation and chipping used on one occasion. This combination of inputs conforms with the Roundup Ready Flex Crop Management Plan which requires that: (1) no more than three Roundup Ready Herbicide applications are made during this crop growth period; and (2) that weeds that survive a Roundup Ready Herbicide application are controlled by an alternate method before they set seed (the combination of inter-row cultivation and chipping conforms with this requirement). Only a very light chipping should have been required as few weeds would have survived two Roundup applications and a cultivation pass.

Weeds that emerged later in the season would still need to be controlled to prevent problems such as harvesting difficulties, lint contamination and the build up of the weed seedbank (leading to increasing weed problems over time). These weeds could be controlled with a lay-by application

of residual herbicide before canopy closure and a directed application of Roundup Ready Herbicide during the 16 to 22 node stage if required. A pre-harvest application of Roundup Ready Herbicide could also be used to prevent late-season weeds setting seed if sufficient late-season weeds were present to justify this input.

This herbicide program would potentially have used the maximum number of early-season Roundup Ready Herbicide inputs allowed by the label, but probably not all these inputs would have been required in practice, with at least one inter-row cultivation pass replacing a Roundup application. It is also likely that lower than maximum label rates would have been used for the first two Roundup applications as these were applied to young weeds which are easily controlled with lower rates. Rates of 0.5 to 1 kg/ha would give excellent control of most susceptible weed seedlings. An early lay-by application of residual herbicide could have been applied in late-Dec. if an additional weed control input had been required during the critical period.

Rainfall in mid-Oct. allowed a rain-fed crop to be planted on 24th Oct. Post-emergence weed control was required on two occasions, at 5-6 nodes and first squares (282 and 490 day degrees). Weeds which emerged later in the season could have been controlled with a lay-by application of residual herbicide in early Jan. It is unlikely that further weed control inputs would have been required in this season.

The CPWC in 2005-6

Reasonable rainfall again fell in the 2005-6 season at Narrabri, and multiple weed germination events were triggered by rainfall and irrigation (Figure 2).

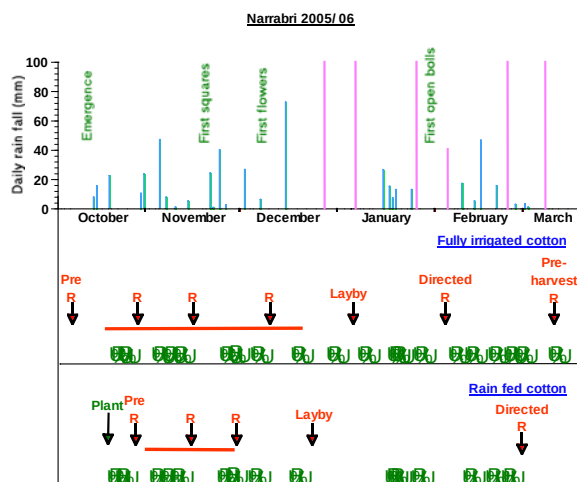


Figure 2. Using the CPWC in the 2005-6 season. Simulations for fully irrigated and rain-fed crops are shown. Weed control operations during the CPWC protect cotton yield. Weed control operations after the CPWC prevent weeds from adding seed to the soil seed bank, leading to problems in later seasons.

Using a 1% yield loss threshold, post-emergence weed control was required at 5 nodes, first squares and first flowers (259, 460, and 803 day degrees). Roundup Ready Herbicide could have been used on all occasions, although an inter-row cultivation and light chipping may have been used on one occasion to remove any weeds that survived the Roundup application, as required by the Crop Management Plan. Weeds which emerged later in the season could have been controlled with a lay-by application of residual herbicide in early Jan. and a directed application of Roundup Ready Herbicide during the 16 to 22 node stage if required. A pre-harvest application of Roundup Ready Herbicide could also be used to prevent late-season weeds setting seed.

This herbicide program may have again used the maximum number of Roundup Ready Herbicide inputs allowed by the label. Lower than maximum label rates would have been required for the first two applications to young weeds, enabling the total in-crop use to remain within label requirements even if both the directed application and the pre-harvest application were required.

Rainfall in mid-Oct allowed a rain-fed crop to be planted on 20th Oct. With a 3% yield loss threshold, post-emergence weed control was required at 7-8 nodes and mid-squaring (245 and 586 day degrees). Later emerging weeds could have been controlled with a lay-by application of residual herbicide in early Jan. A pre-harvest application of Roundup Ready Herbicide may also have been

required to prevent late-season weeds setting seed following good rain in Feb.

The CPWC in 2006-7

Very little rain fell in the 2006-7 season at Narrabri, with most weed germination events triggered by irrigation (Figure 3).

Using a 1% yield loss threshold, post-emergence weed control was only required at first squares (460 day degrees). Weeds which emerged later in the season could have been controlled with inter-row cultivation or a lay-by application of residual herbicide. No other weed control may have been necessary.

Rainfall in early Nov. may have allowed a rain-fed crop to be planted on 8th Nov. With a 3% yield loss threshold, no rainfall occurred during the CPWC and it is likely that few if any weeds emerged during this period. Weeds which emerged later in the season could have been controlled with a lay-by application of residual herbicide.

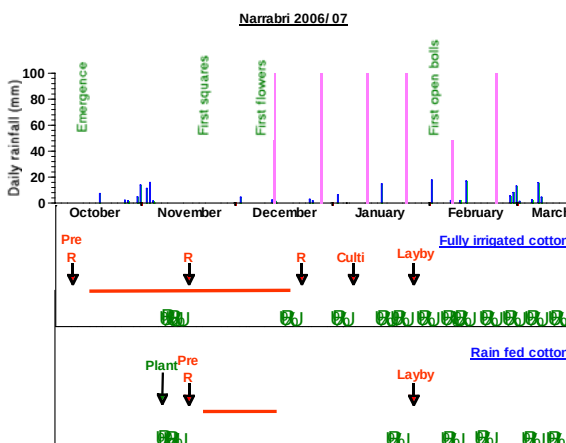


Figure 3. Applying the CPWC in the 2006-7 season. Simulations are for fully irrigated and rain-fed crops.

Observations from these simulations

The CPWC approach can be successfully applied in both irrigated and rain-fed cotton. Applying Roundup Ready Herbicide inputs to small weeds soon after emergence will maximize herbicide efficacy and yields but will not necessarily result in the maximum number of applications being used too early in the season, especially where inter-row cultivation or other herbicides are used on some occasions instead of Roundup.

In seasons where the early season weed pressure is too high (requiring too many early Roundup applications), an early layby application of residual herbicide can be used to replace a Roundup application and reduce weed pressure. Prometryn (Gesagard) or fluometuron (Cotoran), for example, can be applied as an early layby to cotton as small as 15 cm high and will control a wide range of emerged weeds provided they are applied to small weeds, as well as giving residual control, reducing weed pressure. An alternative residual, such as diuron, could then be applied later in the season as a standard layby application.

Resistance to Roundup

Some cotton growers are concerned that relying too heavily on Roundup is likely to lead to future problems with weeds that are resistant to Roundup (glyphosate). The potential for resistance is very real, as shown by the increasing resistance problems with Roundup Ready crops in the US.

However, resistance can be avoided by following two simple rules.

1. Always follow the Roundup Ready Flex Crop Management Plan. Central to this plan is the requirement that crops are checked after a Roundup application and any surviving weeds controlled using an alternative weed management tool before the weeds set seed.
2. Ensure at least one effective alternative weed management tool is used each season. An inter-row cultivation combined with a light chipping is a sound strategy for avoiding resistance. Alternatively, using a directed layby residual herbicide, incorporated with inter-row cultivation can be equally effective, although a light chipping may still be required to control larger weeds in the plant line.

Conclusions

- Using Roundup Ready Flex cotton without pre- or at-planting residual herbicides can be a sound weed management strategy in low weed pressure fields in most seasons.
- Applying the CPWC and controlling weeds within a few days of germination will minimize

yield losses from weeds, while not leading to excessive herbicide use.

- Weeds that emerge after the CPWC still have to be controlled, but timing is not critical provided they are controlled before they set seed.
- Fields that have significant populations of troublesome weeds should always be treated with residual herbicides before or at planting.
- Alternative weed management tools such as inter-row cultivation and chipping can reduce the pressure on Roundup applications.
- Include a directed layby residual herbicide, incorporated with inter-row cultivation in the system.
- Consider an early layby herbicide application if seasonal conditions lead to excessive early season weed pressure.
- These strategies can be applied equally with an alternative technology, such as Liberty Link cotton, although an at-planting residual grass herbicide will be required on most fields with Liberty Link cotton.

Acknowledgements

We gratefully acknowledge the input of the “weeds team” who did the hard and often tedious field work involved in the experiments contributing to this article. This work was funded by NSW Dept Primary Industries, the Cotton Catchment Communities CRC and the Cotton R&D Corporation.

Summary

Application of the Critical Period for Weed Control (CPWC) concept was tested for irrigated and rain-fed Roundup Ready Flex[®] cotton crops using data from the last three seasons.

The CPWC was applied to a relatively dirty field situation, where large numbers of weeds emerged after each rainfall and irrigation event.

The CPWC required that weeds were controlled while still small, potentially using up the in-crop Roundup Ready[®] applications early in the season.

The seasons varied from relatively wet (first half of 2004-5) to extremely dry (2006-7).

All weed flushes were able to be controlled in each season using the CPWC approach, with an early application of a residual layby herbicide available as a backup additional weed management tool.

The results show that ensuring weeds are controlled soon after emergence is a practical approach to weed control which will minimise yield losses from weeds.

USING THE CRITICAL PERIOD FOR WEED CONTROL IN THE 2007/8 SEASON

Graham Charles and Ian Taylor
(NSW Dept of Primary Industries)

Contents	Page
The critical period for weed control	B4.5.1
The critical period in irrigated cotton	B4.5.2
The critical period in dryland cotton	B4.5.3
Observations from the 2007/8 season	B4.5.4
Resistance to Roundup	B4.5.4
Conclusions	B4.5.5
Summary	B4.5.6



Roundup Ready Herbicide® was a powerful tool for controlling weeds in Roundup Ready Flex® cotton in the very wet early-season conditions experienced in the Burdekin this year. The question of the optimum time to apply herbicides still remains.

The critical period for weed control

The critical period for weed control is a concept that relates the yield reduction caused by weed competition to an economic threshold. It establishes an initial period when the weeds are small and do not need to be controlled as they cause no economic loss, and a period at the end of the season when late emerging weeds again cause no economic loss as the cotton plants are relatively large and competitive. These periods define the middle, critical period for weed control, in which weeds must be controlled while still small to avoid significant yield losses. Weeds can be tolerated in the last stage, after the critical period, as they will not reduce crop yields, but may still

need to be controlled to avoid harvesting difficulties and lint contamination and should not be allowed to set seed, as this will lead to increased weed problems in later seasons. These weeds can also harbour pests and diseases.

In practice, the critical period is defined by the type of weed present, the density of weeds, the potential crop yield, the cost of weed control and the economic threshold the cotton grower chooses.

The critical period for weed control is defined in Table 1 for large and medium sized broadleaf and grass weeds using 1% and 3% thresholds. These thresholds approximate likely control thresholds for applying glyphosate to fully irrigated cotton (1% threshold) and lower yielding or rain-fed crops (3% threshold). The thresholds approximate the point where the yield loss caused by the weeds equals the cost of control with glyphosate. The point of the threshold is determined by the cost of the control input and the value of the crop.

To show how these thresholds would be used in the field, we applied them to 3 weed densities in irrigated and dryland cotton crops, using climatic data from Narrabri for the 2007/8 season. We used dirty, average and clean fields, with mixed populations of large and medium broadleaf and grass weeds. Weed germinations were related to rainfall and irrigation events. The models assumed most weeds emerged 50 to 100 day degrees after rain (or irrigation), and all weeds were controlled with glyphosate.

It is essential that glyphosate is not the only herbicide used in fields with very heavy weed densities, or where glyphosate tolerant weeds are present. Residual herbicides, such as prometryn, fluometuron and diuron, or alternative contact herbicides, such as Staple® or Envoke®, should be used in fields where significant numbers of glyphosate tolerant weeds, such as burr medic, rhyngo and emu foot are present. The choice of herbicide(s) is determined by the weed species present.

Table 1. The predicted start and end of the critical period for weed control for a range of weed types and densities, using 1% and 3% control thresholds. Examples of weeds in each category are: thornapples and noogoora burrs (large broad-leaf weeds); bladder ketmia and Chinese lantern (medium broad-leaf weeds); and barnyard grass (grass weed). The minimum weed densities needed to trigger the critical period are also shown.

Weed density (no./m ²)	Critical Period for Weed Control (day degrees since planting)											
	Large broad-leaf weeds				Medium broad-leaf weeds				Grass weeds			
	1%		3%		1%		3%		1%		3%	
	Yield loss threshold		Yield loss threshold		Yield loss threshold		Yield loss threshold		Yield loss threshold		Yield loss threshold	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
0.1	111	210	-	-	111	172	-	-	-	-	-	-
0.2	111	310	178	222	111	249	-	-	-	-	-	-
0.5	110	507	177	365	110	416	-	-	-	-	-	-
1	110	678	175	508	110	583	175	227	-	-	-	-
2	109	827	170	653	109	748	170	331	-	-	-	-
3	108	895	166	725	108	831	166	409	123	141	-	-
5	105	959	158	798	105	913	158	517	122	178	137	148
10	101	1014	142	864	101	987	142	661	121	259	136	206
20	94	1044	119	901	94	1029	119	774	120	383	132	299
50	84	1063	89	926	84	1057	89	866	115	600	124	477
Min.density	0.03		0.14		0.04		0.62		2.1		4.2	

Very dirty fields are normally best managed by applying residual herbicides before or at planting, reducing the pressure on glyphosate later in the season. This is generally more satisfactory than applying these herbicides later in the season after problems have already occurred, when it is difficult to achieve good incorporation of the herbicides, especially in the plant line.

The discussion in this article focuses on the management of Roundup Ready Flex cotton crops because the critical period approach is readily adapted to the Roundup system and this is currently the most common cropping option used. The concept can be equally applied to conventional and Liberty Link cotton crops, but the thresholds will need to be modified to take into account the costs of alternative inputs with these crops.

The critical period in irrigated cotton

The crops were watered-up on 8th Oct. No residual herbicides were applied before or at planting.

The start of the critical period was relatively insensitive to weed density, provided there were enough weeds to trigger the critical period. This minimum number of weeds was very low for large broadleaf weeds, at 3/100 m row (1% threshold), but much higher for grass weeds at 2.1/m row.

Given that the threshold weed density was reached, the first Roundup application was required soon after crop emergence (105 - 110 day degrees after planting), as shown in Figure 1. The end of the critical period for weed control was strongly influenced by weed type and density, rising from 583 day degrees post-planting in the clean field, to 1029 day degrees in the dirty field.

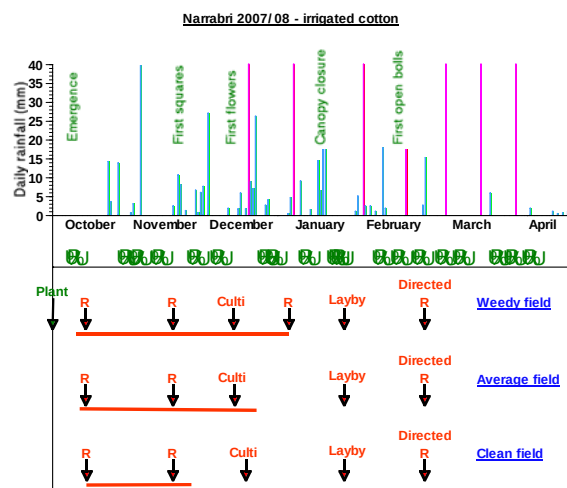


Figure 1. How the critical period for weed control could have been used in the 2007-8 season at Narrabri for weedy, average and clean fields. Symbols are: (top section) rainfall (vertical blue bars) and irrigations (vertical pink bars); (middle section) periods of peak weed emergence, ; and (bottom section) the critical period for weed control, horizontal lines; and planting and weed control inputs, arrows. Symbols used on arrows are: planting, **Plant**; Roundup Ready Herbicide sprays, **R**; inter-row cultivation passes, **Culti**; and application and incorporation of a residual herbicide, **Layby**.

Reasonable rain fell over late spring and summer, in a relatively long, cool season. This resulted in multiple weed germinations, with later germinations triggered by irrigations. A 2nd Roundup application was required on all fields in early-November to control a flush of weeds after rain in late-October. A fall of 40 mm on 6th November delayed this application till mid-November.

Lower than maximum label rates would have been suitable for Roundup applications to young weeds, as weeds are more easily controlled while they are small, provided they have sufficient leaf area to catch the spray. Rates of 0.8 to 1 kg/ha should be sufficient to control susceptible weed seedlings, reducing cost and maintaining late-season options (the product label precludes the use of maximum label rates for all applications if the maximum number of in-crop Roundup applications is used).

An alternative input, such as a cultivation and light chip, may have been required to remove surviving weeds after this application, as required by the Roundup Ready Flex Crop Management Plan. The need for this input is determined by the in-crop survey of weed survivors. Controlling surviving weeds with an alternative management input is essential to avoid species shift and herbicide resistance.

No further weed control in the critical period was required on the clean field, but all fields were inter-row cultivated in early- to mid-December prior to the first irrigation. This cultivation was undertaken to facilitate water movement and would also have controlled most weeds present. A residual herbicide could have been applied and incorporated at this time if required. No further treatment was required in the critical period on the average field, but an additional Roundup was required at the start of January on the weedy field.

A large number of weeds emerged following good rain in December and January, necessitating treatment by Roundup or the use of an incorporated residual herbicide in late January. Roundup could not have been used on the weedy field as only 3 post-emergence applications are permitted up to the 16 node stage of crop growth (this is a requirement of the product label). An additional directed Roundup application could have been made in late February, and a pre-harvest application could also have been used to prevent late-season weeds setting seed if sufficient weeds were present to justify these inputs.

Applying an incorporated, residual herbicide at canopy closure is a sound strategy for most fields. A residual "layby" herbicide should control any weeds that have survived the Roundup applications (reducing the risk of glyphosate resistance developing), and reduce the risk of weeds emerging later in the season when they will be difficult and expensive to control.

The critical period in dryland cotton

The crops were planted on 28th Oct, following rain on the 25th. No residual herbicides were applied before or at planting.

The start of the critical period was again relatively insensitive to weed density, provided there were enough weeds to trigger the critical period. This minimum number of weeds was low for large broadleaf weeds, at 1 in 10 m row (3% threshold), but much higher for grass weeds at 4.2/m row.

Given that the threshold weed density was reached, the first Roundup application was required soon after crop emergence (158 - 177 day degrees after planting) (Figure 2). The end of the critical period for weed control was strongly influenced by weed type and density, rising from 365 day degrees post-planting in the clean field, to 798 day degrees in the dirty field.

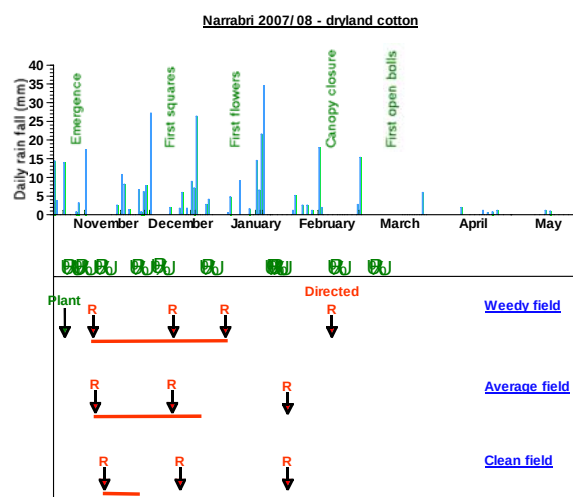


Figure 2. Using the critical period for weed control in dryland cotton in the 2007-8 season at Narrabri for weedy, average and clean fields.

A 2nd Roundup application was required on the average and weedy fields in early-December to control a flush of weeds after rain in late-November. An application may have also been used on the clean field to manage weeds before they set seed.

Lower than maximum label rates would have been suitable for those Roundup applications applied to young weeds, as these weeds are more easily controlled. Rates of 0.8 to 1 kg/ha would give excellent control of susceptible weed seedlings, reducing cost and maintaining late-season options.

No further weed control in the critical period was required on the clean and average fields, but a Roundup may have been used in late-January, again to control weeds before they set seed. A Roundup was required at the start of January on the weedy field.

An alternative treatment, such as a cultivation and light chipping, may have been used to remove surviving weeds after the Roundup applications in mid-December, as required by the Roundup Ready Flex Crop Management Plan. The need for this input is determined by the in-crop survey of weed survivors.

Observations from the 2007/8 season

Using the critical period for weed control approach in this season didn't encounter any difficulties for either irrigated or dryland cotton production and would have closely mirrored the inputs made by good managers. Weeds could have been controlled using Roundup Ready Herbicide within the restrictions of the label.

The main difference for crop management with this approach is that weed control is focussed on the critical period, soon after crop emergence, with all inputs during this period occurring on very small weeds. This contrasts with a more common philosophy, that glyphosate applications to Roundup Ready Flex crops can be delayed to maximise the efficiency of each spray, minimising the number of sprays and ensuring that the maximum number of weeds are controlled with each input. Many cotton growers have concluded that since they are no longer constrained to the 4-node over-the-top glyphosate application window, glyphosate applications can be delayed to about 6 nodes, with a 2nd application at 10 to 12 nodes giving good weed control. While this approach appears to be valid, the science of the critical period has shown that the first glyphosate application may need to occur soon after crop emergence, with further applications following closely after successive weed germination events. This strategy of controlling very small weeds may require more Roundup applications, but can utilize lower herbicide rates and maintains the potential for higher crop yields.

The critical period for weed control approach was successfully applied in both irrigated and dryland cotton in the 2007/9 season. Applying Roundup Ready Herbicide to small weeds soon after emergence maximized herbicide efficacy and crop yields but didn't result in the maximum number of Roundup applications being used too early in the season.

In seasons where the early season weed pressure is excessive (possibly requiring more Roundup applications than are permitted by the product label), an alternative herbicide or early layby application of residual herbicide could be used to replace a Roundup application and reduce weed pressure. Prometryn (Gesagard) or fluometuron (Cotoran), for example, can be applied as an early layby to cotton as small as 15 cm high and control

a wide range of emerged weeds provided they are applied to small weeds, as well as giving residual control, reducing weed pressure. An alternative residual, such as diuron, could be applied later in the season as a standard layby application if necessary.

Resistance to Roundup

Some cotton growers are concerned that relying too heavily on Roundup is likely to lead to future problems with weeds that are resistant to Roundup (glyphosate). The potential for resistance is very real, as shown by the increasing resistance problems with Roundup Ready crops in the US.

However, resistance can be avoided by following two simple rules.

1. Always follow the Roundup Ready Flex Crop Management Plan. The core principle of this plan is to ensure crops are checked after a Roundup application and any surviving weeds are controlled using an alternative weed management tool before they set seed.
2. Ensure at least one effective alternative weed management tool is used each season. An inter-row cultivation combined with a light chipping is a sound strategy for avoiding resistance. Alternatively, using a directed layby residual herbicide, incorporated with inter-row cultivation can be equally effective, although a light chipping may still be required to control larger weeds in the plant line.



The Critical Period for Weed Control was tested using a range of weeds planted and removed at different stages of crop growth. The effects of weeds on crop growth, development and yield was measured.

Conclusions

- Using Roundup Ready Flex cotton without pre- or at-planting residual herbicides can be a sound weed management strategy in low weed pressure fields.
- Including alternative weed management tools in the system, such as inter-row cultivation, can reduce the pressure on Roundup applications.
- Including a directed layby residual herbicide, incorporated with inter-row cultivation, in the system can assist with the management of later emerging weeds and reduce the risk of species shift and herbicide resistance.
- If seasonal conditions lead to excessive early season weed pressure, an early layby herbicide application may be a valuable investment for reducing the pressure on glyphosate.
- Fields with significant populations of glyphosate tolerant or hard-to-control weeds should always be treated with residual herbicides before or at planting.
- These strategies can be applied equally with an alternative technology, such as Liberty Link cotton, although an at-planting residual grass herbicide will be required on most fields with Liberty Link cotton.



Summary

Data from last season was used to test the critical period for weed control approach for irrigated and dryland Roundup Ready Flex[®] cotton crops.

The critical period for weed control was applied to dirty, average and clean fields, where weeds emerged after each rainfall and irrigation event.

Applying the critical period approach required that the start of weed control began soon after crop emergence, while weeds were still small. A lighter herbicide rate might be appropriate for small weeds. The duration of the critical period depended on the density of weeds that emerged after the first treatment.

All weed flushes in the 2007/8 season were controlled using Roundup during the critical period, with an inter-row cultivation or an early application of a residual layby herbicide available as an additional weed management tool if required.

The results show that ensuring weeds are controlled soon after emergence is a practical approach to weed control which will help optimize crop yields. The approach can be equally applied to irrigated and dryland crops using Roundup Ready Flex, Liberty Link[®] or conventional cotton varieties.

MANAGING WEEDS USING THE CRITICAL PERIOD FOR WEED CONTROL

Graham Charles and Ian Taylor
(NSW Dept of Primary Industries)

Contents	Page
The critical period for weed control	B4.6.1
The critical period in irrigated cotton	B4.6.2
The critical period in dryland cotton	B4.6.3
Observations from the 2007/8 season	B4.6.3
Summary	B4.6.4



Weeds can compete strongly with cotton, reducing yields. Weeds can also harbour pests and diseases, interfere with water flow and picking and contaminate lint. This heavy infestation of Australian bindweed is far more serious than it may appear.

The critical period for weed control

The critical period for weed control is a concept that relates the yield losses caused by weed competition to an economic threshold. It establishes an initial period when weeds are small and do not need to be controlled as they cause no economic loss, and a period later in the season when the cotton plants are relatively large and small weeds again cause no economic loss. These periods define the middle, critical period for weed control, in which weeds must be controlled while still small to avoid significant yield losses. Weeds which emerge after the critical period may still need to be controlled to avoid harvesting difficulties and lint contamination and should not be allowed to set seed, as this will lead to

increased weed problems in later seasons. These weeds can also harbour pests and diseases. However, the timing of this control is flexible, provided seed set is prevented, and can be delayed to minimise the number of spray applications required over the season.

In practice, the critical period is defined by the type and density of weeds, potential crop yield, the cost of weed control and the economic threshold the cotton grower chooses. The critical period is defined in Table 1 for large and medium sized broadleaf and grass weeds in high yielding, fully irrigated cotton, and lower yielding or rain-fed crops. Earlier articles defined a critical period based on lower thresholds. The increased thresholds reflect the jump in the glyphosate prices late last year.

To show how the critical period would have worked last season, we applied it to irrigated and dryland cotton crops, using climatic data from Narrabri. We used weedy, average and clean fields, with mixed populations of large and medium broadleaf and grass weeds.

The discussion focuses on the management of Roundup Ready Flex cotton crops because the critical period is readily adapted to the Roundup system and this is the most common cropping option used. The concept can be equally applied to conventional and Liberty Link crops.

Table 1. The predicted start and end of the critical period for weed control for a range of weed types and densities. Examples of weeds in each category are: thornapples and noogoora burrs (large broad-leaf weeds); bladder ketmia and Chinese lantern (medium broad-leaf weeds); and barnyard grass (grass weed). The minimum weed densities needed to trigger the critical period are also shown.

Weed density (no./m ²)	Start and end of the critical period for weed control (day degrees since planting)											
	Irrigated (high yielding) cotton						Dryland (low yielding) cotton					
	Broad-leaf weeds						Broad-leaf weeds					
	Large		Medium		Grasses		Large		Medium		Grasses	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
0.1	145	189	145	172	-	-	-	-	-	-	-	-
0.2	144	275	144	244	-	-	254	229	-	-	-	-
0.5	143	447	143	387	-	-	251	368	-	-	-	-
1	141	600	141	514	-	-	246	498	246	319	-	-
2	139	738	139	627	-	-	238	620	238	421	-	-
5	131	862	131	729	129	174	215	735	215	537	-	-
10	121	915	121	771	127	248	184	785	184	595	152	206
20	106	944	106	795	125	357	142	812	142	631	147	290
50	87	962	87	810	119	531	93	830	93	654	134	431
Min. density	0.06		0.07		2.5		0.24		0.59		5.4	

The critical period in irrigated cotton

The crops were watered-up on 8th Oct. No residual herbicides were applied before or at planting.

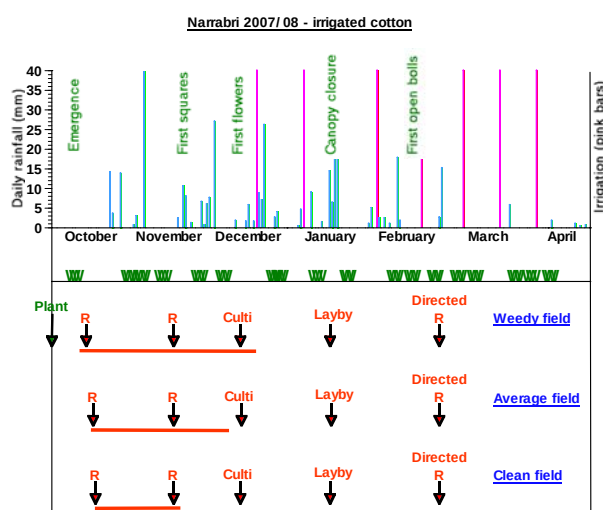


Figure 1. How the critical period for weed control could have been used in the 2007-8 season at Narrabri for weedy, average and clean fields. Symbols are: (top section) rainfall (vertical blue bars) and irrigations (vertical pink bars); (middle section) periods of peak weed emergence, W; and (bottom section) the critical period for weed control, H; and horizontal lines; and planting and weed control inputs, arrows. Symbols used on arrows are: planting, **Plant**; Roundup Ready Herbicide sprays, **R**; inter-row cultivation passes, **Culti**; and application and incorporation of a residual herbicide, **Layby**.

The start of the critical period was relatively insensitive to weed density, provided there were enough weeds to trigger the critical period. Given that the threshold weed density was reached, the first Roundup application was required soon after crop emergence (106 - 141 day degrees after planting, Figure 1). The end of the critical period was strongly influenced by weed type and density,

rising from 514 day degrees post-planting in the clean field, to 862 day degrees in the weedy field.

Lower than maximum label rates would have been suitable for Roundup applications to young weeds, as weeds are more easily controlled while they are small, provided they have sufficient leaf area to catch the spray. Rates of 0.8 to 1 kg/ha should be sufficient to control susceptible weed seedlings, reducing cost and maintaining late-season options (the product label precludes the use of maximum label rates for all applications if the maximum number of in-crop Roundup applications is used).

An alternative input, such as a cultivation and light chip, may have been required to remove surviving weeds after this application, as required by the Roundup Ready Flex Crop Management Plan. The need for this input is determined by the in-crop survey of weed survivors. Controlling surviving weeds is essential to avoid species shift and herbicide resistance.

Reasonable rain fell over late spring and summer, in a relatively long, cool season. This resulted in multiple weed germinations, with later germinations triggered by irrigations. A 2nd Roundup application was required on all fields in early-November to control a flush of weeds after rain in late-October. A fall of 40 mm delayed this application till mid-November.

No further weed control in the critical period was required on the clean or average fields, but all fields were inter-row cultivated in early- to mid-December prior to the first irrigation. This cultivation was undertaken to facilitate water movement and would also have controlled most weeds present. A supplementary Roundup application and/or chipping may have been required in the weedy field.

WEEDpak

section **B4.6**

A large number of weeds emerged following further rain in December and January, necessitating treatment by Roundup or the use of an incorporated residual herbicide in mid-January. An additional directed Roundup application could have been made in late-February, and a pre-harvest application could also have been used to prevent late-season weeds setting seed if sufficient weeds were present to justify these inputs.

The critical period in dryland cotton

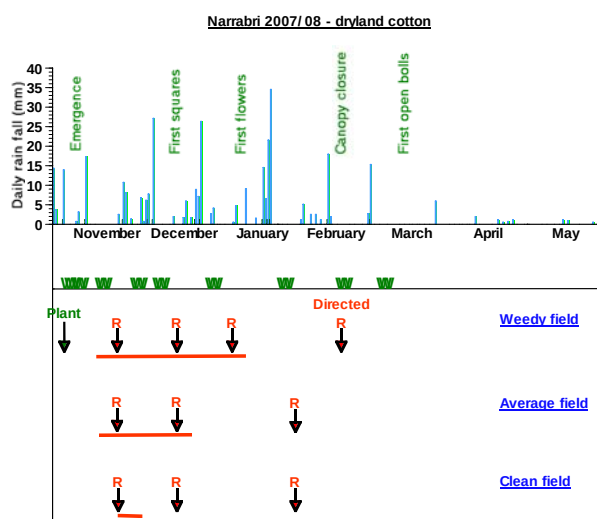


Figure 2. Using the critical period for weed control in dryland cotton in the 2007-8 season at Narrabri. Symbols are explained in the caption to Figure 1.

The crops were planted on 28th Oct, following rain on the 25th. No residual herbicides were applied before or at planting.

The start of the critical period was again relatively insensitive to weed density, provided there were enough weeds to trigger the critical period. Given that the threshold weed density was reached, the first Roundup application was required soon after crop emergence (241 day degrees after planting, Figure 2). The end of the critical period was strongly influenced by weed type and density, rising from 368 day degrees post-planting in the clean field, to 735 day degrees in the weedy field.

A 2nd Roundup application was required on the average and weedy fields in early-December to control a flush of weeds after rain in late-November. An application may have also been used on the clean field to control weeds before they set seed.

No further weed control in the critical period was required on the clean and average fields, but a Roundup may have been used in late-January, again to control weeds before they set seed. A Roundup was required at the start of January on the weedy field.

An alternative treatment, such as a cultivation and light chipping, may have been used to remove surviving weeds after the Roundup applications in mid-December, as required by the Roundup Ready Flex Crop Management Plan. The need for this input is determined by the in-crop survey of weed survivors.



An experiment using a naturally occurring weed population to test the application of the critical period for weed control in cotton at ACRI last season.

Observations from the 2007/8 season

Using the critical period for weed control approach in this season didn't encounter any difficulties for either irrigated or dryland cotton production.

The main difference for crop management with this approach is that weed control is focussed on the critical period, soon after crop emergence, with all inputs during this period necessarily occurring on small weeds. This contrasts with a more common philosophy, that glyphosate applications to Roundup Ready Flex crops can be delayed to maximise the efficiency of each spray, minimising the number of sprays and ensuring that the maximum number of weeds are controlled with each input. Many cotton growers have concluded that since they are no longer constrained to the 4-node over-the-top glyphosate application window, glyphosate applications can be delayed to about 6 nodes, with a 2nd application at 10 to 12 nodes giving good weed control. While this approach is valid, the science of the critical period has shown that to avoid yield losses, the first glyphosate application may need to occur soon after crop emergence, with further applications following closely after successive weed germination events. This strategy of controlling very small weeds may require more Roundup applications, but can utilize lower herbicide rates and maintains the potential for higher crop yields.

In seasons where the early season weed pressure is excessive (possibly requiring more Roundup applications than are permitted by the product label), an alternative herbicide or early layby application of residual herbicide could be used to replace a Roundup application and reduce weed pressure. Prometryn (Gesagard) or fluometuron (Cotoran), for example, can be applied as an early layby to cotton as small as 15 cm high and control a wide range of small emerged weeds, as well as giving residual control, reducing weed pressure. An alternative residual, such as diuron, could be applied later in the season as a standard layby application if necessary.

Summary

Data from last season was used to test the practicality of applying the critical period for weed control for irrigated (higher yielding) and dryland (lower yielding) cotton crops. The critical period was applied to weedy, average and clean Roundup Ready Flex® fields.

Applying the spraying threshold required that weed control began soon after crop emergence, while weeds were still small. A lighter herbicide rate would be appropriate for these weeds. The threshold was reached later in the dryland crop. The duration of the critical period depended on the density of weeds present.

All weed flushes were controlled using Roundup during the critical period within the constraints of the Roundup Ready Herbicide label, with an inter-row cultivation or early layby available as an additional management tool.

The results show that ensuring weeds are controlled soon after emergence is a practical approach to weed control which will help maximize crop yields. The approach can be equally applied to irrigated and dryland crops using Roundup Ready Flex, Liberty Link® or conventional cotton varieties.

SAMPLING METHODS FOR THE CRITICAL PERIOD FOR WEED CONTROL

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
What is the critical period for weed control	B4.7.1
Applying the critical period	B4.7.1
The field sampling technique	B4.7.2
Summary	B4.7.4
The critical period weed assessment sheet	B4.7.5
Examples of large weeds	b4.7.6

What is the critical period for weed control

The critical period for weed control is a concept that relates the yield losses caused by weed competition to an economic threshold. It establishes an initial period when weeds are small and do not need to be controlled as they cause no economic loss, and a period later in the season when the cotton plants are relatively large and small weeds again cause no economic loss. These periods define the middle, critical period for weed control, in which weeds must be controlled while still small to avoid significant yield losses. Weeds which emerge after the critical period may still need to be controlled to avoid harvesting difficulties and lint contamination and should not be allowed to set seed, as this will lead to increased weed problems in later seasons. These weeds can also harbour pests and diseases. However, the timing of this control is flexible, provided seed set is prevented, and can be delayed to minimise the number of spray applications required over the season.

In practice, the critical period is defined by the type and density of weeds, potential crop yield, the cost of weed control and the economic threshold the cotton grower chooses. The critical period is defined in Table 1 for large and medium sized broadleaf and grass weeds in high yielding irrigated cotton, and lower yielding or rain-fed crops. Earlier articles defined a critical period

based on lower thresholds. The increased thresholds reflect the jump in glyphosate prices late last year.

The discussion focuses on the management of Roundup Ready Flex cotton crops because the critical period is readily adapted to the Roundup system and this is the most common cropping option used. The concept can be equally applied to conventional and Liberty Link crops.

Applying the critical period

Determining the critical period for weed control in a field requires a knowledge of the degree days since crop planting and the type and density of weeds present in the field. Degree days are calculated from the daily maximum and minimum temperatures since planting.

The type and density of weeds is determined from an in-field assessment. This assessment may take 30 - 40 minutes for each field, but is only required in the early part of the season and only after rainfall or irrigation events trigger new flushes of weeds.

The ability to identify weeds to species level is not necessary for the weed assessment, as weeds are grouped into 3 categories. Commonly occurring weeds in each category are:

- Large broadleaf weeds:
 - the noogoora burr group (Noogoora burr, Californian burr and Italian cocklebur),
 - thornapples (fierce thornapple, downy thornapple and common thornapple),
 - sesbania and budda pea

Seedling photos of these weeds can be found in WEEDpak on the COTTONpaks cd or at <http://www.cottoncrc.org.au>

Table 1. The start and end of the critical period for weed control for a range of weed types and densities. The minimum weed densities needed to trigger the critical period are also shown.

Weed density (no./m ²)	The Critical Period for Weed Control in cotton (day degrees since planting)											
	High yielding cotton crops						Low yielding cotton crops					
	Broad-leaf weeds				Grasses		Broad-leaf weeds				Grasses	
	Large		Medium		Start	End	Large		Medium		Start	End
	Start	End	Start	End			Start	End	Start	End		
0.1	145	189	145	172	-	-	-	-	-	-	-	-
0.2	144	275	144	244	-	-	254	229	-	-	-	-
0.5	143	447	143	387	-	-	251	368	-	-	-	-
1	141	600	141	514	-	-	246	498	246	319	-	-
2	139	738	139	627	-	-	238	620	238	421	-	-
5	131	862	131	729	129	174	215	735	215	537	-	-
10	121	915	121	771	127	248	184	785	184	595	152	206
20	106	944	106	795	125	357	142	812	142	631	147	290
50	87	962	87	810	119	531	93	830	93	654	134	431
Min. density	0.06		0.07		2.5		0.24		0.59		5.4	

- Medium broadleaf weeds:
 - All other weeds can be included in this group. If in doubt, put them here.
- Grasses:
 - includes the grasses and other grass-like species, such as the nutgrasses

The field sampling technique

The sampling technique to estimate the density of each weed type is similar to the technique used in the weed survey required by the Roundup Ready and Liberty Link Crop Management Plans.

Firstly, weed patchiness is assessed by a “drive-by” survey around the perimeter of the field, noting the location of the more weedy areas in the field. The density of each weed type is then assessed in 3 to 5 different areas of the field, with more sampling required on larger fields. The location of these assessments is determined from the drive-by survey, ensuring that the more weedy areas of the field are included in the assessments. Ensure that both head ditch and tail ditch ends of the field are checked, and that the observations are not concentrated on the edge of the field. On deep fields with runs of 1000 m or more, it may be necessary to go further into the field than the 250 m suggested below.

Once the areas for assessment are located, the assessment is undertaken by walking approximately 250 m into the field in each area and estimating weed density and type. The 500m walk (250 m each way) is broken into 50m strips, moving across 10 rows after each 50 m strip and estimating the density of each weed type in each 50 m strip (each strip is 1 m wide, from cotton row to cotton row). Ensure that the survey covers both beds and furrows in 2 m beds or other configurations).

The weed assessment method is simple. In each strip, the density of large and medium broadleaf weeds and grasses is assessed. This is done by estimating the density of each weed type as <5/50 m row, 5-50/50 m row, 50-500/50 m, or > 500/50 m. At first it may be necessary to count a few weeds to get an idea of what these densities look like, but the densities can be easily estimated by eye with experience. Density can be easily calculated in cotton on a 1 m planting configuration by visualizing a 1 m square area and counting the number of weeds in this area. One weed per square m equates to 50 weeds per 50 m². The exact length of each transect (50 m) is not critical, but is a guide to the amount of area which should be covered. It is essential that the survey goes towards the middle of the field, as the edge area may not be representative of the whole field.

A table for the weed assessments is given at the end of this document. To use this table:

1. For each 50 m strip, write a score of 1, 2, 3 or 4 corresponding to the estimated density of each weed type.
2. Add the scores in each column and add the columns to give a total for the assessment, as in the example below.

Large broadleaf		Number per 50 m of row			
weeds	<5	5 - 50	50 - 500	>500	
	1	2	3	4	
0-50 m		2			
50-100 m		2			
100-150 m		2			
150-200 m	1				
200-250 m		2			
250-200 m	1				
200-150 m	1				
150-100 m	1				
100-50 m	1				
50 - 0 m			3		Total
Sum	<u>5</u>	<u>8</u>	<u>3</u>		16

3. The scores from this assessment, along with the scores from the other assessments done in the paddock are transferred to the Score Summary, as in the example below.

Score Summary	1	2	3	4	5
Large broadleaf	16	12	23	19	30
Medium broadleaf					
Grasses					

4. These numbers are converted to weed density using the table of Scores and Weed densities on the right hand side of the page, recorded in the Assessment Summary, and the average entered, as shown below.

Assessment summary	1	2	3	4	5	Average
Large broadleaf	0.2	0.079	1	0.4	5	<u>1.3</u>
Medium broadleaf						—
Grasses						—

5. This average is the field density of broadleaf weeds used to determine the critical period for weed control for this field. In this case, a density of 1.3 translates to a critical period from 139 to 738 day degrees duration, using the closest higher number from the Critical Period table (Table 1).

If the density of large broadleaf weeds ($1.3/\text{m}^2$) occurred within the Critical period, then a spray should be applied as soon as practical.

Outside the Critical Period, this weed density could be tolerated, provided the weeds are controlled before they set seed. However, if another flush of weeds emerges soon after, the field may need to be reassessed, as the increased weed density may fall within the new Critical Period that is derived by the new, larger, weed population.

Summary

- Use a drive-by survey to identify patches of heavier weeds in the field
- Assess weeds in 3 - 5 of the more weedy areas (depending on field size)
- Estimate the weed type and density on a 250 m strip into the field at each assessment point
- Use these assessments to determine the Critical Period for Weed Control for this crop.
- Organise to control weeds as soon as practical if the weed flush is within the Critical Period
- If not, monitor the weeds and control them before they set seed.

Applying the critical period requires that weed control begins soon after emergence in high yielding crops, while weeds are still small. A lighter herbicide rate would be appropriate for these weeds. The threshold will be reached later in lower yielding crops. The duration of the critical period depends on the density of weeds present.

All weed flushes can be controlled with Roundup during the critical period within the constraints of the Roundup Ready Herbicide label, with an inter-row cultivation or early layby available as an additional management tool if required.

Ensuring weeds are controlled soon after emergence is a practical approach to weed control which will help maximize crop yields. The approach can be equally applied to irrigated and dryland crops using Roundup Ready Flex, Liberty Link[®] or conventional cotton varieties.

The Critical Period Weed Sampling Sheet

Date:
Property:

Recorder:
Field:

Assessment:

Large broadleaf
weeds

Number per 50 m of row

<5	5 - 50	50 - 500	>500
1	2	3	4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Large broadleaf – Noogoora burrs,
thornapples, sesbania & budda pea
Medium broadleaf – all other
broadleaf weeds
Grasses – grasses and all grass like
weeds

Sum

—	—	—	—

Total

Medium broadleaf
weeds

<5	5 - 50	50 - 500	>500
1	2	3	4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Sum

—	—	—	—

Total

Grasses

<5	5 - 50	50 - 500	>500
1	2	3	4

0-50 m				
50-100 m				
100-150 m				
150-200 m				
200-250 m				
250-200 m				
200-150 m				
150-100 m				
100-50 m				
50 - 0 m				

Sum

—	—	—	—

Total

Assessment score

1	2	3	4	5

Large broadleaf

Medium broadleaf

Grasses

Assessment summary

1	2	3	4	5

Large broadleaf

Medium broadleaf

Grasses

Average

—

—

—

Assessment
score

Weed
density

1	0.006
2	0.008
3	0.010
4	0.013
5	0.016
6	0.020
7	0.025
8	0.032
9	0.040
10	0.05
11	0.063
12	0.079
13	0.10
14	0.13
15	0.16
16	0.20
17	0.25
18	0.32
19	0.40
20	0.5
21	0.63
22	0.79
23	1.00
24	1.26
25	1.58
26	1.99
27	2.51
28	3.15
29	3.97
30	5
31	6.29
32	7.92
33	10
34	12.6
35	15.8
36	19.9
37	25.1
38	31.5
39	39.7
40	50



Examples of Large Weeds



Noogoora burr complex:
Italian cocklebur, Californian burr
and Noogoora burr (L to R)



Thornapple complex:
common thornapple,
fierce thornapple, and
downy thornapple



Sesbania and budda pea



The Critical Period for Weed Control in cotton (day degrees since planting)												
Weed density (no./m ²)	High yielding cotton crops						Low yielding cotton crops					
	Broad-leaf weeds				Grasses		Broad-leaf weeds				Grasses	
	Large		Medium				Large		Medium			
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
0.1	145	189	145	172	-	-	-	-	-	-	-	-
0.2	144	275	144	244	-	-	254	229	-	-	-	-
0.5	143	447	143	387	-	-	251	368	-	-	-	-
1	141	600	141	514	-	-	246	498	246	319	-	-
2	139	738	139	627	-	-	238	620	238	421	-	-
5	131	862	131	729	129	174	215	735	215	537	-	-
10	121	915	121	771	127	248	184	785	184	595	152	206
20	106	944	106	795	125	357	142	812	142	631	147	290
50	87	962	87	810	119	531	93	830	93	654	134	431
Min. density	0.06		0.07		2.5		0.24		0.59		5.4	

HERBICIDE RESISTANCE

Introduction

Pesticides have been used widely in agriculture for many decades to manage weeds, insects and diseases. Over this time there has been an ever-increasing range of products available to deal with pests. Products range from those with very specific target sites and minimal environmental impact, to products that are broad-spectrum, and may remain active in the environment for weeks or months.

While there has been an ever increasing range and number of products available to manage weeds, there is also now an increasing number of weeds that are resistant to some of these products. These weeds were initially controlled by the herbicides, but as a result of repeated exposure, resistant individuals have been selected from the population and have come to dominate the population.

No herbicide resistant weeds are currently known to exist in the Australian cotton industry. It is the aim of the cotton industry to maintain its position as free of resistant weeds, enabling it to make use of the full spectrum of available herbicides.

This resistance-free status can best be maintained by using an integrated approach to weed management, ensuring that herbicides, and especially herbicides with the same mode of action, are never used as the only method of weed control. Steps to ensure the continuation of the resistance-free status are covered in the following article.

C2. Managing Herbicide Resistance in Cotton

When applied correctly, a herbicide effectively controls its target weed. Repeated use of a herbicide has two effects. Firstly, the herbicide selects for the more tolerant weed species, resulting in a species shift in favour of those tolerant species. Secondly, the herbicide selects out the more herbicide resistant individuals from within a species and the frequency of these individuals increases within the population, leading to the development of herbicide resistance.

The development of species shift and herbicide resistance can be managed using an integrated weed management strategy that combines the use of all the weed management tools, including herbicides from different herbicide groups, cultivation, chipping and good crop agronomy.

Basic information is given on herbicide resistance, herbicide groups, herbicide modes of action, weed monitoring and the necessary response to a suspected case of herbicide resistance.

C3. Herbicide Resistance and the Crop Management Plan

Many cotton growers are concerned that relying too heavily on Roundup (glyphosate) will lead to future problems with weeds becoming resistant to this herbicide. The potential for resistance is very real, as shown by the increasing resistance problems with Roundup Ready crops in the US, and emerging problems with glyphosate resistant ryegrass and awnless barnyard grass in the Australian cotton growing area.

This paper discusses these issues and explains the value of the approach used in the Crop Management Plans of Roundup Ready, Roundup Ready Flex and Liberty Link cotton for managing the development of resistance.

MANAGING HERBICIDE RESISTANCE IN COTTON

Graham Charles
(NSW Agriculture)

Contents	Page
Herbicide resistance	C2.1
Genetic variability	C2.1
Selection pressure	C2.2
Herbicide groups	C2.3
Herbicide modes of action	C2.4
Rotating herbicide groups	C2.5
Weed monitoring	C2.5
Suspected herbicide resistance	C2.6
Managing herbicide resistance	C2.6
Summary	C2.6

Herbicide resistance

Herbicide resistance occurs when a plant is able to tolerate a rate of a herbicide that kills other plants of the same species under the same conditions (both spray conditions and plant growing conditions).

Herbicide resistant individuals can occur at very low frequency in any natural plant population. Although these individuals may be present before a herbicide is first used in a field, their frequency is likely to remain low until a selection pressure is applied. This happens when a herbicide is applied. Individuals that are more tolerant of the herbicide survive the herbicide application and grow to set seed. This seed produces more individuals that tolerate the herbicide and set more seed, and so on. Eventually, the herbicide tolerant individuals represent a noticeable proportion of the weed population, and herbicide resistance occurs.

Genetic variability

Genetic variability is a characteristic of all populations. Even in a plant population (within a plant species), where all individuals may appear to be identical, there will be some genetic variability. Many of these genetic differences are of no obvious importance. Leaf shape and leaf colour in sow thistle, for example, are quite variable, but the differences do not appear to confer any difference in fitness or competitive ability.

Genetic differences that confer differences in the plant's tolerance to herbicides can exist in any plant population. Sometimes these differences are large enough that some individual plants may be able to tolerate quite high levels of herbicide without any apparent effect. These individuals are said to be herbicide resistant.

The level of herbicide resistance depends on the nature of the resistance and the genetic differences between resistance and susceptible individuals. Herbicide resistance could be as simple as the production of a waxy leaf surface that prevents the herbicide entering the leaf. Alternatively, resistance could be inferred by an individual over-producing a plant enzyme that was blocked by the herbicide, or producing a completely new enzyme that substitutes for the enzyme blocked by the herbicide, or by any number of other pathways.

The expression of herbicide resistance also depends on the genetics involved. Where herbicide resistance is caused by a single plant gene, this gene could be recessive and only expressed when the individual is homozygote (carries two copies of the gene). Alternatively, the gene could be dominant, expressing even when the plant only carries a single copy of the gene (heterozygote). In many cases, the heterozygote individual will express a lower level of herbicide resistance than homozygote individuals. A range of levels of herbicide resistance could occur when resistance is conferred by multiple genes.

Nevertheless, the selection for herbicide resistant individuals is the inevitable outcome of repeated use of a single herbicide or herbicide group. This selection pressure is greatly reduced when other weed management tools are used in combination with the herbicide.

Worldwide 156 weeds are resistant to herbicides. Some weeds have developed resistance to a range of different herbicides. Annual ryegrass in Australia, for example, is resistant to a wide range of herbicides from six different herbicide groups.

Selection pressure

When applied correctly, a herbicide effectively controls its target weed. Repeated use of a herbicide has two effects. Firstly, the herbicide selects for the more tolerant weed species, resulting in a species shift in favour of those tolerant species. That is, the frequency of the species most susceptible to the herbicide declines, while there is a relative increase in the frequency of species that are more tolerant of the herbicide. Species shift is a common occurrence. Secondly, the herbicide selects out the more herbicide resistant individuals from within a species and the frequency of these individuals increases within the population, leading to the development of herbicide resistance.

The rate at which these changes occur depends on a number of factors, including:

- the selection pressure imposed, which is determined by herbicide efficacy, the frequency of herbicide application and the generation interval
- the level of tolerance to the herbicide, the frequency of herbicide resistant individuals within the population, and the nature of the weed's reproductive mechanism,
- dilution of the population from the seed bank and external sources, and
- use of other weed management tools that reduce the population of tolerant and resistant individuals.

Herbicide groups

Every herbicide comes with detailed product information attached to the chemical container. Additional information may be included in an attached product booklet. This information includes details on the use of the product, the range of weeds controlled, application conditions, safety, and herbicide resistance (for the more recently registered products).

Included on the product label is information on the herbicide group to which the product belongs. This information is displayed prominently on the front of the product label.

The herbicide group information is essential for developing a weed management strategy which avoids selecting out herbicide resistant weeds. The herbicide groups are indicated by a lettering system, as shown in Table 1.

While all herbicides have the potential to cause a species shift in the weed population, they do not all have the same risk of developing a resistant weed population. Within the herbicide groups, there are three broad categories.

- herbicides with high risk (groups **A** and **B**).
- herbicides with moderate risk (groups **C** to **H**).
- herbicides with low risk (groups **I** to **N**).

The herbicide groups are based on the modes of action of the various herbicides, that is, the specific ways the herbicides work within a plant. There are many different modes of herbicidal action and a single herbicide may act on more than one plant process.

The herbicide risk categories have been developed from an understanding of the modes of action of these herbicide groups, and have been proven in practice.

The high risk herbicides (Groups **A** and **B**) target specific processes in the plant cell. Plants that are resistant to these herbicides occur relatively commonly in some weed populations. Herbicide resistant populations of weeds such as ryegrass and black oats, for example, have been selected out after as few as two or three herbicide applications in extreme cases. This means that the herbicide completely fails to control the weeds by the third or fourth application, because by this time the weed population is completely dominated by individuals that are resistant to the herbicide.

*Table 1. The herbicide groups of the herbicides commonly used in the cotton farming system. Examples of products containing these active ingredients are shown. A complete list of products is given in the **Herbicide and formulation lists** in **WEEDpak**.*

	Herbicide group	Active ingredient	Example
High risk	A	butroxydim clethodim fluzifop-P haloxyfop propaquizafop sethoxydim	Falcon Select Fusilade Verdict Correct Sertin
	B	chlorsulfuron halosulfuron-methyl imazapyr metsulfuron-methyl pyrithiobac sodium	Glean Sempra Arsenal Ally Staple
Moderate risk	C	atrazine diuron fluometuron prometryn	Cotoran Gesagard
	D	pendimethalin trifluralin	Stomp
Low risk	F	norflurazon	Zoliar
	G	oxyfluorfen	Goal
	I	2,4-D dicamba fluroxypyr MCPA	Starane
	K	metolachlor MSMA	Dual Daconate
	L	diquat paraquat	Reglone Gramoxone
	M	glyphosate glyphosate-trimesium	Touchdown

The post-emergence grass herbicides and Staple® are also in this category. Resistance to these products is likely to occur if they are used repeatedly without other weed management tools.

The herbicides in the moderate risk category (Groups **C** to **H**) are less specific in their mode of action, targeting more general plant processes. Individual plants with resistance to these herbicides may still occur, but they are less likely. Some of these herbicides, such as trifluralin, have been used repeatedly over many years without any apparent resistance problems occurring. Nevertheless, resistance can occur.

Weeds are unlikely to develop resistance to the herbicides in the low risk category (Groups **I** to **N**), as these herbicides have very general modes of action, or multiple modes of action. Nevertheless, over-reliance on these herbicides can still lead to resistance. For many years, it was believed that resistance to glyphosate (Group **M**) could not

occur, yet there are now examples of three weeds that have developed resistance to glyphosate. Resistance to glyphosate has developed in a number of different annual ryegrass populations in Australia. Resistance has developed in ryegrass populations where glyphosate was used as the main or only form of weed control over a number of years, with multiple applications each year. There is every reason to believe that further weeds can develop resistance to herbicides in this category if these herbicides are over-used.

Once herbicide resistance develops, an alternate management system is needed, as the herbicide is no longer of any use for controlling the target weed. Loss of a broad-spectrum herbicide such as glyphosate would have a major negative impact on the cotton farming system.

Further information on weeds that have developed resistance to herbicides in Australia is covered in the document **Integrated Weed Management Systems for Australian Cotton Production** in **WEEDpak**.

Herbicide modes of action

Similar herbicides often have similar modes of action. For example, the post-emergence grass herbicides (Group A) are all herbicides that act through inhibiting acetyl-coA carboxylase, an enzyme that is involved in fatty-acid synthesis in plant cells. This inhibition leads to membrane disruption in the plant cells and causes plant death.

Consequently, although six chemically distinct herbicides are listed in Group A in Table 1, they all act on the same plant pathway. In practice, a weed that develops resistance to one of these herbicides may be resistant to all six herbicides, even though it may never have been exposed to the other five herbicides. This is called cross-resistance.

However, apparently similar herbicides do not always have similar modes of action. Of the pre-emergent grass herbicides, trifluralin and pendimethalin are both group **D** herbicides, which inhibit tubulin formation, effectively inhibiting plant growth, while metolachlor is a group **K** herbicide, with multiple modes of action, inhibiting growth and root elongation. If a weed repeatedly exposed to trifluralin developed resistance to this herbicide, it may have cross-resistance to pendimethalin, but is extremely unlikely to have resistance to metolachlor.

Rotating herbicide groups

Where herbicides with similar weed spectrums have different modes of action, opportunity exists to rotate herbicides, reducing the risk of selecting weeds resistant to any one herbicidal mode of action. This strategy is difficult to implement in cotton, as many of the herbicides that could be readily substituted are from the same herbicide groups.

For example, as discussed earlier, although the post-emergence grass herbicides Correct®, Falcon®, Fusilade®, Select®, Sertin® and Verdict® are chemically different, they are all group **A** herbicides with similar modes of action. A weed that develops resistance to one of these herbicides may be cross-resistant to all of them, even though the weed had not been exposed to the other herbicides.

Similarly, the residual, broad-leaf herbicides most commonly used with cotton production (diuron, prometryn and fluometuron) are all group **C** herbicides, with similar modes of action.

However, the pre-emergent grass herbicides belong to groups **D** (trifluralin and pendimethalin), **K** (metolachlor) and **F** (Zoliar®). Use of these herbicides in rotation allows an opportunity to expose weeds to totally different herbicide groups, greatly reducing the risk of developing herbicide resistance.

Overall, the most effective approach to reduce the risk of the development of herbicide resistance and species shift to herbicide tolerant individuals, is to ensure that herbicides are used correctly, and to use an integrated approach to weed management, using as wide a range of herbicide groups as practical, and a variety of weed management tools. Detailed information on the integrated weed management tools and developing an integrated weed management system in cotton is covered in the document **Integrated Weed Management Systems for Australian Cotton Production** in **WEEDpak**.

Special care needs to be taken when making repeated use of the high risk group **A** and **B** herbicides.

Weed monitoring

The underlying principle of integrated weed management is to continually monitor the presence of weeds and the success or otherwise of the weed management tools used. Where a weed is not successfully controlled by one tool (herbicide, cultivation, chipping etc.), an alternate tool should then be used to manage the weed. This approach of scouting and rotating weed management tools as necessary, will not only result in an effective weed management system, but will also prevent the development of herbicide resistance.

Cotton growers should always check fields after every herbicide application to ensure that the target weeds have been satisfactorily controlled. Where control has not been satisfactory, an alternate management tool should be used. A weed control failure may not be due to herbicide resistance, but could be caused by a variety of other factors such as:

- poor application. Nozzles may have been poorly positioned, or too little herbicide hit the target etc.
- an inappropriate (too low) herbicide rate. Larger weeds generally require higher herbicide rates. Mature weeds may be impossible to control with a given herbicide.
- unsuitable conditions. Weeds may be moisture, heat or cold stressed, or conditions may have been too hot for spraying, humidity too low etc.
- incorrect weed identification. Similar, closely related weeds may have very different susceptibility to some herbicides.

Where weeds that should have been controlled by a herbicide have survived the application, growers should immediately act to ensure that the surviving weeds do not set seed. Assistance from an agronomist or chemical company representative should then be sought to determine whether the survival of the weeds is due to herbicide resistance.

Suspected herbicide resistance

Most apparent cases of herbicide resistance are due to other factors. Incorrect identification of the weed is a common problem. Similar looking weeds often occur in mixed populations without being individually identified. A good example of this occurs with yellow vine and caltrop. Broad-spectrum herbicides such as trifluralin and glyphosate are equally effective in controlling both weeds, but specific herbicides such as Staple® may only be effective in controlling one species (Staple® only controls yellow vine). An apparent spray failure with Staple® on yellow vine can be caused by Staple® effectively controlling the yellow vine, but leaving a large population of caltrop. An alternative control method is needed for the caltrop.

Another general guide to herbicide resistance is that the problem is most likely to show up in a small area of a field, corresponding to the location of the individual plant that initially had resistance. A resistance problem would be extremely unlikely to first appear on a field-wide basis, unless the problem had been spread by land-levelling in the previous season. A field-wide problem would be a very good indication of an application problem or herbicide rate problem.

If the weed has been correctly identified, and no other problems are apparent, then the simplest method of checking for resistance is to re-apply the herbicide at a range of rates on test-strips, ensuring that no suspect weeds are allowed to set seed. Contact a chemical company representative and a weeds agronomist from NSW Agriculture or Queensland Department of Primary Industries immediately if the weeds are still not controlled by the recommended rate.

Managing herbicide resistance

Weeds are relatively immobile and will only move large distances if transported by water, animals, people, or machinery. Experience from other cropping systems has shown that resistance can often be confined to a single paddock, or even to an area within a paddock.

Where resistance is identified before it has become widely spread, and appropriate measures are taken, resistance can be relatively easily managed and may eventually be eliminated from an area. The keys to managing resistance are:

- early identification, before the problem becomes widespread,
- treatment, preventing the weeds seeding, and
- isolation, to prevent the weed spreading to new areas.

Summary

The development of herbicide resistance is not inevitable. There has not yet been a single case of a herbicide resistant weed in the Australian cotton industry, due largely to the long-term use of an integrated weed management strategy using a combination of herbicides, cultivation, chipping and good crop agronomy.

Failure to use an integrated weed management program will lead to the development of herbicide resistance. Herbicide resistant individuals can occur naturally in a plant population. Over-reliance on a single herbicide or herbicide group will cause a species shift to weeds that are tolerant of the herbicide and may eventually result in the development of herbicide resistant weeds

Prevention is the simplest way of managing herbicide resistance. The development of herbicide resistance can be prevented by using an integrated weed management system. Integrated weed management is based on regular scouting for weeds and treating problems with a range of management tools.

HERBICIDE RESISTANCE AND THE CROP MANAGEMENT PLAN

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
Background	C3.1
Introduction	C3.1
So what causes the problems?	C3.2
Herbicide resistance in the cotton system	C3.2
Selection in a glyphosate based system	C3.3
The importance of the crop management plan	C3.4
Maintaining the whole glyphosate system	C3.4
At risk weeds	C3.5
Summary	C3.6

Background

Many cotton growers are concerned that relying too heavily on Roundup (glyphosate) will lead to future problems with weeds becoming resistant to this herbicide. The potential for resistance is very real, as shown by the increasing resistance problems with Roundup Ready crops in the US, and emerging problems with glyphosate resistant ryegrass and awnless barnyard grass in the Australian cotton growing area.

This paper discusses these issues and explains the value of the approach used in the Crop Management Plans of Roundup Ready and Liberty Link cotton for managing the development of resistance.

Introduction

One of the first questions I was asked twenty years ago when I started in the cotton industry was: "Do we have herbicide resistant weeds in the cotton industry yet?"

The answer at the time was a resounding "no", and we shouldn't get resistant weeds as long as we keep using a multi-input approach to weed management in cotton.

Unfortunately, 20 years later, this is no-longer the case. Cotton is now being grown with a rapidly shrinking array of weed management inputs. There are almost certainly herbicide resistant weeds in the cereal component of the cotton farming system on a number of properties, and probably also resistant weeds in the cotton component, somewhere in the industry, although they haven't been detected yet. While these resistance problems may not have been caused by the way weeds are managed in cotton, in the end it doesn't matter, the problem doesn't go away just because it was caused somewhere else.

The stark reality of size of the herbicide resistance problem is brought home in an article by Werth and Thornby (2008). There are now 185 different weed species resistant to a herbicide somewhere in the world. Thirty four weed species have resistance in Australia, and while most of these are resistant to the high risk Group A and B¹ herbicides, there is resistance to nearly every herbicide group, including the groups that include our residual cotton herbicides and glyphosate. In WA and the US, resistance has even developed to 2,4-D (Group I), a herbicide very widely used since the 50's, which had never had a resistance

¹ Herbicides are grouped according to their mode of action in the plant. Group A & B herbicides are at high risk of developing resistance, Groups C to H are moderate risk, and groups I - Z are low risk. Resistance to any group is possible, regardless of the ranking.

problem anywhere in the world up until a couple of years ago. It just shows that if you push the system hard enough, resistance will eventually occur.

In the cotton growing areas there are numerous instances of ryegrass and wild oats populations with resistance to Group A herbicides and ryegrass populations resistant to glyphosate (Group M). We now also have 2 confirmed awnless barnyard grass populations with resistance to glyphosate, with a 3rd suspected population and doubtless other populations yet to be detected. This season we had a suspected resistant awnless barnyard grass population in cotton. It turned out not to be resistant, but it was a wakeup call – it could have been glyphosate resistant awnless barnyard grass in cotton.

So what causes the problems?

In a single word (or two): selection pressure. The more effective a product is, the more strongly it selects for resistant individuals. If a highly effective product is used often enough on enough individuals, eventually a resistant individual is likely to be encountered and selected (assuming that resistant individuals exist). This is the start of resistance.

A big unknown is the number of resistant individuals in the natural population. It is possible that no individuals resistant to a given herbicide exist in a weed population, but there is no way of knowing this. Unfortunately, experience is showing that individual weeds carrying a resistance gene occur in many weed populations, with resistance to a wide range of herbicides now common.

Selection pressure occurs every time a population is exposed to a herbicide. However, it is not simply a matter of how many times a herbicide is applied in a season, but of how many generations of a weed are selected and whether these generations are also being controlled by another input or inputs. The selection pressure is greatly reduced where a range of other inputs is also used on the same weed population (as commonly occurred in the traditional cotton system), as a resistant individual has to simultaneously develop resistance to more than one weed management tool.

So, the selection pressure on glyphosate is not overly strong in a traditional weed management system where survivors from a glyphosate spray are normally controlled by cultivation, chipping or a residual herbicide.

Herbicide resistance in the cotton system

The traditional cotton system is a robust system for managing most weeds because it employs a range of weed management tools, including multiple applications of residual herbicides with different modes of action, cultivation, chipping, cropping rotations etc. Few, if any, of the weed management inputs (herbicides, cultivation etc.) are 100% effective (most are less than 95% effective, giving low selection pressure), but the combined system is effective for most weeds. Any weeds which survive the multiple residual herbicide applications (and there are always a few survivors), are controlled by the cultivator, or if they escape this, by the chipping crew, or the next cultivator and the next chipping crew, or the next herbicide etc. Herbicide resistant weeds are unlikely to emerge in this system, as the system responds to any survivors by throwing yet another (different) management tool at them.

Unfortunately, this system has its drawbacks, including expense, undesirable off-target impacts of herbicides and unavoidable damage to the cotton crop. Twenty years ago, many chipping bills were in excess of \$100/ha, with bills up to \$300/ha not uncommon. These bills are not affordable in the current economic climate, even if the large chipping crews are still available, which they generally are not. These issues have forced the weed management system to evolve over the years to one which is less reliant on chipping, substituting residual and contact herbicides for chipping inputs. Unfortunately, the drawbacks of off-target impacts and damage to the cotton crop remain and are accentuated by the heavy reliance on residual herbicides required. While this damage was hardly noticeable in the 2½ bale cotton crops of the 1980's, it is unacceptable in the 5 and 6 bale crops of this decade.

Fortunately, alternative weed management systems became available with the release of Roundup Ready[®] cotton, and more recently Roundup Ready Flex[®] and Liberty Link[®] cotton varieties. Use of these transgenic traits has allowed cotton growers to develop new, lower input, more environmentally friendly weed management systems which are conducive to higher cotton yields. The strength of these systems is that they rely on broad-spectrum, contact herbicides, with excellent crop safety (Roundup Ready Flex and Liberty Link), which are more environmentally benign than the residual herbicides they replaced and are only applied when a weed problem is present, allowing the application rate and number of applications to be tailored to match the problem/s.

The down-side with the use of the Roundup Ready trait is that the system which has evolved relies

very heavily on glyphosate in both the cotton and fallow phases, and in some instances, especially with dryland cotton, may be relying exclusively on glyphosate for the control of some weeds. This places very strong selection pressure on glyphosate and is a recipe for glyphosate resistance. Species shift is also an inevitable outcome of a glyphosate intensive system, which selects for glyphosate-tolerant species (a species-shift to glyphosate tolerant weeds). Many of the glyphosate tolerant species, such as rhyncho and emu foot, which were minor pests of the traditional cotton system, will increase in number in a glyphosate intensive system, eventually becoming significant weed problems. Ultimately, the density of these weeds will increase to the point that other weed management tools will have to be reintroduced to manage them.

So, how to maintain a glyphosate based system?

Selection in a glyphosate based system

A number of factors influence the genetic response to selection pressure, including the frequency of resistant genes, the plants reproductive characteristics, seed-bank longevity and the fitness of resistant individuals.

Resistance is not simply a factor of how many times a herbicide is applied in a season, but of how many generations of a weed are selected, the characteristics of the plant and whether other effective weed management tools are being used on the same generation/s.

There is relatively weak selection pressure on glyphosate in a traditional weed management system, where survivors from a glyphosate spray are normally controlled by cultivation, chipping or another herbicide. However, the selection pressure on individual weed species may be stronger than it appears to be at first glance. For example, nutgrass is a weed which is not well managed by the traditional weed management system, but can be effectively managed when glyphosate is added to the system. However, when it is only being controlled by the glyphosate component of the system, nutgrass is under intensive selection pressure from glyphosate in the traditional cotton system. Nutgrass would be under the same level of selection pressure in a Roundup Ready Flex crop, where it is again only being controlled by glyphosate. The additional residual herbicides, inter-row cultivation and chipping in the traditional system are not controlling nutgrass, so they do not reduce the selection pressure on this weed. Fortunately, nutgrass is a very low risk weed which is unlikely to develop resistance to glyphosate. This is primarily because nutgrass predominantly reproduces vegetatively, producing

'clones' of itself, so that most, if not all, plants in a field are from the same generation and genetically identical. Even plants in different years are likely to be from a single generation and genetically identical.

Some weeds are exposed to much stronger selection pressure in a Roundup Ready Flex system. A weed such as awnless barnyard grass, for example, is controlled to some extent by each of the residual herbicide inputs used in the traditional system. However, awnless barnyard grass may have 2 or 3 generations within a single season and each generation may be exposed to selection from glyphosate in a Roundup Ready Flex system. Consequently, this weed is at a high risk of developing resistance to glyphosate in this system.

However, not all weeds are at the same level of risk. The selection pressure on a weed such as Italian cocklebur (one of the Noogoora burr complex), may be low in both traditional and Roundup Ready Flex systems. The selection pressure on Italian cocklebur in Roundup Ready Flex cotton, where three or four Roundup Ready Herbicide applications are made during the season, is no higher than the selection pressure where only one application is made. This is because all applications are made to the same generation of the weed (the burrs don't flower until late summer and autumn). Effectively, one late-season application to all burrs would impose the same selection pressure as four applications during the season, although the single application is not a practical option, as the weeds would be very large by this time, would have reduced crop yield and would be difficult to control. Traditional and Roundup Ready Flex systems, where surviving burrs are controlled by chipping or spot-spraying, impose no effective selection pressure on this weed.



Starting the season with low weed numbers is an important component of the CMP with herbicide tolerant cotton varieties. High weed numbers necessitate multiple herbicides inputs and high selection pressure.

The importance of the crop management plan

Of the factors in the development of herbicide resistance, the one a farmer has the most control over is selection pressure. In order to reduce the selection pressure on a weed, it is essential that weeds which survive a herbicide are subsequently controlled by another (different) management option before they set seed. If this is done, then there is effectively no selection pressure from the first herbicide.

This is the core principle of the crop management plans developed for Roundup Ready and Liberty Link cottons. These plans require that at least once a season, each field is assessed for weeds that have survived a herbicide application (the weed audit), and any survivors are controlled by a different input before they can set seed. Ideally, this would be done after each herbicide application and no surviving weeds would be allowed to set seed. While the requirements of the weed audit may seem onerous, it is a simple way to ensure that each crop is checked for surviving weeds at least once a season, and provides a valuable set of data to TIMS and the APVMA. Collective information over valleys and years provides a broad overview of the performance of these products and gives these bodies a basis for confidence in the application of these transgenic systems, as well as guidance on any issues which may arise.

In reality, good operators check the performance of each weed management input (and other inputs) throughout the season and rectify issues as they arise. The crop management plan provides a simple, auditable framework to facilitate this process.

A second factor the farmer has control over is the number of weeds in a field. This is important because as weed numbers increase in a field, the chance of a resistant individual being present also increases and the chance of the resistant individual surviving a herbicide application increases. This is why the crop management plans recommend entering a cropping phase with low weed numbers. It is statistically unlikely that any resistant individuals will be present in fields with low numbers of weeds.

Low weed numbers can be achieved in one of two ways. Firstly, low weed numbers can be the result of good weed management practices over a number of years. Weed surveys over the last 20 years found that generally cotton fields have become cleaner, with fewer weeds over time. Fields with low weed numbers are ideally suited to the transgenic systems where residual herbicides are replaced by contact herbicides.

A second way of achieving low weed numbers is by retaining some residual herbicides in the system. Residual herbicides might be applied pre-planting or at-planting, or can be applied from around 6 - 8 nodes (15 cm of crop height) post-emergence. The type of residual herbicide and time of application can be tailored to meet the expected weed population. Inclusion of a residual grass herbicide, for example, is strongly recommended in fields which have a history of high grass numbers. Use of these residual herbicides is a simple and effective way of greatly reducing the numbers of weeds that have to be controlled by the post-emergence contact herbicides, reducing the selection pressure on these herbicides. In practice, if residual herbicides are not included at planting in fields with high weed numbers, post-emergence inputs, which will probably include residual herbicides, will be required to control survivors from the contact herbicides. Where high weed numbers are expected, it is simpler and more effective to apply the residual herbicides at planting.

Maintaining the whole glyphosate system

One of the biggest threats to the sustainability of the Roundup Ready system is the use of glyphosate in the rest of the farming system.

For example, where cotton is grown in a wheat rotation in an irrigated system, it would be common for a field to be in fallow for nearly 12 months in every 24 month period. In this system, weeds in the fallow are commonly controlled with glyphosate, and a field may receive 5 or 6 applications (or even more) over the fallow period, especially where wheat stubble is retained. This again places strong selection pressure on glyphosate, but can be addressed using the same approach of controlling any survivors of a glyphosate application using an alternative option before they set seed. This control input could be an alternative herbicide, cultivation or chipping. An approach widely supported in the southern farming system is to follow a glyphosate application with a paraquat/diquat (Spray.Seed) application in a double-knock, with 5 to 7 days between the herbicide applications. This combination is effective for controlling small, annual weeds and the strategy is very effective for preventing resistance developing, provided that resistance to either of these herbicides has not already occurred. The double-knock strategy can be equally applied using a range of alternative inputs, such as cultivation, or other herbicides following closely after the glyphosate application.

One practice commonly used in the cotton system is to tank-mix an alternative herbicide such as 2,4-D with glyphosate applications made to fallows

during winter. This may appear to be an effective way of reducing selection pressure on glyphosate, but has major limitations. Firstly, most weeds are seasonal and are more prolific in either the winter or summer. This is more so in the southern areas. Consequently, the spectrum of weeds exposed to the glyphosate/2,4-D combination will not necessarily be the same as the spectrum controlled by just glyphosate in the summer. Some weeds, which predominantly grow in summer, will not be exposed to 2,4-D and so are still under very strong selection pressure. Secondly, the reduction in selection pressure is only applied to broad-leaf weeds. Grass weeds are not controlled by 2,4-D, and so the addition of 2,4-D does not reduce the selection pressure on grasses. Thirdly, the mixture is normally used to achieve some synergism between the two products, increasing the spectrum of weeds controlled but with a reduction in the rate of glyphosate used. To be effective to reduce selection pressure, it is necessary that both products are used at rates that will kill the target weeds, so that if there is resistance to one product, the weed is still killed by the other product. **Adding 2,4-D to a reduced rate of glyphosate will improve the spectrum of weeds controlled, but will not reduce the selection pressure on glyphosate.**

Selection pressure can be even stronger in the dryland system, where cotton might only be grown every third year, with long fallow periods and little if any thorough cultivation. Glyphosate resistance is most likely to occur in these systems unless an alternative weed control input is used to control weeds which survive the glyphosate applications. The cases of awnless barnyard grass which have developed resistance to glyphosate in the cotton growing area have occurred in zero-tillage dryland farming systems where fallow weeds are being controlled by glyphosate year after year. **Unless farmers are proactive in controlling weed survivors, it seems certain that glyphosate resistance will develop in the dryland cotton farming system.**

At risk weeds

While herbicide resistance can develop in any species, some weed species are more at risk than others. The plant characteristics which contribute to the risk of developing resistance are: method of reproduction, plant frequency (how common the weed is), seed production rate and seed dormancy (seed-bank longevity). Plants at the highest risk are those which reproduce sexually, commonly occur at high densities, produce large numbers of seeds and have little or no seed dormancy (the seed dormancy can act like a refuge, diluting the population with older, non-resistant plants). Unfortunately, weeds such as awnless barnyard grass, common sowthistle and fleabane are already problematic in a glyphosate dominant system and are at high risk of developing resistance. These plants are often present at 10s or even 100s per m² early in the season, can produce thousands of seeds per plant and have little or no seed dormancy, with two or three generations possible each season.

Many of the weeds which are more problematic in the traditional cotton system and tend to get more attention by managers, such as thornapples and the burrs, are at much less risk of developing resistance. They are normally present at much lower densities (1 Italian cocklebur per m² would be a major infestation), produce fewer seeds (a few hundred per plant), have only one generation per year, and have strong seed dormancy, prolonging the effective generation period.

Consequently, managing a glyphosate dominant system requires a mind-shift, where the most important weeds become not just those that can individually cause the greatest yield reductions (such as thornapples), but those that have the greatest risk of developing resistance (such as awnless barnyard grass). Resistance in awnless barnyard grass, for example, would be a major nuisance in cotton, requiring a cotton grower to revert to a system which included a residual grass herbicide and regular inclusion of an alternative herbicide such as Spray.Seed in fallows. This would significantly increase the cost of weed control in the system. Resistant sowthistle would be even more expensive to manage, being very difficult to control in crop and in summer fallows without reverting to hormone sprays or other products which are themselves highly problematic.

Plant characteristics that contribute to the risk of developing herbicide resistance.

Risk	Reproduction method	Frequency	Seed production	Seed dormancy	Examples
High risk	Sexual	Common	Large	Short	Awnless barnyard grass
Moderate risk	Sexual	Common	Small	Long	Thornapple
	Sexual	Uncommon	Large	Short	Tall sedge
Low risk	Sexual	Uncommon	Small	Long	Desert cowvine
	Vegetative				Nutgrass



The easiest way to manage herbicide resistance is to avoid it, but if resistance is suspected, it is vital that it is identified as soon as possible. Even the best farmer can end up with herbicide resistance due to the accidental introduction of a resistant seed or plant from an external source. Dirty headers, hay and grain are likely potential sources of herbicide resistant weed seeds. Herbicide resistance has the potential to rapidly expand from a small problem in one field to a farm-wide problem within a season or two, and has no respect for farm boundaries.

Any cotton-grower suspecting herbicide resistance in a transgenic cotton crop is required to notify the respective technology provider immediately. This is a legal requirement under the crop management plan. The TIMS committee will also be notified to ensure that appropriate action is taken as soon as possible.



Herbicide resistance is a whole-season and whole-farm problem. High weed numbers in a rotation crop, such as this sorghum, are just as much a problem as if they were in cotton.

Summary

The best way to manage herbicide resistance is to avoid it. Herbicide resistance can be avoided by following four simple rules.

- Always follow the Crop Management Plan. The core principle of this plan is to ensure crops are checked after a herbicide application and any surviving weeds are controlled using an alternative weed management tool before they set seed.
- Ensure at least one effective alternative weed management tool is used each season on all major weeds, especially those in the high-risk category. An inter-row cultivation, combined with a light chipping, is a sound strategy for avoiding selecting for resistance in-crop. Alternatively, using a directed layby residual herbicide, incorporated with inter-row cultivation, may be equally effective, although a light chipping may still be required to control larger weeds in the plant line.
- Adopt a double-knock or follow-up approach at least once a season for managing weeds in fallows.
- Always control weed escapes before they set seed

HERBICIDES

Introduction

Herbicides are an important component of an integrated weed management plan on Australian cotton farms. However they need to be used in conjunction with other techniques to prevent the development of herbicide resistance.

There are a number of different herbicides sold by various companies under different brand names. Although these herbicides may have the same active ingredient, differences can exist in the concentration or formulation of the active ingredient.

Herbicides are often classified into groups based on their mode of action, with each herbicide within the group having a similar mode of action or target site within the weed. There may be a number of different herbicides within a herbicide group, each with a different active ingredient. It is important to remember that the chance of a weed developing resistance to a particular group when sprayed with any herbicide from the same group is very high. Rotation of herbicide chemistry from different groups, and using integrated weed management, will help prevent resistance from occurring. The information contained in the first article will help growers and consultants to understand the differences between herbicides and will assist in more informed decision-making.

The selection of an appropriate herbicide to treat a correctly identified weed is the first step in the herbicide application process. The second is the effective application of the herbicide. To help ensure that this occurs, the second article in this section contains a brief summary of some of the aspects covered by the SPRAYpak manual, published by the Australian Cotton CRC. The SPRAYpak manual contains a depth of information that should be referred to when herbicides, and pesticides in general, are applied.

This section contains two articles: -

D2. Herbicide and Formulation lists,

which includes various herbicides listed by their active ingredient, and

D3. SPRAYpak/Spray Application,

an introductory article highlighting some of the important considerations involved with herbicide application.

A compendium of registered herbicides for the weed species encountered on Australian cotton farms is being produced for WEEDpak and will be available **Information on the use of herbicides is updated annually in the Cotton Pest Management Guide (NSW Agriculture).**

in the near future. This compendium is in poster format and will be able to be folded and filed in WEEDpak or attached to a wall.

Information on the use of herbicides is updated annually in the **Cotton Pest Management Guide (NSW Agriculture).**

HERBICIDE AND FORMULATION LISTS

Stephen Johnson and Annie Spora
(University of New England & NSW Agriculture)

The following section contains a number of herbicide lists. These lists have been arranged as follows: -

Weed control in cotton

Herbicides registered for in-crop use are listed in Table 1.

Weed control in fallow

Herbicides in this category are listed in Table 2. Refer to Table 1 for other herbicides that may be useful in fallows.

Active Ingredients

The herbicides in Tables 1 and 2 have also been listed by active ingredient within each herbicide group. Brand names and chemical companies for each of the active ingredients listed in Tables 1 and 2 have been listed in Tables 3 - 9.

Herbicide Groups and Resistance

The herbicides in Tables 1 and 2 have been grouped by mode of herbicidal action. All herbicides in each group have a similar mode of action or target site.

Group A and B herbicides have the highest risk of developing resistance. Group C and D herbicides have a lower risk. Groups F – M have the lowest risk and weeds would require long-term constant exposure for weeds to develop resistance to them.

Any population of weeds may contain some individuals that are resistant to a herbicide but these are present at a low level. Continued exposure to a herbicide group and successful reproduction from resistant adult plants results in the build up of a resistant population.

For further details on weed resistance and weed resistance management refer to section C in **WEEDpak, Managing herbicide resistance in cotton**.

Brand names

The information in Tables 3 - 9 has been sourced from two databases, the National Registration Authority (NRA) – PUBCRIS database and the Infopest database. The PUBCRIS database has a complete list of all agricultural chemicals registered in Australia while the Infopest database highlights those that are sold commercially. Only commercial brand names current at February 18 2002 have been listed in Tables 3 - 9. Please refer to the databases, chemical company representatives or resellers for more up-to-date information.

The PUBCRIS database can be found by following the links from the NRA website at www.nra.gov.au while the Infopest database is available for purchase by contacting the Queensland Department of Primary Industries.

If an active ingredient is registered for use in cotton crops, then only those brand names that are registered in cotton crops have been listed in Tables 3 - 9, for example, the brand names for glyphosate (Table 9). When an active ingredient has not been registered for use in cotton crops, but is registered for fallow use, all products containing this active ingredient have been listed, for example, the chlorsulfuron brand names (Table 4). Brand names containing a mixture of two or more herbicides have been excluded, with the exception of fluometuron and prometryn, and paraquat and diquat.

Chemical Formulations

Multiple chemical formulations exist for some of the herbicide brand names listed in Tables 3 - 9.

Different formulations of the same herbicide brand name, for example SC (suspension concentrates) or EC (emulsifiable concentrates) are listed, with an explanation of the formulation abbreviations listed at the end of the section. Further information on formulation differences is contained in **SPRAYpak**, or from chemical company representatives and resellers.

**The information contained in this list
is a guide only.**

**Always consult the information on the label
before using any product.**

Table 1a. *Herbicides registered for in-crop cotton use (Groups A – D).*

Herbicide Group	Active ingredient(s)	Main uses	A selection of weeds controlled/suppressed	
			Monocots	Broad leaf
A	Butoxydim	Early post-emergent	Awnless barnyard grass, Barnyard grass, Liverseed grass, Volunteer sorghum.	
A	Clethodim	Post-emergent	Barnyard grass, Liverseed grass, Volunteer sorghum.	
A	Fluazifop-p	Post-emergent	Barnyard grass, Liverseed grass.	
A	Haloxyfop-r	Post-emergent	Barnyard grass, Liverseed grass, Volunteer cereals.	
A	Propaquizafop	Post-emergent	Barnyard grass, Liverseed grass, Volunteer sorghum.	
A	Sethoxydim	Post-emergent	Awnless barnyard grass, Barnyard grass, Volunteer cereals.	
B	Pyriithiobac sodium	Post-emergent		Anoda weed, Bathurst burr, Bellvine, Boggabri weed, Cowvine, Ground cherry, Noogoora burr, Polymeria (annual), Spineless caltrop, Volunteer sunflower.
C	Diuron	Pre-emergent or Post-emergent	Barnyard grass.	Amaranthus species, Blackberry nightshade, Cobbler's pegs, Common sowthistle, Pigweed, Turnip weed, Wild radish, Wireweed.
C	Fluometuron + Prometryn	Soil incorporated, Pre-emergent or Post-emergent.	Barnyard grass, Liverseed grass.	Bathurst burr, Bellvine, Blackberry nightshade, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Cowvine, Dwarf amaranth, Giant pigweed, Noogoora burr, Pigweed, Sesbania pea, Wild gooseberry.
C	Fluometuron	Soil incorporated, Pre-emergent or Post-emergent.	Barnyard grass, Liverseed grass.	Bathurst burr, Bellvine, Blackberry nightshade, Bladder ketmia, Caltrop, Common sowthistle, Common thornapple, Cowvine, Giant pigweed, Native rosella, Noogoora burr, Pigweed, Sesbania pea, Wild gooseberry, Wild melon.
C	Prometryn	Pre-emergent or Post-emergent	Barnyard grass.	Bathurst burr, Bellvine, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Cowvine, Dwarf amaranth, Giant pigweed, Mintweed, Noogoora burr, Pigweed, Wild gooseberry, Wild radish.
D	Chlorthal Dimethyl	Pre-emergent	Liverseed grass.	Common sowthistle, Wireweed.
D	Pendimethalin	Pre-emergent	Barnyard grass, Liverseed grass.	Blackberry nightshade, Caltrop, Common sowthistle, Dwarf amaranth, Mintweed, Pigweed, Wireweed.
D	Trifluralin	Pre-emergent	Barnyard grass, Liverseed grass.	Caltrop, Giant pigweed, Pigweed, Wireweed.

Table 1b. *Herbicides registered for in-crop cotton use (Groups F – M).*

Herbicide Group	Active ingredient	Main uses	A selection of weeds controlled/suppressed	
			Monocots	Broad leaf
F	Norflurazon	Fallow, Pre-planting	Barnyard grass, Nutgrass.	Anoda weed, Bladder ketmia, Common sowthistle, Cowvine, Giant pigweed, Mintweed, Pigweed.
J	Dalapon (2,2-DPA)	Inter-row spray	Annual grasses.	
K	Metolachlor	Pre-emergent	Barnyard grass, Liverseed grass, Scurvy weed.	Blackberry nightshade, Caltrop, Common thornapple, Mintweed, Noogoora burr, Pigweed.
K	MSMA	Post-emergent (see label)	Barnyard grass, Nutgrass.	Bathurst burr, Noogoora burr.
L	Diquat	Crop and weed desiccant only (See label)	Barnyard grass, Liverseed grass	Some annual broad leaf weeds.
M	Glyphosate	Shielded spray (inter-row), or pre-harvest (non seed crops), or post emergent (Roundup Ready crops only)*	Barnyard grass, Liverseed grass, Nutgrass, Volunteer cereals.	Amaranthus species, Bathurst burr, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Fierce thornapple, Giant pigweed, Ground cherry, Mintweed, Noogoora burr, Pigweed.

* Roundup Ready herbicide is the only herbicide containing glyphosate that is registered for this application.

Table 2a. Herbicides useful for the control of fallow weeds (Groups B – I).

Refer to Table 1 for other herbicides that may be useful in fallows.

Herbicide Group	Active ingredient	Maximum plant back period*	A selection of weeds controlled/suppressed	
			Monocots	Broad leaf
B	Chlorsulfuron	**		Mintweed, Wireweed.
B	Metsulfuron methyl	**		Common sowthistle, Dwarf amaranth, Pigweed, Volunteer sunflower, Wireweed.
B	Triasulfuron	24 months		Common sowthistle, Wild radish, Wireweed.
C	Atrazine	18 months	Barnyard grass.	Amaranthus species, Blackberry nightshade, Bladder ketmia, Common thornapple, Ground cherry, Mintweed, Pigweed, Sesbania pea, Spineless caltrop, Wild melon, Wireweed.
G	Carfentrazone-ethyl	Pre-emergent		Some annual broad leaf weeds.
G	Flumioxazin	Refer to label	Barnyard grass, Liverseed grass, Nutgrass.	Amaranthus species, Bathurst burr, Bellvine, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Cowvine, Fierce thornapple, Giant pigweed, Ground cherry, Mintweed, Noogoora burr, Pigweed, Wild radish, Wireweed
G	Oxyfluorfen	Pre-emergent. Not recommended at high rates.		Amaranthus species, Bathurst burr, Blackberry nightshade, Bladder ketmia, Bellvine, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Fierce thornapple, Giant pigweed, Ground cherry, Mintweed, Noogoora burr, Pigweed, Sesbania pea, Wireweed.
I	2,4-D amine	21 days***		Amaranthus species, Bathurst burr, Bellvine, Blackberry nightshade, Bladder ketmia, Caltrop, Cowvine, Common sowthistle, Common thornapple, Ground cherry, Noogoora burr, Spineless caltrop, Volunteer sunflower, Wild radish, Wireweed.
I	2,4-D ester (highly volatile)	28 days***	Nutgrass.	Amaranthus species, Bathurst burr, Caltrop, Common thornapple, Fierce thornapple, Mintweed, Noogoora burr, Spineless caltrop, Wild radish, Wireweed.
I	Dicamba	21 days***	Barnyard grass, Liverseed grass.	Amaranthus species, Bathurst burr, Bellvine, Blackberry nightshade, Caltrop, Common sowthistle, Common thornapple, Fierce thornapple, Mintweed, Noogoora burr, Turnip weed, Volunteer sunflower, Wireweed.
I	Fluroxypyr	60 days		Bathurst burr, Bellvine, Bladder ketmia, Caltrop, Common sowthistle, Common thornapple, Cowvine, Dwarf amaranth, Fierce thornapple, Giant pigweed, Ground cherry, Mintweed, Noogoora burr, Pigweed, Sesbania pea, Spineless caltrop, Wireweed.
I	Triclopyr	14 days		Wild melon, Prickly paddy melon.

* These are the maximum label plant back periods for cotton. Plant back periods are dependent on soil conditions such as pH, moisture, temperature, organic matter and microbial activity. Contact chemical company representatives or resellers for further information.

** Contact DuPont for further information.

*** The plant back period commences only after a minimum of 15 mm of rain.

Table 2b. Herbicides useful for the control of fallow weeds (Groups L–M). Refer to Table 1 for other herbicides that may be useful in fallows.

Herbicide Group	Active ingredient(s)	Maximum plant back period*	selection of weeds controlled/suppressed	
			Monocots	Broad leaf
L	Paraquat	None	Some annual grasses.	Some annual broad leaf weeds.
L	Diquat	None	Barnyard grass, Liverseed grass.	Some annual broad leaf weeds.
L	Diquat + Paraquat	None	Barnyard grass, Liverseed grass.	Amaranthus species, Bathurst burr, Bellvine, Blackberry nightshade, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Cowvine, Fierce thornapple, Giant pigweed, Mintweed, Noogoora burr, Sesbania pea, Wild gooseberry, Wireweed.
M	Glyphosate	None	Barnyard grass, Liverseed grass, Nutgrass, Volunteer cereals.	Amaranthus species, Bathurst burr, Bladder ketmia, Caltrop, Caustic weed, Common sowthistle, Common thornapple, Fierce thornapple, Giant pigweed, Ground cherry, Mintweed, Noogoora burr, Pigweed.
M	Glyphosate-trimesium	None	Awnless barnyard grass, Barnyard grass, Liverseed grass.	Bathurst burr, Bellvine, Caltrop, Common sowthistle, Common thornapple, Fierce thornapple, Mintweed, Spineless caltrop, Turnip weed, Wireweed.

* These are the maximum label plant back periods for cotton. Plant back periods are dependent on soil conditions such as pH, moisture, temperature, organic matter and microbial activity. Contact chemical company representatives or resellers for further information.

Table 3. Brand names and chemical companies of Group A products.

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Butroxydim	250 g/kg	Falcon WG	Crop Care	WDG
Clethodim	240 g/L	Select Select	Sumitomo Tomen	EC EC
Fluazifop-p	212 g/L	Fusilade	Syngenta	EC
Haloxypor-r	130 g/L	Asset	Nufarm	EC
	"	Typhoon 130	Artferm	EC
	520 g/L	Verdict 520	Dow AgroSciences	EC
Propaquizafop	100 g/L	Correct 100 EC	Bayer	EC
		Shogun 100 EC	Bayer	EC
Sethoxydim	120 g/L	Sertin Plus	Aventis	EC
	186 g/L	Sertin 186 EC	Aventis	EC

Table 4. Brand names and chemical companies of Group B products.

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Chlorsulfuron	750 g/kg	Accolade WDG Accolade WP Chlorsulfuron Chlorsulfuron 750 Chlorsulfuron 750 Chlorsulfuron 750 WDG Chlorsulfuron 750 WP Chlorsulfuron 750 WP Chlorsulfuron 750 WP Chlorsulfuron WG Chlorsulfuron WG Chlorsun 750 Glean Ken-Chlor 750 Lusta Platoon WDG Sum-Chlor DF Tackle 750	Sipcam Pacific Sipcam Pacific Generex SU United Farmers 4Farmers 4Farmers ChemAg TechChem ChemAg Crop Care Grow Choice DuPont Kenso Agcare Nufarm Artern Sumitomo Farmoz	WDG WP WDG WDG WP WDG WP WP WP WDG WDG WDG WP WDG WDG WDG WDG WP
Metsulfuron-methyl	600 g/kg	Aim WDG Ally Associate Esteem WDG Ken-Met 600 Lynx 600 Metmac 600 Metsulfuron Metsulfuron 600 Metsulfuron 600 WG Metsulfuron WG Metsulfuron Methyl 600 Metsulfuron Methyl 600 Metsulfuron Methyl 600 Metsulfuron Methyl 600 WP Metsulfuron-Methyl WG Metsun 600 Sum-Met DF	Artern DuPont Nufarm Sipcam Pacific Kenso Agcare Farmoz Macspred Generex SU Conquest ChemAg 4Farmers ChemAg United Farmers TechChem Crop Care Grow Choice Sumitomo	WDG WDG WDG WDG WDG WDG WDG WDG WDG WDG WP WP WP WP WDG WDG WG
Pyrithiobac sodium	850 g/kg	Staple	DuPont	SP
Triasulfuron	750 g/kg	Ausgran 750 WG Logran 750 WG Lonestar 750 WG Nugran Triasulfuron WG Trisure Rival 750 WG	4Farmers Syngenta Farmoz Nufarm Crop Care DuPont Conquest	WDG WDG WDG WDG WDG WDG WDG

Table 5a. Brand names and chemical companies of Group C products (Atrazine and Diuron).

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Atrazine	500 g/L	Atramax Flowable	Artfern	SC
	"	Atrazine Flowable	Crop Care	SC
	"	Atrazine 500	Sumitomo	L
	"	Atrazine 500 SC	4Farmers	SC
	"	Farmozine 500	Farmoz	SC
	"	Flowable Gesaprim 500 SC	Syngenta	SC
	"	Maizina 500 Flowable	Sipcam Pacific	SC
	"	Nu-Trazine Liquid	Nufarm	SC
	600 g/L	Gesaprim 600 SC	Syngenta	SC
	900 g/kg	Atradex WG	Crop Care	WDG
	"	Atragranz	Crop Care	WDG
	"	Atramax 900 WG	Artfern	WDG
	"	Atrazine 900 DF	Sumitomo	WDG
	"	Farmozine 900 WDG	Farmoz	WDG
	"	Gesaprim 900 WG	Syngenta	WDG
	"	Maizina 900 WDG	Sipcam Pacific	WDG
	"	Nu-Trazine 900 DF	Nufarm	DF
Diuron	500 g/L	Diurmax	Artfern	SC
	"	Diuron	Sumitomo	SC
	"	Diuron 500	Farmoz	SC
	"	Diuron 500 SC	Bayer	SC
	"	Diuron 500 SC	Generex	SC
	"	Diuron 500 SC	Rotam	SC
	"	Diuron Flowable	Crop Care	SC
	"	Diuron Flowable	Farmoz	SC
	"	Diuron Flowable	Selchem	SC
	"	Diuron Liquid	ChemAg	SC
	"	Diuron Liquid	Nufarm	SC
	"	Striker 500 SC	Sanonda	SC
	900 g/kg	Diurex WG	Crop Care	WDG
	"	Diurgranz WG	Crop Care	WDG
	"	Diurmax 900 WDG	Artfern	WDG
	"	Diuron 900 DF	Nufarm	DF
	"	Diuron 900 WDG	Farmoz	WDG
	"	Diuron 900 WG	A & C Rural	WDG
	"	Diuron 900 WG	Bayer	WDG
	"	Diuron 900 WG	ChemAg	WDG
	"	Diuron DF	DuPont	WDG
	"	Diuron WG	Griffin	WDG

Table 5b. Brand names and chemical companies of Group C products (Fluometuron/ Prometryn, Fluometuron and Prometryn).

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Fluometuron	500 g/L	Cotoran 500 SC	Syngenta	SC
	"	Fluocam 500	Sipcam Pacific	SC
	"	Fluometuron 500	Artferm	SC
	"	Fluometuron 500	Farmoz	SC
	"	Fluometuron 500 SC	Crop Care	AC
	"	Fluron 500 SC	I.PI.CI.	SC
	900 g/kg	Cotoran 900 WG	Syngenta	WDG
	"	Fluometuron 900 WDG	Farmoz	WDG
Fluometuron/ Prometryn	"	Nu-Tron 900 DF	Nufarm	DF
	250/250 g/L	Bandit Liquid	Crop Care	AC
	"	Convoy	Nufarm	SC
	"	Cotogard 500 SC	Syngenta	SC
	"	Flupromix 500	Sipcam Pacific	SC
	"	Promo-Mix	Farmoz	SC
	"	Tempest 500	Artferm	SC
	425/425 g/L	Bandit WG	Crop Care	WDG
	"	Tempest WG	Artferm	WDG
	440/440 g/kg	Convoy DF	Nufarm	DF
	"	Cotogard WG	Syngenta	WDG
Prometryn	"	Promo-Mix WDG	Farmoz	WDG
	500 g/L	Gesagard 500 SC	Syngenta	SC
	"	Promesip 500	Sipcam Pacific	SC
	"	Prometryn 500	Farmoz	SC
	"	Prometryn Flowable	Artferm	AC
	"	Proton	Crop Care	AC
	900 g/kg	Gesagard 900 WG	Syngenta	WDG
	"	Prometryn 900 DF	Nufarm	DF
	"	Prometryn 900 WDG	Farmoz	WDG
	"	Proton 900 WG	Crop Care	WDG

Table 6. Brand names and chemical companies of Groups D, F and G products.

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Chlorthal Dimethyl (Group D)	750 g/L	Chlorthal Dimethyl 750 WP Warrant 750 WP	Crop Care Artfern	WP WP
Pendimethalin (Group D)	330 g/L	Cyclone 330 EC	ChemAg	EC
	"	Pendimethalin 330	United Farmers	EC
	"	Pendimethalin 330 EC	Crop Care	EC
	"	Rebel 330 EC	Artfern	EC
	"	Rifle 330	Nufarm	EC
	"	Stomp 330 E	BASF	EC
	440 g/L	Argo 440 EC	Campbell	EC
Trifluralin (Group D)	455 g/L	Stomp*Xtra	BASF	AC
	260 g/L	Trifluralin CR	Nufarm	EC
	480 g/L	Treflan 480	Crop Care	EC
	"	Triflur 480	Nufarm	EC
	"	Trifluralin 480	4Farmers	EC
	"	Trifluralin 480	Farmoz	EC
	"	Trifluralin 480	Selchem	EC
Norflurazon (Group F)	800 g/kg	Trifluramax 480	Artfern	EC
		Triflurasip 480	Sipcam Pacific	EC
		Zoliar DF	Syngenta	DF
Carfentrazone-ethyl (Group G)	240 g/L	Hammer	FMC Chemicals	EC
Flumioxazin (Group G)	500 g/kg	Pledge 500 WDG	Sumitomo	WDG
Oxyfluorfen (Group G)	240 g/L	Goal	Dow AgroSciences	EC
		Point	Kendon	EC
		Spark	Crop Care	EC
		Striker	Nufarm	EC

Table 7. Brand names and chemical companies of Group I products.

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
2,4-D amine	225 g/L	2,4-D ISO	Crop Care	AC
	"	2,4-D Mate	Generex	L
	"	Amine 225	Artfern	AC
	"	Aminoz CT 225	Sanonda	AC
	"	Amizina 225	Sipcam Pacific	AC
	"	Complement	Sumitomo	SC
	"	Glymate	Generex	L
	"	Rodamine 225 2,4-D	Rotam	L
	"	Smash 225	ChemAg	AC
	"	Zulu	Farmoz	AC
	300 g/L	Amine 300	Artfern	AC
	"	Ken-Star 300	Kenso Agcare	AC
	"	Smash 300	ChemAg	AC
	"	Surpass 300	Nufarm	AC
	"	Zulu 300	Farmoz	AC
2,4-D ester (Highly volatile)	400 g/L	Low volatile Ester 400	Nufarm	EC
	600 g/L	LV Estericide 600	Nufarm	EC
	800 g/L	2,4-D Ester 800	4Farmers	EC
	"	2,4-D Ester 800	Crop Care	EC
	"	2,4-D Ester 800	Farmoz	EC
	"	2,4-D Ester 800	Halley	EC
	"	2,4-D Ester 800	Selchem	EC
	"	2,4-D Ester 800	Western Stock Distributors (WSD)	EC
	"	2,4-D Ester 800 L	Generex	EC
	"	Ester 800	Artfern	EC
	"	Ester 800	ChemAg	EC
	"	Ester 800	Conquest	EC
	"	Ester 800	United Farmers	EC
	"	Estericide 800	Nufarm	EC
	"	Ken-Ester 800	Kenso Agcare	EC
	"	Sekira	A H Marks	SC
	"	Siester 800	Sipcam Pacific	EC
	"	Sum-Ester 800 L	Sumitomo	EC
Dicamba	200 g/L	Banvel 200	Crop Care	AC
	"	Synban 200	Syngenta	AC
	500 g/L	Cutlass 500	Farmoz	AC
	"	Dicamba 500	ChemAg	AC
	"	Kamba 500	Nufarm	AC
	700 g/kg	Kamba Dry	Nufarm	WDG
Fluroxypyr	200 g/L	Flagship 200	Farmoz	EC
		Starane 200	Dow AgroSciences	EC
		Tomigan 200EC	Nufarm	EC
Triclopyr	600 g/L	Garlon 600	Dow AgroSciences	EC
		Hurricane 600	ChemAg	EC
		Invader 600	Nufarm	EC
		Safari 600EC	Farmoz	EC
		Triclon 600	Grow Choice	EC
		Triclopyr 600	Allfire	EC
		Triclopyr 600	Generex	EC
		Triclopyr 600	Halley	EC
		Triclopyr 600	Kenso Agcare	EC

Table 8. Brand names and chemical companies of Groups J, K and L products.

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Dalapon (2,2-DPA) (Group J)	740 g/kg	Cerelon 2,2-DPA Propon 2,2-DPA	Artferm Nufarm	SP SP
Metolachlor (Group K)	720 g/L	Bouncer Clincher Support Metolachlor Metolachlor Metolachlor 720 Metolachlor 720	Artferm Farmoz Sumitomo Allfire Crop Care 4Farmers TechChem	EC EC EC EC EC EC EC
s-Metolachlor (Group K)	960 g/L	Dual Gold	Syngenta	EC
MSMA (Group K)	500 g/L 720 g/L 800 g/L "	MSMA MSMA Daconate MSMA 800	Agspray Barmac Crop Care Farmoz	SC AC L SC
Paraquat (Group L)	250g/L " " " " " " " " "	Boa 250 Gramoxone 250 Maxitop 250 Nuquat 250 Paraquat 250 Paraquat 250 Paraquat 250 Shirquat 250 Sprayquat 250 Spraytop 250 SL	Griffin Syngenta Artferm Nufarm A & C Rural ChemAg Halley Crop Care Kendon Farmoz	SC SC SC SC SC AC AC SC L SC
Paraquat/Diquat (Group L)	135/115 g/L	Spray.Seed 250	Syngenta	SC
Diquat (Group L)	200 g/L	Reglone	Syngenta	AC

Table 9a. Brand names and chemical companies of Group M products (Glyphosate 360 g/L).

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Glyphosate	360 g/L	Biochoice 360	Grow Choice	AC
	"	Clearup 360	Gulf Ag	AC
	"	Clearup Bio 360	Gulf Ag	AC
	"	Envirospray 360	ChemAg	AC
	"	Glycel 360	Excel	AC
	"	Glymac 360	Macspred	AC
	"	Glyphosate 360	4Farmers	AC
	"	Glyphosate 360	A1 Chemicals	EC
	"	Glyphosate 360	A & C Rural	L
	"	Glyphosate 360	Artfern	AC
	"	Glyphosate 360	Aus-Good	AC
	"	Glyphosate 360	ChemAg	AC
	"	Glyphosate 360	Craig Mostyn & Co.	AC
	"	Glyphosate 360	David Gray & Co.	L
	"	Glyphosate 360	Echem	AC
	"	Glyphosate 360	Halley	AC
	"	Glyphosate 360	Nufarm	AC
	"	Glyphosate 360	Ozchem	L
	"	Glyphosate 360	Oztec Rural	AC
	"	Glyphosate 360	Selchem	AC
	"	Glyphosate 360	Sumitomo	L
	"	Glyphosate 360	Superway	AC
	"	Glyphosate 360	Triox	AC
	"	Glyphosate 360	WSD	AC
	"	Glyphosate 360 L	Generex	EC
	"	Glyweed 360	Sabero	SC
	"	Ken-Up	Kenso Agcare	SC
	"	Nihil	Check-Mark	AC
	"	Razor Sharp	Nuturf	AC
	"	Rosphosate 360	Rotam	AC
	"	Roundup	Nufarm	AC
	"	Roundup Biactive	Nufarm	AC
	"	Sanos 360	Sanonda	AC
	"	Weedmaster 360	Nufarm	AC
	"	Weedmaster Duo	Nufarm	AC
	"	Wipe-Out 360	Farmoz	AC

Table 9b. Brand names and chemical companies of Group M products (Glyphosate 450 – 840 g/kg and Glyphosate-trimesium).

Active ingredient	Amount of active ingredient	Brand name	Chemical company	Formulation
Glyphosate	450 g/L	Gladiator	Crop Care	AC
	"	Glymac 450	Macspred	AC
	"	Glyphosate 450	Conquest	L
	"	Glyphosate 450	Echem	AC
	"	Glyphosate 450	Halley	AC
	"	Glyphosate 450	Quantum	L
	"	Glyphosate 450	Sumitomo	AC
	"	Glyphosate 450 CT	Nipro Products	AC
	"	Glyphosate 450 L	Generex	AC
	"	Glyphosate Agric CT	Bowa Organics	AC
	"	Glyphosate CT	Nufarm	AC
	"	Glyphosate CT	Selchem	AC
	"	Ken-Up 450 CT	Kenso Agcare	AC
	"	Rosphosate 450	Rotam	AC
	"	Roundup CT	Nufarm	AC
	"	Trigger	Artfern	AC
	"	Wipe Out 450	Farmoz	AC
	490 g/L	490 Glyphosate	Echem	AC
	"	Glyphosate 490	Halley	AC
	"	Glyphosate 490	Mastra	AC
	"	Glyphosate 490	Sumitomo	AC
	"	Glyphosate Extra CT	ChemAg	AC
	"	Rosphosate 490	Rotam	AC
	"	Trigger 490	Artfern	AC
	"	Wipe-Out CT Elite	Farmoz	AC
	510 g/L	Roundup Max	Nufarm	AC
	540 g/L	Credit Broadhectare	Nufarm	AC
	680 g/kg	Roundup Dry	Nufarm	WDG
	690 g/kg	Roundup Ready Herbicide	Nufarm	WDG
	840 g/kg	Trigger Dry-Flo 840	Artfern	WDG
Glyphosate-trimesium	600 g/L	Touchdown Broadacre	Syngenta	AC

Chemical Formulations

The formulation of a herbicide involves mixing the active ingredient with other materials, for example mixing with dry or liquid diluents, grinding, or the adding of emulsifiers, stabilisers, or other substances. A summary of the most commonly used formulations follows.

Aqueous Concentrates (AC)

A stable water based concentrate that mixes easily and needs no agitation once the herbicide has been made up.

Dry Flowables (DF)

Made up of a finely milled active ingredient and a wetting agent, these formulations offer many of the same advantages as soluble concentrates. Agitation is necessary to maintain the consistency of the made up herbicide.

Emulsifiable Concentrates (EC) and Emulsions (E)

Because some chemicals are insoluble in water, these concentrates are dissolved in a petroleum-based solvent to form a liquid. Emulsifiers, stabilisers, and spreaders are also added. The product turns milky white when mixed with water.

Granular formulation (GF)

Active ingredients that have a high level of toxicity to humans are granulated to reduce the risk. These granules contain a small amount of the active ingredient and a large amount of inert material. Because the active ingredient is distributed in this way, the chances of contact are lessened in the event of an accident.

Liquid (L) and Liquid Concentrate (LC)

The herbicide is a liquid that disperses evenly throughout the made up herbicide and needs no agitation.

Soluble Powders (SP) (see Wettable Powders)

Suspension Concentrates (SC)

Suspension concentrates are also referred to as flowable concentrates. They are formulated by dispersing small particles in a liquid usually water. Dispersing and suspending agents are added during formulation to keep these particles suspended in solution. Flowables need thorough shaking in the drum to make sure the solution is evenly mixed before use.

Wettable Powders (WP)

Wettable or dispersible powders are made by finely grinding the active ingredient into a dry powder that is blended with dispersants, surfactants and an inert carrier. Because the active constituent does not readily dissolve in water, a slurry must be formed before the mixture is added to the tank. Constant agitation is needed to prevent the particles from settling out in the spray tank.

Water Dispersable Granules (WDG)

This formulation consists of granules that are dispersed in water. When low toxicity chemicals are involved, the granules can be concentrated with up to 90% active making them easy to transport, store and measure.

Readers should refer to the following publications for further details on the above formulations:-

Chambers, A. and Andreini, M. (editors.) (2000). *Field Crop Herbicide Guide 6*. Kondinin Group, Cloverdale, WA. pp 480.

Rankine, I. and Hughes, P. (editors.) (2002). *SPRAYpak - Cotton Growers Spray Application Handbook*, 2nd Edition. Cotton Research and Development Corporation, Narrabri, NSW. pp. 167.

SPRAYpak/SPRAY APPLICATION

Introduction

Herbicides are a principal component of most weed management plans; hence it is important that they are used in the most effective manner possible. Herbicide efficacy is highly dependant on the use of correct application techniques and procedures. SPRAYpak, an Australian Cotton CRC and CRDC publication, outlines a number of important factors that need to be considered by growers, applicators and other personnel in the cotton industry. The following section gives a brief overview of the contents of SPRAYpak, highlighting some of the important information to consider before applying herbicides. The reader should refer to SPRAYpak for more information.

Managing spray applications

Weather conditions play a critical role in all herbicide applications. Therefore, proper monitoring of conditions before, during, and after the application is critical. During herbicide applications the following key meteorological conditions should be monitored and recorded:

- Wind speed - Spraying should only be done if wind speed is between 3 km/hr and 15 km/hr (0.8 - 4.2 m/sec) and relatively steady,
- Wind direction - Take additional precautions if the wind direction is towards environmentally sensitive non-target areas. In addition, consider chemical odours that may persist after the spraying has been completed,
- Atmospheric stability, turbulence, local wind effects, surface temperature inversion layers, changes in wind effects and any changes that occur whilst spraying is being undertaken,
- Temperature - Generally, optimum temperatures for spraying water-based herbicide mixtures are less than 28°C. Risks of reduced efficacy and off-target movement increase at temperatures greater than 28°C. Spraying should proceed with caution at temperatures greater than 28°C and applicators should exercise extreme care if the ambient air temperature at the time of application exceeds 30°C,

- Relative humidity - It is preferable to spray in conditions where the relative humidity is greater than 45%,
- Rainfall - Do not spray if rainfall is imminent. Rainfall during or within 48 hours after application may reduce efficacy and/or move the herbicide off-target.

Be prepared to stop spraying if conditions change and become unsuitable.

Proper planning is one of the most fundamental prerequisites of effective herbicide applications. The cornerstone of effective planning is the development of a comprehensive pesticide application management plan (PAMP). Relevant training of all farm personnel is another important part of effective, safe herbicide application and must be part of the planning and management processes.

Efficient record keeping is an essential part of herbicide management. Records of chemicals stored on-farm, together with the relevant labels and MSDS should be maintained so that they are readily accessible by all personnel at all times.

Correct identification of the target weed is often crucial. It is important that personnel involved in the spraying have an understanding of how the target weed influences herbicide type and formulation, and equipment selection. SPRAYpak provides guidelines on other important aspects of pesticides in general, and herbicides in particular. The selection of appropriate spray application machinery, calibration, set-up procedures and the selection of nozzles are all outlined.

The reader should refer to SPRAYpak for more information on each of these areas before applying herbicides.

ROUNDUP READY® COTTON

Introduction

The introduction of Roundup Ready® cotton offers tremendous advantages to the Australian cotton industry for weed management. When used as a component of an integrated weed management system some of the benefits that may arise from its introduction include:

- reduced dependence on residual herbicides;
- improved control of some of the more difficult-to-control weeds;
- greater flexibility in weed management programs; reduced chipping and cultivation expenses and,
- the potential to improve establishment and vigour of young cotton seedlings by reducing the pre-emergence use of residual herbicides.

While Roundup Ready® cotton has many benefits, this technology has only been recently introduced and currently has some limitations. As a consequence, two articles have been prepared to enable growers and agronomists to obtain the best results from the varieties of Roundup Ready® that they plant.

The first article *Managing Roundup Ready® Cotton* provides general guidelines on using this technology as well as providing information on herbicide resistance and species shift. The article also includes an economic comparison to illustrate the costs of weed management using this technology in comparison to conventional farming systems. The second article *Research Results with Roundup Ready® Cotton* provides additional information on the performance of the Roundup Ready® technology and some of the experiences researchers have had in trials using Roundup Ready® cotton varieties.

E2. Managing Roundup Ready® cotton

Roundup Ready cotton offers a number of benefits to the Australian cotton industry however there are a few limitations when using this technology and for optimum results Roundup Ready® cotton needs to be managed within these limitations. Roundup Ready® cotton is only registered for over-the-top applications up to the fourth true leaf and prior to unfolding of the fifth true leaf of the cotton crop. Sequential applications of Roundup Ready® herbicide must be applied at least 10 days apart, and with at least two nodes of crop growth between applications.

Shielded and directed applications of Roundup Ready® herbicide can be very effective in controlling weeds in cotton, however there is always potential for spray drift when applying Roundup ready herbicide in this manner. Shields must be designed to minimise drift and to prevent fine spray droplets from contacting the leaves. Likewise when applying directed applications the nozzles must be angled such that none of the spray contacts the lower leaves of the cotton plants.

To minimise the impacts of both species shift and herbicide resistance an Integrated Weed Management (IWM) approach to weed control must be adopted.

E3. Research results with Roundup Ready® Cotton

The weed management system adopted by growers and consultants should be able to respond to weed pressure on a season by season and field by field basis. The addition of Roundup Ready® cotton to a crop management plan should allow growers to modify their systems and reduce their dependence on residual herbicides. Any changes to the weed management system, however, should be made gradually, based on personal experience.

Results from 5 seasons of back-to-back Roundup Ready® cotton are examined. Yields and the level of weed control from a range of Roundup Ready® systems are compared to the results from more traditional weed management systems that rely on residual herbicides.

The results highlight the potential benefits from using the Roundup Ready® technology, but also show some of the possible traps with relying too heavily on this technology. Timing of the over-the-top Roundup application was especially critical.

MANAGING ROUNDUP READY® COTTON

Ian Taylor and Graham Charles
(NSW Agriculture)

Contents	Page
Introduction	E2.1
Over-the-top applications of Roundup	E2.1
Directed and shielded applications of Roundup	E2.2
Limitations with using Roundup in-crop	E2.3
Thresholds for spraying weeds	E2.3
Species shift	E2.4
Herbicide resistance	E2.4
Economics of production	E2.5
Control of volunteer and ratoon cotton	E2.6
Roundup Ready® Audit	E2.6
Case studies	E2.7
Summary	E2.8

Introduction

The introduction of cotton varieties that have the capacity to continue to grow and function normally after over-the-top applications of Roundup Ready® herbicide offers enormous benefits to the Australian cotton industry in terms of weed management. These benefits include:

- Reduced dependence on residual herbicides.
- Improved control of some of the more difficult to control weeds.
- Greater flexibility in weed management programs.
- Reduced chipping and cultivation expenses.
- Potential to improve establishment and vigour of young cotton seedlings by reducing the pre-emergence use of residual herbicides.

The level of performance obtained from Roundup Ready cotton and ultimately yield and lint quality, are governed by the management and agronomic practices used in the cotton farming system. It is therefore essential, that growers and agronomists are aware of the benefits and limitations of this technology and how best to use the technology so that a comprehensive weed management plan is developed. It should be stressed from the outset that Roundup Ready cotton is not by itself the

answer to weed management problems. It should be seen as another tool in the weed management program and must form part of an integrated weed management package. A sustainable weed management program cannot be based solely on Roundup Ready herbicide.

Over-the-top applications of Roundup®

As well as potential benefits, Roundup Ready technology has some constraints. These include:

- Currently, Roundup Ready herbicide is registered for over-the-top applications up to the fourth true leaf and prior to the unfolding of the fifth true leaf of the cotton crop. Up to two applications can be made during this window.
- Sequential applications of Roundup Ready herbicide must be applied at least 10 days apart, and with at least two nodes of crop growth between applications.
- Under hot growing conditions, such as in Central Queensland, the four true leaf stage can be attained within two to three weeks of sowing. Consequently, the useful window for over the top applications of Roundup Ready herbicide in these locations may be quite narrow.

Over the top applications of Roundup Ready herbicide are particularly useful for controlling weeds that emerge at planting or just after planting. In warmer areas where the fourth leaf stage may be reached quite rapidly it may be more appropriate to apply Sprayseed at planting and then an over the top application of Roundup Ready herbicide prior to the four-leaf stage. This will enable growers to apply a further two directed or shielded applications of Roundup Ready herbicide in-crop thus, increasing the duration of effective weed control. In addition, using a herbicide from a different chemical group will delay or prevent the onset of herbicide resistance.

Directed and shielded applications of Roundup®

The Roundup Ready herbicide label permits three applications of Roundup Ready herbicide in-crop within a single season, with a maximum of 1.5 kg/ha being applied in any single spray event. It is likely that one or two of these applications will be applied as a shielded or directed spray. Roundup Ready cotton is sensitive to Roundup drift after the four-leaf stage and boll loss can occur if Roundup Ready herbicide contacts the leaves of cotton plants. Cotton is particularly sensitive during square formation and flowering. Roundup affected cotton plants may produce sterile pollen, resulting in poor boll retention. Extreme cases can result in deformed bolls, as shown in Figure 1.

The most important fact to remember with spraying is that spray nozzles always produce some fine particles, and these particles always move (drift). The aim of spraying a herbicide within a herbicide susceptible crop canopy is to manage the movement of these spray particles (spray drift) to minimise their impact on the crop.

The following guidelines are included to assist growers with shielded and directed applications of Roundup Ready herbicide.

- Shields need to be set at a height that minimises spray drift. Shields may be lifted later in the season to allow spray to penetrate to the top of the hill, but it is essential to ensure that spray does not contact the cotton foliage. The higher the shield, the more spray drift is likely to result.
- The susceptibility of the shield to spray drift depends on the shield design; the more open the design, the more susceptible to drift problems. Shielded sprayers that have open sides (most commonly top, front or back) can have material such as flywire or shade cloth fitted to reduce spray drift. Material should be fitted to the rear of the shields to capture fine droplets that escape as the sprayer travels along the furrow.
- Attention needs to be given to environmental conditions at the time of spraying. Temperature, wind speed, wind direction, and humidity all impact the movement of spray droplets as they leave the sprayer and the rate of spray evaporation. High temperatures and low relative humidity result in increased volatilisation of spray droplets, increasing the likelihood of spray drift.
- As a general rule shielded sprayers should not be operated when wind speeds are greater than 8 km/hr. Open shields and directed sprays have



Figure 1. Suspected Roundup Ready herbicide drift damage to Roundup Ready cotton plants. Roundup damage can cause a loss of first position fruit (top) and parrot-beaking due to pollen sterility (bottom).

a lower safety factor than this. Crop growth stage and susceptibility also affect the safety factor.

- Tractor speed is also a major contributor to air movement. A tractor operating at 12 km/h will already be operating outside the 8 km/h guideline for spraying.
- Spray drift can also be minimised by using low drift nozzles or 80° flat fan nozzles, operated at low pressure (a maximum pressure of 2 bars). Higher water volumes will also assist in reducing the production of fine droplets.

Directed sprays can be effective for managing weeds in Roundup Ready cotton. However, it is very difficult to accurately apply Roundup through a directed spray without some contact with the cotton foliage, either from spray drift or from over-spraying.

Spray drift is almost inevitable with directed sprays, and will occur if there is any air movement around the nozzle. Spraying in calm conditions is equally hazardous, as some fine particles remain suspended until they eventually contact something, generally a cotton plant.

Over-spraying is also a likely outcome with a directed spray as it is very difficult to direct a nozzle to spray against the crop plant-line without contacting the crop. Low branches on the cotton plant often droop into the furrow area. These branches should be brushed aside by the spray shield, but are likely to be sprayed by a directed spray. Also the spray nozzles often bounce or swing as the spray boom moves down the field, resulting in occasional contact with the crop.

Limitations with using Roundup® in-crop

Shielded and directed applications of Roundup Ready herbicide can be very effective in controlling weeds in cotton. However, there are a few limitations to the use of this technology. These limitations are not necessarily a disadvantage, but must be considered in a weed management plan using Roundup Ready herbicide. These include:

- The potential for spray drift can be a major limitation to the aerial application of Roundup over-the-top of young Roundup Ready cotton. Some spray drift will always occur with aerial applications. Potential drift onto conventional cotton, crops, pastures or other sensitive areas cannot be tolerated.
- Roundup is most effective against young, actively growing weeds, especially grass weeds. Roundup can be ineffective on stressed weeds; especially moisture stressed weeds and may not be effective on large, broadleaf weeds.
- Shielded and directed applications of Roundup are likely to be ineffective in controlling weeds that emerge in the crop line after the four-leaf stage of the cotton crop. Weeds in the crop line are not normally controllable using this technology. In fields where a significant number of weeds are likely to emerge in the crop line, it is essential that they be managed using another herbicide, such as a residual herbicide at planting.
- Roundup is a non-residual herbicide. It will only control weeds present at the time of spraying. Subsequent germinations of weeds require repeat applications of the herbicide.
- Roundup does not control all weeds. Some weeds are naturally tolerant of Roundup and must be managed some other way.
- Roundup is inactivated on contact with soil. Roundup efficacy can be greatly reduced by dust when spraying in very dusty conditions or

when spraying weeds that are covered in dust. Spray shields that drag on the ground can generate a lot of dust, reducing spray effectiveness.

- Roundup may be used to replace inter-row cultivation, but cultivation may be necessary to maintain irrigation furrows. With some weeds such as nutgrass, it is desirable to allow the weed to grow for about four weeks before treating with Roundup and another couple of weeks after treatment, before cultivation. Juggling irrigation, cultivation and Roundup applications over a number of fields, under changing weather conditions, can be very difficult.

Thresholds for spraying weeds

Several benefits can flow from using Roundup Ready technology to manage weeds, and from the decrease in the use of residual herbicides that may result from the use of this technology in the cotton production system. These benefits include:

- Improvement in establishment and vigour of young cotton seedlings from reducing the pre-emergence use of residual herbicides.
- Reduced herbicide application costs.
- Reduced likelihood of contaminating waterways with residual herbicides either leaching through soil profiles or by overland flows.

Researchers at ACRI are attempting to determine weed thresholds where it may be appropriate to modify, reduce or eliminate the use of residual pre-plant and pre-emergent herbicides using Roundup Ready cotton technology.

Trials to date show that it can be practical to grow cotton without the addition of residual herbicides. However, on fields with high weed pressure, not using residual herbicides can lead to major problems and can exacerbate the weed problem. A weed control failure not only leads to dirty fields during the season but more importantly, replenishes the soil seed bank (number of weed seeds in the soil), creating problems in future years.

On fields where no residual herbicides are used, weed control is most likely to break down when seasonal conditions prevent the over-the-top Roundup application, and weeds in the crop line become unmanageable. The timing of the first Roundup application can be critical, as growers will be tempted to leave the application as late as

possible before spraying. However, if wet or windy conditions prevent this spray, weeds in the plant line can be almost impossible to control. Spraying over-the-top after the fourth true cotton leaf can result in crop damage and reduced cotton yield.

The decision whether or not to use pre-plant herbicides is likely to be based on economic rationale. Obviously, growers and managers want to maximise profits and minimise input costs. The cost of weed control alone should not be the underlying factor on which the decision is made. Increases or decreases in production, fibre quality and weeds that contribute to the seed bank load all need to be included in the decision making process. As well, the decision may be quite different for each field. A knowledge of the weed pressure and species composition of each field is crucial to the decision making process as there is often great variation in weed numbers and the species that pose problems between fields.

Species composition in the field is also important for deciding on a weed management plan. Some species, such as red pigweed and common sowthistle, are tolerant of Roundup Ready herbicide, and are difficult to manage in a Roundup based system. The use of Roundup Ready herbicide in fields that have high numbers of Roundup tolerant weeds will result in these species becoming more prevalent and competing with the cotton (known as species shift). The addition of residual herbicides such as Cotogard or Diuron pre-plant will alleviate this problem.

This decision maybe further complicated by the ability of the grower to spray all fields planted with Roundup Ready cotton in the required time-period prior to the four-leaf stage of crop growth.

Growers may consider the use of reduced or half rates of residual herbicides rather than a full residual herbicide program which may not be needed. Reduced herbicide rates provide some level of weed control, but for less of the season, and reduced risk of crop damage. This would be better than eliminating residual herbicides, as this can exacerbate weed problems.

In clean fields where the weed pressure is light, residual herbicides may be safely eliminated. These fields should be monitored over time to ensure that weed problems are not developing.

Species shift

No weed management tool controls all weeds equally well. Some species are very susceptible to control using a given management tool, while other species are naturally tolerant. For example, inter-row-cultivation effectively controls most grass and broadleaf weeds but is ineffective on the perennial weeds such as nutgrass and ploymeria takeall.

The effect of using any weed management tool or set of weed management tools is to select out the species that are most tolerant of the tools. These species will quickly spread and will dominate the weed spectrum in a field, termed species shift. This is not a new phenomenon, but is constantly occurring. The weed species that are currently in cotton fields are the species that have been most tolerant of the management tools used in the past.

Where Roundup is used in-crop as an additional management tool, there is likely to be little change in the weed spectrum. However, if Roundup is used to replace other management tools, such as residual herbicides, inter-row cultivation or chipping, there is likely to be a relatively rapid change in the in-field weed spectrum towards those weeds that were previously controlled by the alternative management tools, but are relatively tolerant of Roundup. This change may become apparent within three or four seasons of using Roundup Ready cotton.

A change in the weed spectrum (species shift) is inevitable where Roundup is used to replace other weed management tools. However, the change should be easily identified and easily managed. Regular field observations will identify changes in the weed spectrum. Changes in management will then need to be targeted to address these problems.

In the long-term, a sustainable weed management system will be one that employs a range of weed management tools in combination so that all weeds are controlled by some management tools.

Herbicide resistance

As distinct from species shift, which relates to naturally tolerant weed species, herbicide resistance is a factor of the very small number of individual plants within a weed species that have natural resistance to a herbicide. These individuals may occur at very low frequency within a population where all other individuals are easily killed by the herbicide. Herbicide resistance occurs when repeated use of a herbicide selects out these individuals such that the resistant individuals spread and eventually dominate the weed population. The herbicide is no longer of any value for controlling the weed when this happens.

At present, there are no known herbicide resistant weeds in the Australian cotton industry. However, herbicide resistance can occur. There are numerous examples of herbicide resistant weeds in some of the other cropping systems in Australia.

The primary reason for herbicide resistance not being a problem in Australian cotton production has been the traditional philosophy of weed management and the reliance on a combination of weed management tools. Inter-row cultivation and

especially hand hoeing have been the most important resistance management tools as both these tools are relatively non-selective. Any weeds that were not controlled by herbicides, and so were potentially herbicide resistant, were removed by the combination of cultivation and chipping. The philosophy of using these tools to remove all weed escapes from the field has prevented the emergence of herbicide resistant weeds.

The development of herbicide resistance is influenced by a number of factors including:

- the intensity of the selection pressure
- the frequency of herbicide resistant genes within a particular species
- the fitness of the resistant biotype
- and the biology of the particular weed species

With the introduction of Roundup Ready cotton, it is likely that one or two additional Roundup applications will be introduced to the cotton production system. This increased herbicide use will slightly increase the selection pressure for Roundup resistant weeds. Additionally, a reduction in the use of alternative control methods will accompany the widespread introduction of Roundup Ready cotton. This reduction will greatly increase the selection pressure on Roundup, and greatly increase the likelihood of Roundup resistant weeds developing (being selected out by a management system that relies too heavily on glyphosate).

The situation now exists where good weed control in some fields can be achieved with just Roundup Ready herbicide. Consequently, the temptation exists to forgo all other weed control methods in favour of using this technology alone. From a short-term economic perspective this may make sense, and good weed control may be achieved (in the short-term), but in the long-term, species shift and herbicide resistant weeds will be a reality. Dealing with herbicide resistant weeds will be far more costly to the entire industry than maintaining weed susceptibility through an integrated approach to weed management.

To slow or prevent the development of herbicide resistance, it is important that growers maintain an integrated approach to their weed management. The Roundup Ready Management Guide requires that after growers apply their final in-crop Roundup application, they:

- assess the occurrence of surviving weeds on three 100 m lengths of row per 40 ha crop
- take remedial action to stop seed set of these weeds
- report any adverse findings (potential resistance problems)

This resistance management plan appears to be very simple, but is technically sound. It is based on the principle that any weed that is not controlled by the Roundup application (potentially resistant) is controlled by some other means before it is able to set seed. This plan will prevent the occurrence of herbicide resistance if it is properly implemented.

The resistance management plan also makes good farming sense. Weeds that are controlled before they set seed don't contribute to future weed problems, maintaining the stability of the system. Weeds that survive the Roundup application may or may not be resistant, but will contribute to a larger problem in future years of weeds that are not controlled by Roundup if they are allowed to set seed.

More specific information on herbicide resistance is provided in section C2.1 of **WEEDpak**.

Economics of production

A study evaluating the economic aspects of using Roundup Ready technology in comparison to conventional cotton varieties and herbicide systems is being undertaken. Case studies have been included (Appendix A) that may serve as a useful guide on the economics of growing Roundup Ready cotton. Growers using both Roundup Ready and conventional cotton varieties during the 2001/2002 season provided the herbicide regimes used in the case studies.

It should be stressed that yield gains or penalties have not been included in the figures provided as these are currently unknown and may have a profound bearing on the way that the data is interpreted. In addition, there is no provision in the data set to allow for a rating of the effectiveness of the weed control program for the current year.

Results from research trials from previous seasons showed that production could be economically competitive using Roundup Ready technology. In some treatments, improvements in cotton establishment, weed control and cotton yield more than compensate for the cost of the technology.

Control of volunteer and ratoon cotton

The control of volunteer and ratoon cotton in successive cotton crops is one of the major difficulties associated with using the Roundup Ready technology. An article dealing specifically with volunteer and ratoon cotton control can be found in section F4 **Controlling Volunteer Cotton** in **WEEDpak**. Volunteer and ratoon Roundup Ready cotton plants continue to express the Roundup Ready gene in successive seasons and are difficult to control in crop and particularly within the plant line. Control is required due to varietal purity, insect and disease pressures associated with the reduced fitness of volunteer plants and the likelihood that ratoon cotton may act as a refuge for insect pest species.

Control of volunteer cotton may be achieved by pre-irrigating fields to encourage seed germination, then using pre-plant or pre-emergent applications of Sprayseed @1.5-2.2L/ha depending on growth stage. Hammer® (carfentrazone), a new product being registered by Crop Care Australia may offer a new alternative. Hammer can be mixed with glyphosate and has no residual plant back. This herbicide can't be used as an over the top application in either Roundup Ready or conventional cotton crops.

Ratoon cotton is more difficult to control. Effective control may be achieved with root cutting and/or centre busting at the end of the season. Herbicide control alone is very difficult. Various farmers have used 2-4,D Amine, Starane and Dicamba, but with limited success.

Roundup Ready® Audit

Growers of Roundup Ready cotton are required to perform an audit of the effectiveness of the weed control achieved. This audit includes:

- 1) An assessment of the weeds that have not effectively been controlled by the Roundup Ready herbicide following, the final Roundup Ready application. Three rows of 100m should be assessed for every 40 ha of cotton that is planted prior to seed set of those weeds.
- 2) The remedial action taken to prevent seed set of those weeds that have "escaped" the Roundup Ready treatment.
- 3) Details of the weed management program during the season (Includes herbicides used, rates of application and number of applications).
- 4) Comments on the level of weed control achieved.
- 5) Adverse event reporting

It is important that farmers conduct this audit within three weeks of the last in-crop Roundup application, to accurately determine the success or otherwise of the spray application. If the assessment occurs more than three weeks after spraying, it is quite possible that new weeds will have emerged by this time. These weeds may be counted when they have never been exposed to glyphosate. This result will indicate a spray failure, when no failure occurred. The audit is designed only to find weeds that have been exposed to glyphosate, to try to detect any potential resistant weeds that are developing. Control of all weeds before they set seed is the aim of good management.

Appendix A. Case studies describing herbicide regimes and associated costs of using Roundup Ready Technology.

Field	License Fee	Preplant herbicide		Planting herb	Post emergence herbicide			Chipping	Lay -by	No of Cultivat-ions	Total costs/ha
Conventional dirty		2.2 L/Ha Triflur + application	3.5 L/Ha Cotoran 50% band + application	1.7 kg/Ha diurex + application					1.5 L/Ha Gesagard 1.5 kg diuron + application	2	
Cost \$/Ha		\$22.20	\$30.05	\$30.80				\$40.00	\$61.85	\$16	\$200.90
Roundup Ready dirty		2.2 L/Ha Triflur + application	3.5 L/Ha Cotoran + application	1.7 kg/Ha Diurex + application	1.5 kg/Ha Roundup + application	1.5 kg/Ha Roundup + application	1.5 kg/Ha Roundup + application		1.5 L/Ha Gesagard 1.5 kg diuron + application	2	
Cost \$/Ha	\$49	\$22.20	\$30.05	\$30.80	\$22.25	\$22.25	\$22.25		\$61.85	\$16	\$276.65
Moderately Dirty Roundup Ready				1.5 kg/Ha Roundup + application	1.5 kg/Ha Roundup + application	1.5 kg/Ha Roundup + application			1.5 L/Ha Gesagard 1.5 kg diuron + application	2	
Cost \$/Ha	\$49			\$22.25	\$22.25	\$22.25			\$61.85	\$16	\$193.60
Clean Field Roundup Ready				Sprayseed 1.5L/ha + application	1.5kg/Ha Roundup + application	1.0kg/Ha Roundup + application	Staple 60g/Ha 40% band + application			2	
Cost \$/Ha	\$49			\$23.21	\$22.25	\$17.50	\$33.20			\$16	\$161.16
Clean field conventional		Diuron 1.5kg + cotogard 2.0l + application		Sprayseed 1.5l/ha + application	Cotogard 50% band + application		Staple 60g/Ha 40% band + application			2	
Cost \$/Ha		\$52.90		\$23.21	\$20.40		\$33.20			\$16	\$145.71

Field	License Fee	Preplant herb 1	Preplant herb 2	Planting herb 1	Post emerg	Post emerg	Post emerg	Lay -by	Chipping	No. of Cultivat-ions	Total Costs / ha
Roundup Ready		2.3L Triflur 480 1.0kg Diuron + Application		2.3L Convoy 0.5kg Diuron + Application	1.5kg/Ha Roundup + Application	1.5kg/Ha Roundup + Application		1.5kg Roundup 1.9kg Convoy 2.0L Liase + Application		2	
Cost \$/Ha	\$49	\$36.35		\$57.64	\$23.25	\$23.25		\$58.36	\$8.44	\$16.00	\$272.29
Conventional		2.3L Triflur 480 1.0kg Diuron + Application	2.0L Roundup + Application	2.3L Convoy 0.5kg Diuron + Application		2.8L MSMA + Application		2.0L MSMA 2.0L Prometryn + Application		2	
Cost \$/Ha		\$36.35	\$18.80	\$57.64		\$41.20		\$68.96	\$50.85	\$16.00	\$289.80
Roundup Ready			Roundup CT @ 1.3l/Ha + Application	Stomp @ 3.5l + Cotoran @ 2kg/ha 40% band	1.5kg/Ha Roundup Ready Herbicide + Application	Select @375mls/ha 40%band + application		Cotogard WG @ 1.9kg/HA 85% Band		1	
Cost \$/Ha	\$49.00		\$7.20+\$9	\$29.00	\$12.40+ \$9	\$13.60 + \$9		\$36.30		\$12	\$186.50
Conventional			Triflur@2.3l + Cotoran @2l	Cotogard@ 1.4kgs/ha 40% band				Gesagard @ 3l/ha 85% band		3	
Cost \$/Ha			\$41.90	\$12.60				\$39.00	\$68	\$36	\$197.5

Summary

Roundup Ready cotton offers a number of benefits to the Australian cotton industry however, there are a few limitations when using this technology and for optimum results, Roundup Ready cotton needs to be managed within these limitations. Roundup Ready cotton is only registered for over the top applications up to the fourth true leaf and prior to unfolding of the fifth true leaf of the cotton crop. Sequential applications of Roundup Ready herbicide must be applied at least 10 days apart, and with at least two nodes of crop growth between applications.

Shielded and directed applications of Roundup Ready herbicide can be very effective in controlling weeds in cotton, however there is always potential for spray drift when applying Roundup ready herbicide in this manner. Shields must be designed to minimise drift and to prevent fine spray droplets from contacting the leaves. Likewise, when applying directed applications the nozzles must be angled such that none of the spray contacts the lower leaves of the cotton plants.

To minimise the impacts of both species shift and herbicide resistance an Integrated Weed Management approach to weed control must be adopted.

RESEARCH RESULTS WITH ROUNDUP READY® COTTON

Graham Charles
(NSW Agriculture)

Contents	Page
Introduction	E3.1
Comparison of Roundup Ready® systems	E3.2
Managing perennial weeds	E3.2
Managing annual weeds	E3.3
Timing of the over-the-top Roundup® application	E3.4
Applying Roundup® over-the-top of older cotton	E3.4
Strategies for applying Roundup® over-the-top	E3.5
Salvage applications of Roundup® over-the-top	E3.5
Species shift	E3.6
Developing a Roundup Ready® management system	E3.7
Economic comparison of the systems	E3.7
Summary	E3.8

Introduction

Roundup Ready® is a transgenic, herbicide tolerant cotton developed by Monsanto. It has been genetically modified to increase its tolerance to Roundup (glyphosate) herbicide, but is otherwise substantially equivalent to conventional cotton. The Roundup Ready genetic material can be transferred to conventional cotton varieties through conventional plant breeding. Consequently, a range of cotton varieties is available in conventional or Roundup Ready options. These varieties may also include a genetically modified, insect resistance gene (Ingard®).

Roundup Ready cotton varieties are tolerant to Roundup applied over-the-top of young cotton (up to four true leaves), but older cotton is less tolerant and Roundup applied in older cotton must be directed to avoid contact with the leaves of the crop. This is normally done using a directed spray, with spray nozzles directed away from the cotton plant, or through a shielded sprayer, where a metal or plastic shield surrounds the spray, preventing the spray coming in contact with the crop plants.

A weed pressure index has been used to compare the over-all weed control achieved under various weed management systems. This index was derived from actual weed numbers per square metre on trial plots and fields. The weed count for each species has then been modified to take into account the competitiveness of the different species. The data are combined to form the weed pressure index. An index of 0 indicates a weed-free system, while a high number indicates a weedy system. A typical clean field would have an index of around 0.1 to 2, while a dirty field may have an index between 50 and 100, or even higher.

Comparison of Roundup Ready® systems

Roundup Ready cotton was grown from 1996/97 to 1999/00 in a weed management systems experiment at the Australian Cotton Research Institute, Narrabri. Small plots of Roundup Ready cotton were grown in the first season using early generation breeding material. Roundup Ready Siokra 189+ was used for the last two seasons of the experiment. Plots were 8 rows by 50 m in length.

The results from five Roundup Ready systems and two conventional systems are compared below. The cotton type and herbicides used in each system is shown in Table 1.

Results for systems using Roundup Ready cotton were very promising, but have also highlighted some of the potential difficulties with the Roundup Ready technology.

Roundup is very effective in controlling most small broadleaf and grass weeds present in young cotton. At a higher rate it is effective against more difficult to control weeds, such as large weeds and some perennial weeds. A Roundup application at the emergence to four leaf stage of crop growth can substitute for an earlier application of Roundup (pre-emergence for conventional cotton), or can substitute for some residual herbicides.

Table 1. Cotton type and herbicides (L/ha) used in the weed management systems experiment. A total of three post-emergence Roundup applications occurred.

System	Cotton type	Pre-planting & at-planting	Post-emergence & layby
1 - C	Conventional	Trifluralin 2.8 & Cotoran 4.0	Gesagard 2.2 & Gesagard 2.3
1 - RR	Roundup Ready	Trifluralin 2.8 & Cotoran 4.0	3 applications Roundup CT 2.0
2 - C	Conventional	Trifluralin 2.8 + Diuron 1.9	Gesagard 2.2 & Gesagard 2.3
2 - RR	Roundup Ready	Trifluralin 2.8 + Diuron 1.9	3 applications Roundup CT 2.0
3 - RR	Roundup Ready	Trifluralin 2.8	3 applications Roundup CT 2.0
4 - RR	Roundup Ready		3 applications Roundup CT 2.0 + 2 applications Staple 120 g
5 - RR	Roundup Ready		3 applications Roundup CT 2.0

Managing perennial weeds

Roundup Ready cotton has been a very useful tool for managing nutgrass (*Cyperus rotundus*). Nutgrass was present on the field before the experiment was commenced. Over the five seasons of the experiment, the nutgrass infestation on the conventional systems increased from 0.3 to 39% of the plot on system 1 - C and 14 to 80% on system 2 - C (Figure 1). In contrast, the nutgrass infestation was stable or decreased on the Roundup Ready systems over this period.

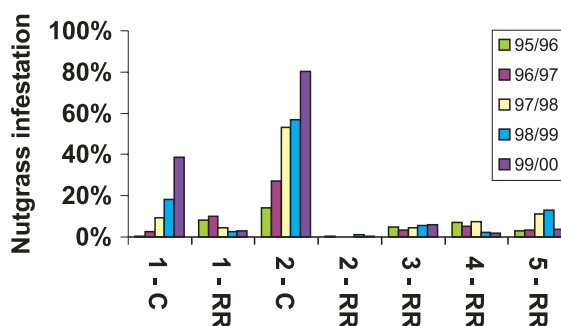


Figure 1. Changes in nutgrass infestation on the different systems over five seasons of back-to-back cotton.

The over-the-top Roundup application in spring was relatively ineffective in controlling nutgrass in some seasons, as the weed was often moisture and/or cold stressed at this time. The later applications were more effective. Nevertheless, nutgrass remained a problem in all treatments, as some unsprayed plants always remained in the crop plant-line. Also, some cultivation operations re-introduced tubers from neighboring uncontrolled plots.

The use of Roundup Ready cotton did not greatly improve nutgrass control compared to a conventional treatment where a shielded application of Roundup was used in-crop (these results are not shown). The use of Roundup Ready cotton did greatly improve crop safety from the Roundup application.

Managing annual weeds

Management of annual weeds was also improved on the Roundup Ready systems compared to the conventional systems. Results of the weed pressure index and average yields from the 1998/99 and 1999/00 seasons are shown in Table 2.

Table 2. Comparison of weed pressure and crop yields from conventional and Roundup Ready systems. Weed pressure was assessed mid-season.

System	Weed pressure index	Lint yield (bales/ha)
1 - C	30.7	4.7
1 - RR	7.8	5.1
2 - C	25.2	3.3
2 - RR	8.0	4.7
3 - RR	12.8	4.7
4 - RR	9.5	5.1
5 - RR	12.8	5.4

The highest cotton lint yield was recorded on the Roundup only system (system 5 - RR), which also had relatively low weed pressure.

Weed pressure was relatively low on the systems using Roundup Ready cotton and in-crop Roundup applications. Where direct comparisons of conventional and Roundup Ready systems are possible (systems 1 - C and 1 - RR, 2 - C and 2 - RR), the Roundup Ready systems had much lower weed pressure (better weed control) and better yields.



Small barnyard grass and Italian cocklebur¹ plants were easily controlled by a Roundup application over-the-top of young cotton (left of centre). No residual herbicides had been applied to either treatment.

However, the relatively good weed control results were not achieved in all seasons. In December 1997, system 1 - C had a weed index of 18, but system 5 - RR (only using Roundup) had an index of 348!

In this season (1997/98), the cotton was planted into moisture on Sept. 30. Fifty two mm of rain over Oct. 6 & 7 brought the crop up, but also germinated a large number of weeds, predominantly barnyard grass. It was decided not to spray these weeds immediately, but to wait for further germinations and spray the crop closer to four true leaves. This decision appeared to be sound, as early season weed pressure does not reduce crop yields.

The crop and weeds ran out of moisture in November. The treatments were sprayed with Roundup over-the-top at the four-leaf stage on Nov. 6, but the weeds were stressed and control was poor. Consequently, the field was irrigated on Nov. 19. A large number of new weeds emerged following this irrigation. The in-furrow weeds were subsequently controlled with a directed Roundup application, but weeds in the plant-line were not controlled, resulting in a "hedge-hog" line of weeds which remained for the rest of the season. Control of these established barnyard grass plants with a grass herbicide was attempted, but control failed as the weeds were too advanced. The yield on this plot was still quite good, but significant lint contamination occurred.

¹ Italian cocklebur is very similar to Noogoora burr and often confused with Noogoora burr. They are most easily distinguished by the shape of the claws at the end of the burrs. Initial observations indicate that much of the burr in the NSW cotton area is Italian cocklebur, not Noogoora burr.

Timing of the over-the-top Roundup application

The timing of the over-the-top Roundup application can be the key to successfully managing a Roundup Ready crop. The temptation is to wait as long as possible to allow as many weeds as possible to emerge before spraying, but this strategy puts a lot of pressure on a small application window. Bad weather (rain or wind), wet fields, dry fields (moisture stress), breakdowns, or the inability to cover sufficient ground in a limited time, can make it impossible to apply Roundup at the desired stage. If this happens and residual herbicides have not been applied, weeds can become unmanageable.

Problems were encountered with Roundup application timing in both the 1997/98 and 1998/99 seasons. Similar problems could be expected on large properties where Roundup has to be applied to multiple fields.

Cotton was planted on Sept. 30 in the 1997/98 season, but was slow to emerge with minimum temperatures below 12°C on 15 of the following 23 days. The cotton was due to be sprayed in mid-November. Rain on Nov. 11, 12, 15, 16, 18, 25, 26 and 30 made this task very difficult to accomplish.

In the 1998/99 season, the field was wet and planting was delayed. Cotton was planted on Oct. 21 and again should have been sprayed in mid-November. Rain on Nov. 12, 13, 14, 18, 23, 26 and 28 again made the task difficult to accomplish.

Similar problems occurred on a commercial field, where the planned over-the-top Roundup application was not applied due to unfavorable weather conditions.



Small Italian cocklebur plants were easily controlled by a Roundup application over-the-top of young cotton (left of centre). No residual herbicides had been applied to either treatment.

Applying Roundup over-the-top to older cotton

The obvious solution to missing the Roundup Ready over-the-top application window is to apply Roundup as soon as possible after the missed target date. This strategy is contrary to the label and is likely to result in reduced crop yields.

The emergence to four true leaves application safety window for over-the-top Roundup applications was established from research data and grower experience. It reflects a very real application restriction. Applications outside of this window can result in yield penalties.

This yield reduction is clearly seen in the results provided by Grant Roberts (Cotton CRC and CSIRO), shown in Table 3. In this experiment, an over-the-top Roundup application at crop six-leaf stage resulted in a 20% yield reduction (Treatment 3), compared to two later, directed applications (Treatment 2). Three over-the-top applications resulted in a 67% yield reduction (Treatment 5).

Table 3. Yield reduction from Roundup applied to Roundup Ready cotton at the wrong stage. Applications were over-the-top (OTT) or directed (D)

Treatment	Roundup Applications			Lint yield bales/ha
1	4 leaf ^{OTT}			3.4
2	4 leaf ^{OTT}	First square ^D	First flower ^D	3.6
3	4 leaf ^{OTT}	6 leaf ^{OTT}	First flower ^D	2.9
4	4 leaf ^{OTT}	First square ^{OTT}	First flower ^D	2.8
5	4 leaf ^{OTT}	6 leaf ^{OTT}	First flower ^{OTT}	1.2

Note. The applications in treatments 3, 4 and 5 are contrary to the label directions.

Strategies for applying Roundup over-the-top

One of three strategies can be used to avoid the problem of missing the over-the-top application window. Firstly, growers may elect to apply the over-the-top application earlier than the fourth leaf stage, as a way of ensuring that the application occurs. Some weeds will emerge after the Roundup application and will need to be controlled. A second over-the-top application before four leaves is possible in some situations, where the first application occurs at one or two leaves. The difficulty with this approach is that it may leave only one Roundup application available to control weeds for the rest of the season.

An alternative strategy is to continue to use residual herbicides applied pre-planting or at planting. These herbicides will control most weeds, greatly reducing the pressure on the Roundup application. This strategy has the drawback of increasing the cost of weed control compared to a Roundup only system, but is much better suited to dirty fields.

A compromise strategy, using a reduced program of residual herbicides, would seem to be the best option, especially on cleaner fields. With this approach, growers might, for example, use half-rates of Cotoran and Stomp on a 30% band behind the planter. This would ensure reasonable weed control in the crop plant-line, at a reduced cost, allowing Roundup and/or cultivation to be effectively used to control all in-furrow weeds. Roundup would also be used to control weeds that emerged later in the season after the residual herbicides ran-out. A lay-by application of residual herbicide may also be used.

Salvage applications of Roundup over-the-top

Incorrectly applied Roundup primarily affects the flowers of Roundup Ready cotton, but over-the-top applications, even late in the season, can still be disastrous.

The photo below shows a set of Roundup Ready plots that were heavily infested with both nutgrass and Italian cocklebur. The Italian cocklebur emerged above the crop and were almost completely covering the shorter cotton plants. An over-the-top Roundup application would seem to be an easy way to manage these weeds, with minimal contact with the cotton expected. Any damage to the Roundup Ready cotton from the Roundup could be expected to be far less than the damage caused by the weeds.



A severe infestation of nutgrass and Italian cocklebur in Roundup Ready cotton. The cockleburs were almost completely covering the cotton.

This proved not to be the case, with major yield reductions resulting from the Roundup applications (Table 4). A single over-the-top Roundup application in late January reduced the cotton yield by 32%, while two applications reduced yield by 78%.

Table 4. Yields after late, over-the-top Roundup applications to severely weed infested Roundup Ready cotton.

Roundup applied over-the-top			Yield (bales/ha)
11 Jan	27 Jan	15 Feb	
-	-	-	3.7
-	2 L	-	2.5
2 L	-	2 L	0.8

Even in a salvage situation, applying Roundup outside the application window can result in massive yield losses.

Species shift

Some of the features of Roundup are that it has a broad weed spectrum, it is translocated to the root system and so kills most weeds (doesn't just burn off the foliage), and has no residual activity, reducing off-target and environmental problems. However, weeds continue to emerge throughout the cotton season and consequently continue to emerge after the initial Roundup application. Roundup can be safely applied later in the season as a directed spray, but must be applied so as to avoid contact with cotton foliage. This effectively reduces the area to which Roundup can be applied to the furrow area and the base of the cotton plants.



Italian cockleburrs emerging in the plant line of a Roundup Ready system that relied only on Roundup for weed control.

A problem that became apparent over time in the systems experiment was the buildup of Roundup tolerant weeds, particularly in the system using only Roundup (System 5 – RR, Table 1). The weed causing the most problems in this system in the fifth year of Roundup Ready cotton was Italian cocklebur. Italian cocklebur is not strictly speaking a Roundup tolerant weed and is easily controlled with Roundup. Italian cockleburrs were not detected in this treatment in the first couple of seasons.

However, Italian cockleburrs that emerged after the over-the-top Roundup application and were in the crop row, missed the later directed or shielded Roundup applications and emerged above the

crop canopy late in the season. By this time, they are quite large and very difficult to control. If left, these cockleburrs set a lot of seed, increasing the problem over time. Removal by hand or control with MSMA were both very expensive options.

While it is unlikely that Italian cocklebur will become an industry-wide problem in Roundup only fields, this result clearly shows the effect of relying too heavily on a single method of weed control. Relying too heavily on any single method of weed control will inevitably select out a weed or weeds that tolerate that management tool. Problems weeds such as nutgrass, sesbania and cowvine have been selected by the conventional weed management systems that have been used in the past. Other weeds are likely to become serious problems as the weed management systems change.

Roundup doesn't control all weed species and so the more the system relies on Roundup, the more the Roundup tolerant species will become difficult to control. The simplest way to reduce these problems is to continue to use an integrated approach to weed management, using a range of weed management tools in combination.

Cotton growers also need to take heed of the lessons from the grain farming systems where a large number of weeds have developed resistance to specific herbicides. Some weeds are now resistant to almost every available herbicide. Resistance to glyphosate has already developed in a few paddocks where glyphosate has been used as almost the only weed management tool over a number of years. The loss of glyphosate to the farming system would be very costly, but the solution is simple. Herbicide resistant weeds have not been a problem in the Australian cotton industry to date because of the adoption of an integrated approach to weed management. Continuing this approach will ensure that resistance does not become a problem in the future.

More information on integrated weed management (IWM) is included in the IWM guidelines in WEEDpak.

Developing a Roundup Ready management system

In many ways, the introduction of Roundup Ready cotton contributes little to weed management, except the ability to apply Roundup over-the-top between crop emergence and the four-leaf stage. In-crop shielded applications of glyphosate can be made to conventional and Roundup Ready cotton varieties alike. The major advance is in the improvement in crop safety from the Roundup applications.

However, Roundup Ready cotton brings the opportunity to develop new weed management systems that rely less heavily on residual herbicides, inter-row cultivation and hand chipping. The introduction of new weed management systems should not be attempted on a property-wide basis. Like all new technology, it takes time to learn how best to use Roundup Ready cotton. Growers can safely introduce Roundup Ready cotton as an additional weed management tool to all fields, but should introduce new management systems far more slowly.

One of the best ways to learn to use Roundup Ready cotton can be to use herbicide test strips in a few fields. The test strips could, for example, be used to compare conventional cotton, Roundup Ready cotton using a conventional herbicide regime with the addition of Roundup, and various modified systems, where the rates of some residual herbicides are reduced or herbicides are eliminated. This could be compared with a Roundup only system.

The importance of adopting this test strip approach was highlighted by the results given earlier in the section "Managing annual weeds", where in the 1997/98 season, the Roundup only system (System 5 – RR) was completely overrun by weeds and unmanageable. Management of this system improved with experience.

The Roundup Ready system offers real opportunities to modify weed management systems, but the optimal solutions will vary between valleys and farms. Only experience can develop the best system for a given field and farm.

Economic comparison of the systems

The most optimal Roundup Ready system is the one that gives the best net return and maintains or reduces the weed population. A system that results in an increase in the weed population may give good yields and good returns in the very short-term, but will have reduced yields and will not be sustainable in the long-term. Table 5 gives a comparison of the net return for the weed management systems presented in Tables 1 and 2.

Table 5. Comparison of production costs, yields and gross returns from conventional and Roundup Ready® systems. The gross return is compared with System 1. The analysis assumes that the cost of the herbicides is the only difference in production costs between the systems.

System	Cost of inputs		Yield (bales/ha)	Net return (\$/ha)
	Herbicides	Roundup Ready license		
1 - C	\$138		4.7	-
1 - RR	\$131	\$49	5.1	\$362
2 - C	\$126		3.3	-\$587
2 - RR	\$125	\$49	4.7	\$130
3 - RR	\$81	\$49	4.7	\$169
4 - RR	\$196	\$49	5.1	\$269
5 - RR	\$60	\$49	5.4	\$555

The Roundup only system (System 5 – RR) had both the best yields and the best net return. However, this system was not sustainable, as it did not adequately control the Italian cocklebur problem. System 1 - RR, a combination of conventional herbicides and Roundup Ready cotton, was the optimal system, giving the second best yield and net return, and the best weed control. This system was the most likely to be sustainable in the long-term. Lower rates of Cotoran at planting may have improved the net return without compromising weed control.

While the Roundup Ready systems did give good returns in this experiment (on a weedy field), there is no guarantee that similar results will be achieved on cleaner fields or even other dirty fields, where a different spectrum of weeds will be present.

One thing that is clear from this analysis, is that cotton yield has by far the largest impact on the net value of a system. A small increase or decrease in crop yield will more than compensate for the cost of herbicide inputs. Time spent in putting down herbicide test strips and in determining crop yield from these strips will be a very valuable investment in a production system.

Consequently, it is important that cotton growers develop their weed management systems primarily based on these two factors: the cotton yield achieved on a system, and the level of weed control, which measures the sustainability of the system.

To do otherwise would be like adopting an insect management strategy where all cotton fields on all farms receive the same insecticide on the same day, regardless of what insects were actually present on a given field. Like insect management, weed management should be tailored to the needs of each field and each farm.

Summary

- Weed management must continue to use an integrated approach, not relying too heavily on any one management tool.
- A weed management system should respond to weed pressure on a season by season and field by field basis.
- Roundup Ready cotton should allow growers to reduce their dependence on residual herbicides, but changes to the weed management system should be made gradually, based on personal experience.
- Timing is critical for the over-the-top Roundup application. Never rely solely on this application for early season weed control.
- Be on the lookout for weeds that are tolerant of Roundup. Other weed management tools will be needed to control these weeds.

FARM HYGIENE

Introduction

Weeds are a major problem on most Australian cotton farms and considerable amounts of money are spent annually on the management of weeds that interfere within the cotton crop. Often, however, weeds growing in fallows, along roads, channels and storages and the waste areas on farms are neglected, and these may have a significant impact on production by infesting cotton crops. These weeds can be spread into fields via machinery, water flow in channels and by a number of other means. It is essential that a complete integrated weed management strategy account for the weeds associated with these areas.

This section contains information on a number of different areas of farm hygiene. The following articles have been included in this section: -

F2. Farm Hygiene in Integrated Weed Management,

F3. Managing Weeds on Roads, Channels and Water Storages,

F4. Controlling Volunteer Cotton and

F5. Plant Protection Interactions with Weeds.

The first article explains that there are a number of steps in achieving good farm hygiene including the identification and detection of weeds, cleaning down machinery and practicing integrated weed management.

Good farm hygiene extends to roads, channels and storages. The management of weeds in these areas is explained in the second article. This article also explains what species may be present and how these species spread.

Volunteer cotton is one of the more prevalent weeds in cotton farming systems. The third article reviews the management of volunteer cotton with sections on the control of seedlings, established cotton and ratoon cotton.

The last article in this section flags the interactions that the common insects and disease causing organisms have with weeds. The interaction between weeds and insects has been well documented in ENTOpak, an Australian Cotton CRC publication. The interaction between weeds, pathogens and cotton diseases is covered in greater detail and a list of weeds known to be hosts of cotton pathogens is included.

FARM HYGIENE IN INTEGRATED WEED MANAGEMENT

Annie Spora and Stephen Johnson
(NSW Agriculture & University of New England)

Contents	Page
Introduction	F2.1
Identification	F2.1
Detection	F2.1
Communication	F2.1
Scouting	F2.2
Farm hygiene	F2.2
Management of weeds	F2.2
Keeping farms clean	F2.2
Identification and planning	F2.3
Crop management	F2.3
Herbicides	F2.3
Cultivation and chipping	F2.4
Summary	F2.4
The importance of farm hygiene: a growers perspective	F2.5

Introduction

There are a number of steps in achieving good farm hygiene. These include the identification of unknown plant species, the detection of new weeds or weeds that have limited distributions, cleaning soil and crop debris from machinery combined with farm hygiene and practising integrated weed management. Each of these steps is important in achieving integrated weed management through farm hygiene on cotton farms.

Identification

The positive identification of an unknown plant species is the first step in preventing the establishment of the species and controlling its spread. Positive identification can be achieved by using the **Weed Identification and Information Guide**, section A in **WEEDpak**, by referring to other publications, or by seeking expert advice from consulting agronomists, weed scientists, or botanists at the State herbaria.

Detection

The early detection of a new weed, or one that has a limited distribution on the property, makes it easier to control and prevents it from spreading further. To ensure that this process takes place, communication and observation are important.

Communication

Everyone on the farm should be aware of the existence of the problem weeds so that they can take precautions to prevent the spread of these weeds around the farm, or onto other farms. This includes

- Workers,
- Consultants and Visitors,
- Contractors/Module Carriers and
- Neighbours.

In return, growers should be kept informed of any potential weed outbreaks that could affect their operation by agronomists and other farm staff.

Scouting

Agronomists who regularly inspect cotton fields for insects and diseases, can inspect for weeds at the same time. It is important to monitor risk areas such as river and channel banks for new weeds so that infestations can be controlled before they become widespread.



Good farm hygiene is important to prevent the spread of weeds on farm machinery. Photo: Greg Salmond.

Farm hygiene

Weeds are easily spread between fields and farms, in soil and crop trash, attached to vehicles and machinery. Thorough cleaning practices for all farm vehicles and machinery during the entire year will help prevent the spread of weeds.

Clean off soil and crop debris from

- Farm vehicles and tyres,
- Boots,
- Cotton pickers and strippers,
- Grain harvesters,
- Tillage implements,
- Stubble pullers and mulchers,
- Modules builders and loaders and
- Earth movers and laser levelers.

Remember to inspect areas where machinery has broken down as seeds may have dropped from parts of the machinery that are not regularly cleaned.

It is important to clean machinery when moving between different areas of one farm and between different farms to prevent the spread of weeds.

A guide to cleaning vehicles and machinery is contained in the Appendix of the Farm Hygiene booklet of the Best Management Practice Manual.



Always remember to clean soil off machinery like this root cutter before moving the machinery to different areas. This will help to prevent the spread of weeds. Photo: Greg Salmond

Management of weeds

(Also see **Integrated Weed Management**, section B in **WEEDpak** for further details).

Integrated weed management needs to be a year round activity to prevent seed set and vegetative spread, and because weeds grow at various times of the year. Remember that many weeds support harmful insects and disease causing organisms of cotton. Insects and diseases will be better controlled when weeds are controlled.

Keeping farms clean

(See **Managing weeds on Roads, Channels and Water Storages**, section F3 in **WEEDpak** for further details).

- Consider that the seeds of many species may be spread in irrigation water. Remove weeds from around irrigation channels and storages to help prevent this spread.
- Ensure that tail water and storm water run-off is retained on farm to prevent weeds spreading to clean farms.
- Maintain a strict weed control program in and around each field. This includes roadways, channels and fence lines.
- Minimize new weeds entering clean fields by cleaning machinery between fields and properties.

Identification and planning

- Accurate identification of weeds on a farm is important for effective control (see case study).
- Make a priority list of weeds to control.
- Eradicate new weeds when they are in small patches.
- Maintain accurate records of weed control methods and effectiveness.
- Record the field locations of herbicide tolerant cotton varieties. Volunteer crop plants are often the most numerous weeds in the field and this is a particular problem where herbicide tolerant cotton is grown. Accurate field identification will help achieve effective control of herbicide tolerant volunteers. For example, it is important to use weed control techniques other than the herbicide RoundUp® in previous RoundUp Ready® fields.
- Part of integrated weed management is the rotation of weed control methods. This will help prevent herbicide resistance (refer to Section C, **Managing Herbicide Resistance in Cotton**, in WEEDpak).

Crop Management

- Select rotation crops that enhance the control of weeds in cotton crops.
- Maximizing water use efficiency will reduce the amount of weed seeds brought onto farms in irrigation water.



Selection of appropriate rotation crops will help manage weeds in cotton crops.

Photo: Ian Rochester.

Herbicides

- Reduce herbicide rates or the numbers of herbicide applications on fields that you are confident have low weed pressure. Leave untreated strips in the field if you are uncertain of the size of the seed bank.
- Use shielded and weed detecting sprayers with non-selective herbicides.
- Use post-emergent herbicides and herbicide tolerant cotton varieties as another tool in integrated weed management. This will allow weeds to be sprayed after multiple germination events, and, only when they are present.
- Ensure that weeds that have escaped post-emergent herbicide applications are treated using a different weed control method, for example, cultivation, chipping or the application of herbicides from a different herbicide group (refer Section C, **Managing Herbicide Resistance in WEEDpak**).
- Continue the use of residual herbicides in combination with other weed management practices.

Inspecting fields shortly after herbicide application for weed escapes is crucial.

Cultivation and chipping

- To prevent weed escapes setting seed use manual chipping.
- To control furrow weeds use inter-row cultivation.
- Be careful about shifting weeds along the rows and between cultivation sets. For example, the shifting of nutgrass tubers is a common problem when cultivating through nutgrass patches when the soil is moist.



Remember to clean weeds hanging off cultivation machinery regularly to help prevent weeds spreading along rows or between cultivation sets.

Photo: Stephen Johnson.

Summary

- Prevent weeds from setting seed or spreading vegetatively.
- Control all weeds on farm.
- Scout for weed escapes after herbicide applications.
- Prevent weeds from establishing in new areas.
- Clean down machinery.

Acknowledgements

This article has been modified from the *Australian Cotton Industry Best Management Practices Manual*, September 2000, Editor Allan Williams. For more detailed information please consult the manual.

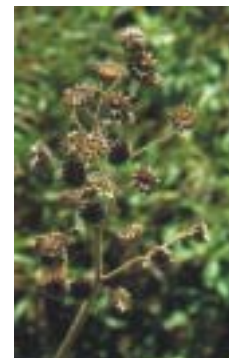
Readers are also referred to the Australian Cotton CRC Information sheet Farm Hygiene for Disease and Weed Control, March 2000 available at <http://www.cotton.crc.org.au> or at the Technology Resource Centre, ACRI, Narrabri.

The importance of farm hygiene

A grower's perspective

Nick Barton the Northern Regional Agronomist for the Twynam Agricultural Group talks about the need for good farm hygiene to manage velvetleaf (*Abutilon theophrasti* as pictured) on Telleraga Station where he was the former Head Agronomist.

Mature seed heads of velvetleaf (Abutilon theophrasti)



"It was during our BMP (Best Management Practice) audit that we **detected** a new weed that occurred in several small low spots down in our dryland fields beside the Mehi river. Since we did not know what the weed was we decided to get it **identified** and it turned out to be velvetleaf. Apparently velvetleaf is not very widespread here in Australia but it is one of the worst summer cropping weeds in the USA.

We decided that we would **regularly check** the patches of velvetleaf but the weed did not seem to be spreading very far so we weren't too worried about it. We certainly made everyone on the farm aware that this was a weed to watch. **Good communication** between all the staff on farm, from the tractor drivers right through to the farm manager, is another one of the keys to containing potential weed outbreaks.

We pumped a lot of floodwater into our on-farm storages during the floods of 1998. We also had a lot of overland water flows during that time, particularly onto our dryland country. Knowing that any water, and particularly floodwater can spread weed seed, we decided to check the inside of the storages and the dryland fields to see what weeds may have been spread onto the farm once everything started growing some months after the floods.

To our surprise we noticed a lot of velvetleaf that had come up inside the storage walls and in a number of new, low spots in various dryland fields where the water had sat for a while. Unfortunately the velvetleaf in the storages had already set seed and we had inadvertently spread it to our main return storage that was used to supply the whole farm with water. Apparently the mature seed heads and even the seed float quite well and had spread via the irrigation water throughout the farm.

We moved pretty quickly after that and ended up controlling the weeds inside the storage walls so that more seed would not be spread around the farm in the irrigation channels. We had a good success with what we did, but we ensured that we monitored the inside of the storages pretty closely after that to ensure that new plants did not come back through. Hopefully having the storage full of water resulted in the seeds rotting in the mud inside the storage.

The velvetleaf in the dryland fields was less of a worry, but we certainly got rid of it before it went to seed and spread any further. It is always better to try and get rid of any weed while ever it is in small patches that you can keep an eye on and control. We also made sure that we **cleaned down the machinery** that we used in the fields with this weed before we moved it onto clean areas, just in case the machinery spread seeds in attached soil or crop trash.

It is so important to keep an eye out for potential new weeds, to have them correctly identified and to try and control them before they start spreading otherwise things can quickly get away on you. We had enough worry about with the current weeds that we had".

MANAGING WEEDS ON ROADS, CHANNELS AND WATER STORAGES

**Graham Charles, Anne Sullivan,
Ingrid Christiansen and Grant Roberts**
(NSW Agriculture, QDPI, QDPI & CSIRO)

Contents	Page
The problem	F3.1
Weed management options	F3.2
Herbicide options	F3.3
Contact (non-residual) herbicides	F3.3
Residual herbicides	F3.4
Mechanical control	F3.4
Burning	F3.4
Common weeds of roads and channels	F3.5
Spread of seeds through irrigation water	F3.7
Summary	F3.8

The problem

Weeds on roads and irrigation structures are a problem because they:

- can be hosts for insects and diseases;
- are a source of weed seeds that contaminate cotton fields and add to the weed seed-bank;
- may restrict the flow of water, which in turn can reduce irrigation effectiveness, increase waterlogging, lead to blockages in irrigation channels, and can cause erosion and failure of banks;
- make access to channels and structures difficult and provide a habitat for snakes and other pests in areas where siphons are being set;
- can contaminate modules; and
- act as harbours for feral pigs.



A very weedy water storage, dominated by sesbania and cumbungi. This storage is a source of weed seed and a host for pests and diseases.

Ownership and responsibility for weed management may be difficult to establish in some situations. Weeds may not be able to be managed on adjoining public land.

Weed management options

The options for managing weeds on roads and irrigation structures are:

- chemical control with herbicides,
- mechanical control with cultivators, graders, excavators and chippers, and
- burning.

A weed management plan should not rely solely on one weed management strategy, as heavy reliance on a single strategy will inevitably see the emergence of weeds that are able to tolerate that strategy. Over reliance on a single herbicide may result in the selection of weeds that are resistant to that herbicide. For more information, refer to the **Integrated Weed Management (IWM) Guidelines for Australian Cotton Production and Managing Herbicide Resistance in Cotton** in **WEEDpak**.

Weeds are not generally a big problem on roads, as weeds do not grow well on compacted areas and most weeds can be controlled with herbicides and mechanical removal. Weeds are far more difficult to manage on irrigation structures, where

water movement, and the physical size, shape and location of the structures requires management with specialised equipment.



Weed management on adjoining private and public land can be a problem. Weeds growing on roadsides (such as this road between two cotton properties) can be a continual source of infestation. Photo by Sandra Deutscher

Table 1. Herbicides registered for controlling weeds on non-agricultural areas. A range of commercial formulations may be available for each active ingredient. Refer to the product label for specific directions regarding the use of a product.

Herbicide active ingredient	Concentration and formulation	Application rate	Comments
amitrole + ammonium thiocyanate	250 g/L AC 220 g/L	0.28 – 4.5 L / 100 L water	Controls a wide range of plants from seedling grasses, at low rates, to perennial grasses at high rates. Controls young broadleaf plants. Check the label for details.
diuron	500g / L SC 800 g / kg WP 900 g / kg WG	70-150 L / ha 20-40 L / ha 45-90 kg / ha 22 kg / ha	Qld and WA registration. NSW registration only. Controls most weeds but not brown beetle grass (<i>Leptochloa fusca</i>), redshank (<i>Amaranthus</i> spp.), and Johnson grass. Check the label for details. Channels must be flushed after application.
glyphosate	360 g / L AC 450 g / L AC 490 g / L AC 680 g / kg	0.5-9 L / ha 0.4-2.4 L / ha 0.4-2.0 L / ha 1.0-4.5 kg / ha	Controls most weeds. Low rates for annual grasses. High rates for perennials and broadleaves. Mix only as directed on the label. Check label for details,
pendimethalin	330 g / L EC 440 g / L EC 455 g / L	4.5-9 L / ha 3.4-8.1 L / ha 3.3-8.1 L / ha	If 25-50 mm rain has not fallen within 14 days, flush channel (1 day) and drain off.
2,2-DPA	740 g / kg WP	10-20 kg / ha	Controls annual and perennial grasses. Controls cumbungi, phragmites, rushes and sedges.

Herbicide options

A range of herbicides is registered for controlling weeds on non-agricultural areas, roads, drains, and irrigation structures, as shown in Table 1. Always refer to the product label for specific use directions.

Weeds can be very difficult to control on irrigation structures with herbicides as:

- the herbicides may not be safe to use on cotton or other crops, and so must be applied in conditions that preclude drift to crops,
- soil incorporated residual herbicides are difficult to apply to irrigation structures, and may wash into cotton fields,
- residual herbicides may need to be applied at very high rates, which makes them very expensive to apply,
- herbicides may need to be applied in the “off-season” when channels are empty. Channels may have to be flushed before use to dilute high rates of residual herbicides,
- structures may be large enough to make it difficult to apply herbicide to all parts of the structure. Specially designed spray booms are often used for channels and irrigation structures.
- plants growing in water can not be treated with residual herbicides, and
- the constantly changing water level in some channels makes it difficult to treat all weeds at the same time. Some supply channels may remain wet throughout the cotton season, making them very difficult to manage with herbicides.

In using herbicides to manage weeds in channels, head-ditches and storages during the cotton season, it is essential to prevent the movement of herbicides into the crop, either as drift or in water from irrigation or rainfall. The risk greatly diminishes at the end of the cotton season, when the crop is no longer as susceptible to the herbicides. Rotation crops and pastures, however, may also be susceptible to damage from these herbicides, so care must be taken all year round.



A purpose-built sprayer, designed for spraying irrigation channels. Photo by Sandra Deutscher.

Drift can be reduced by applying herbicides with low pressure and high water volume, through low-pressure nozzles, with air assisted sprays and as shielded sprays. Minimising release height, avoiding high ground speeds and using larger droplets will decrease the risk of drift. The overwhelming influence on drift, however, is to only apply herbicides under suitable environmental conditions. Windy and dead-calm conditions are equally unsuitable for spraying and must be avoided. Don't be fooled that a gentle breeze in the tractor cabin equates to similar conditions outside!!

Contact (non-residual) herbicides

Contact, or knockdown herbicides, kill plants that are growing at the time of application. They are generally very effective on seedlings and young plants, but may be less effective on mature and perennial plants.

Glyphosate is generally regarded as the safest, easiest to use knockdown herbicide option for roads, channels and storages where both grasses and broadleaf weeds are present. It is effective on most annual and perennial weeds, but has the potential to cause considerable damage to conventional cotton plants if it is applied inappropriately. Relatively light rates are required to kill most grass weeds, while heavier rates are needed for many broad leaf and perennial weeds. Glyphosate is a slow-acting herbicide. Complete death of weeds may occur up to two to three weeks after application.

Glyphosate should not be applied to water or to weeds standing in water. Where glyphosate is applied to dry drains, there may be a requirement that water not be returned to these drains for some period after herbicide application.

Some formulations, such as Roundup® Bioactive are registered for use on aquatic areas, for controlling emerged weeds that may be standing in water. Always check the product label for specific directions on product use.

Roundup Ready® cotton volunteer plants may be a problem along roadways and channels, as these plants have been modified to make them tolerant of glyphosate. Roundup Ready cotton can not be controlled by glyphosate, and needs to be controlled using an alternative option, such as mechanical control or an alternative herbicide.

Selective grass herbicides may be very useful where grass weeds are the predominant weed problem along the edges of cotton fields. These herbicides are most effective against young, actively growing grass weeds. They may be ineffective when applied to mature or stressed grass weeds. Several of these herbicides are available, and are registered for use in cotton, so can be used without risk of damage to the cotton. Great care must be taken however, when using the grass herbicides near sensitive rotation crops such as sorghum, millet, and winter cereals.

Residual herbicides

The residual herbicides provide longer-term control of weeds, but are difficult to apply to irrigation structures during the cotton season. They must be applied to dry soil. Residual herbicides are normally applied to irrigation structures in autumn after the final irrigation on the cotton. Channels are flushed prior to the next irrigation to dilute any excessive levels of herbicide that may remain. Non-residual herbicides are generally used to control any weeds that emerge during the irrigation period.

For best results, the residual herbicides require either mechanical or water incorporation (rain or irrigation). Application and mechanical

incorporation is easily undertaken on roadways, but may be very difficult to achieve on irrigation structures, and particularly on steep banks. Incorporation with irrigation is more easily achieved, but may wash much of the herbicide away from the target site.



Channels are regularly re-shaped and de-silted with excavators, graders, and delvers.

Mechanical control

Regular grading and upkeep of roadways and channels provides an effective, non-chemical means of weeds control. This may be combined with de-silting operations in channels when required. However, the silt may contain large numbers of weed seeds that will need later control.

Chipping of channels is sometimes done where large weeds such as sesbania, bladder ketmia, the burrs or Roundup Ready cotton need controlling in sensitive or inaccessible areas, or areas where spraying is not an option due to wind conditions.

Burning

In severe cases, where large weeds have grown out of control, burning has been used to remove the bulk of dead weed material. Burning may also kill many weed seeds, pests and diseases. Permits may be required for burning, particularly during the summer months.

Common weeds of roads and channels

Any weed can be a problem on roads and irrigation structures, but some species are more difficult to manage than are others. Among the more troublesome weeds are:

Brown beetle grass	<i>Leptochloa fusca</i>
Cumbungi	<i>Typha</i> spp.
Knotweed	<i>Perscaria</i> spp.
Nutgrass	<i>Cyperus rotundus</i>
Noogoora burr	<i>Xanthium occidentale</i>
Italian cocklebur	<i>Xanthium italicum</i>
Sesbania pea	<i>Sesbania cannabina</i>
Cowvine	<i>Ipomoea lonchophylla</i>
Bellvine	<i>Ipomoea plebeia</i>
Awnless barnyard grass	<i>Echinochloa colona</i>
Summer grass	<i>Digitaria ciliaris</i>
Caltrop	<i>Tribulus terrestris</i>
Spineless caltrop	<i>Tribulus micrococcus</i>
Couch	<i>Cynodon dactylon</i>
Downs nutgrass	<i>Cyperus bifax</i>
Volunteer cotton	conventional and Roundup Ready plants

These weeds are generally problems because they:

- tolerate the herbicides normally used to control weeds on these areas, or
- grow in water, and so are difficult to treat with either contact or residual herbicides.



An irrigation channel heavily infested with brown beetle grass.

Brown beetle grass is a major weed of irrigation channels and is increasingly becoming a problem in cotton. Plants produce a large amount of viable seed and can grow to form large tussocks that obstruct channels. Seeds from plants growing on channels are transported into fields in irrigation water and readily grow and establish in cotton fields.

Brown beetle grass is difficult to control on channels with some herbicides. Pendimethalin will control brown beetle grass, but is difficult to incorporate on irrigation structures. Brown beetle grass is easily controlled in-crop with the residual grass herbicides trifluralin, pendimethalin, metolachlor, and Zoliar. Brown beetle grass is a problem in the furrows in fields where these products are applied in a band behind the planter, with no residual grass herbicide applied to the furrow.

Mechanical control is an option both in-channels and in-crop but this can be time consuming and expensive. Brown beetle grass is very difficult to control in-crop after crop canopy closure.



Brown beetle grass produces masses of seed that germinate and grow in moist places such as channels and irrigation furrows.

Cumbungi and **knotweed** are not commonly problems in irrigation channels, but are more often problems in irrigation storages. Isolated plants are of little importance, but they are large plants, and can form dense mats that are almost impenetrable. They can be hosts to pests including feral pigs. Once established, they are very difficult to control with herbicides. When these weeds become a problem, they may need to be removed with excavators.



Cumbungi is a large plant that grows in water and is tolerant of glyphosate.



Knotweed can form an almost impenetrable mass.

Nutgrass is difficult to control with either herbicides or mechanical control, regardless of its location. It is not as big a problem in channels as it is in cotton, but can restrict water flow and cause the build-up of silt, and is able to spread with machinery and water movement. Nutgrass spreads primarily by tubers, which can float and be moved around in water. Any nutgrass patch can act as a source of infestation to cotton fields.



Nutgrass thrives in wet conditions. Nutgrass tubers move in water and are a constant source of infestation to cotton fields.

The burrs, **Noogoora burr** and **Italian cocklebur**, are perennial problems where ever they occur. They can produce seed while very small, but can become very large plants, producing masses of seed. Their seed easily catches in clothing and cotton lint and can remain viable in the soil for many years.

The burrs are relatively easily controlled with herbicides, but their ability to germinate after every rainfall or irrigation event makes them a major nuisance. Burrs growing on irrigation structures may be a major source of seed infestation into cotton fields.



Italian cocklebur growing on the side of a channel. These plants are carrying a mass of seed, much of which may end up in the field. Note also the presence of sesbania and barnyard grass on the channel bank.

Sesbania is another potentially large weed that produces masses of seed. These seeds move in irrigation water and can easily move from irrigation channels into fields. Sesbania is relatively tolerant of glyphosate and difficult to control with residual herbicides on channels.



A heavy infestation of sesbania in a head-ditch. Sesbania was not common on this property, but seed has been introduced through the irrigation water. The weed will soon become established in the cotton field if it is not controlled.

Cowvine and **bellvine** are difficult to control in conventional cotton. Plants growing on channels and irrigation structures can be an important source of weed seed going into fields.



This channel bank is covered in cowvine plants. These plants are a source of weed seed for the cotton field.

Spread of seeds through irrigation water

Irrigation water can be an important source of weed infestation into cotton fields, and may include large numbers of weed seeds. When this water is being drawn from an external source, such as a river, the cotton grower has little control over the weed seed load in the water. Generally, however, the numbers of seeds introduced in irrigation water is not large in comparison with the numbers of seeds already present in the soil. A study on one field, heavily infested with cowvine, found that around 5500 cowvine seeds were introduced into the field from irrigation water over a single summer. However, this field already had approximately 2000 seeds/m², or 800 million cowvine seeds in the seedbank. The extra 5500 seeds per season are of little importance until the seedbank in the field is greatly reduced.

A study by David Hawkey found large numbers of grass seeds in irrigation water entering fields in the Macquarie Valley. Nevertheless, the introductions still amounted to only a small proportion of the total numbers of weed seeds already present in the fields.

Irrigation water is most important as a potential source of infestation of new weeds to a farm. In the example given above, 5500 seeds per season of a new weed species introduced to a field, would be a major problem and would soon see the weed well established in that field.

The problem of weed seed contamination in irrigation water is generally far worse when pumping floodwater. Some weed seeds are regularly falling into water from plants established on riverbanks etc., but most of these seeds move only a short distance. During a flood, there is the potential for weeds established away from the rivers to contribute large seed loads to the floodwater. Examples of this, were the introduction of velvetleaf to one property in the Gwydir watercourse country during the 1998 flood, and Downs nutgrass to a field on another property during the flood of February 2001, when flood water inundated a cotton field.

There are a number of factors that influence the number and species of seeds that are found in irrigation water. These factors include: soil type; cropping and weed control practices; drainage water return into the channel; distance from the river or main water source; the nature of the watershed; and the environment through which the irrigation channel passes. Weed management in and around channels is likely to influence the numbers and species of seeds that are introduced to fields in irrigation water. Studies have found that the length of time that weed seeds remain viable in fresh water may range from a few months to five or more years, depending on the species concerned.

Channels with poor weed control usually contribute the largest number of seeds to the irrigation water. As water moves through the channel system, the number of seeds in the water is likely to increase from plants growing along the channel banks, seeds blowing into open channels, and by return flows from irrigated fields. The greater the distance that water travels in channels, the longer the exposure to weedy banks. Irrigation is capable of carrying weed seeds over long distances and has the potential to introduce new weed species to a field and region.

Only one viable seed is needed to start a weed infestation in a field. For this reason, the control of weeds in and around channels and drainage ways should receive as much attention as the weeds that occur in the paddock.

Summary

Weeds are undesirable on roads and irrigation structures, as they are a source of weed infestation for cotton fields and can negatively impact on the irrigation system. Control is equally important on channels and structures that may not be in use. All structures should be given the same importance as cotton fields.

A number of strategies can be used to reduce the movement of weed seeds into cotton fields.

1. Carefully monitor irrigation structures for the presence of weeds that are not commonly found on the farm. These species deserve special attention. Elimination of a single plant may remove the need to manage infested fields in later years.
2. Keep all irrigation water sourced from off-farm in a water storage for as long as possible before use (this is especially important with floodwater), in order to allow the weed seeds to sink during storage, effectively removing them from the irrigation water.
3. Flush dirty channels before use, removing most weed seeds into the water storage system.
4. Treat channels with a residual herbicide after the final irrigation.

Use non-residual herbicides as often as necessary to control weeds that emerge during the cotton season.

CONTROLLING VOLUNTEER COTTON

Grant Roberts, Sarah Kerlin and Mark Hickman
(CSIRO, QDPI & NSW Agriculture)

Contents	Page
Introduction	F4.1
Control of seedling volunteer cotton	F4.1
Cultivation	F4.2
Herbicides	F4.2
Control of established cotton	F4.3
Herbicides	F4.4
Control of regrowth or ratoon cotton	F4.4
Summary	F4.5

Introduction

The control of unwanted cotton in the farming system is an important component of rotational flexibility and management and an essential component in farm hygiene. Three types of volunteer cotton are often required to be controlled; seedling cotton, established cotton and regrowth or 'ratoon' cotton. Control of volunteer cotton on all areas of cotton farms and roadsides is highly desirable as they are, in effect, a weed. Seedling volunteers are often scattered across furrows and plant lines within fields, and rarely yield as well as newly planted seed due to seedling disease and early emergence in cool conditions. All three types of volunteers can also be found in channels and along roadsides (photo 1) creating farm hygiene problems. They can cause problems for resistance management of Bt cotton, reduce seed purity and act as early host plants for pests such as spider mites and aphids. In addition, susceptible varieties can interfere with disease management strategies. The release of Roundup Ready® cotton also eliminates the use of glyphosate as a suitable herbicide for controlling volunteers with this gene. The control of seedling volunteer cotton also provides an opportunity to rotate herbicide chemistry or use cultivation which are important components of IWM.

Control of Seedling Cotton

Volunteer cotton plants are plants that have germinated, emerged and established unintentionally. Volunteers normally come from seed cotton (lint + seed) but can also establish directly from fuzzy seed (ginned seed) or planting seed (delinted seed). The source of this seed cotton in cotton fields is mainly from previous cotton crops in which the seed cotton has fallen from the plant to the ground. Seed cotton is also distributed over cotton farms and surrounding roadsides at picking time when large volumes of harvested cotton are transported to cotton gins. Volunteers established from fuzzy seed are usually the result of seed escapes during the transportation of fuzzy seed from gins to end point use. These destinations include crushing plants or stock feeding points. It is also common that planting seed may also be spilt accidentally in transportation on-route to, or within, fields creating a ready source of volunteers.

Cultivation and herbicides are the two most common methods of volunteer cotton control. Both require the cotton plants to have germinated and emerged before control can occur. This is particularly important if the volunteer plants being controlled have the Roundup Ready® gene and the following crop is cotton. The use of glyphosate will not control these seedlings. Cultivation will remove the in-furrow volunteers but miss the volunteers situated in the plant line. Rainfall or pre-irrigation is required to germinate these volunteer plants prior to planting, after which effective control can be attempted.



Photo 1. Established Roundup Ready® cotton volunteers on farm roadways.

Cultivation

Broadacre cultivation will readily control seedling volunteers in most soil conditions, as the root system and hypocotyl of seedling cotton are easily destroyed by the cultivation process. Any damage that occurs below the cotyledons will kill the plant, as there are no growing points from which the plant can recover. Effective cultivation will only occur if the cultivation implement cultivates both the furrow and hill avoiding strips being left uncultivated. Cultivation will also manage other weeds besides seedling volunteer cotton. This non-herbicide method of weed control is part of an Integrated Weed Management system (refer to IWM, section B2). The disadvantage of cultivation is that it only controls established seedlings, is slow and can cause moisture loss or soil damage if conducted at the wrong time (refer to SOILpak). In addition, volunteer establishment will mainly occur in periods very close to planting, which is an inappropriate time to be conducting large scale tillage operations. Never-the-less, cultivation is a valuable integrated weed management tool and should always be considered.



Photo 2. Broadacre cultivation can be used to effectively control volunteer cotton.

Herbicides

The broad spectrum herbicide glyphosate has often been used extensively to control seedling volunteer cotton. Control has either been deliberate or inadvertent when targeting other weeds prior to cotton planting as a fallow spray or within crop as a shielded spray. Glyphosate rates of 1.2 L/ha (450 g/L) will easily control seedling cotton at the 1st and 2nd true leaf stage. The release and widespread adoption of Roundup Ready[®] cotton, which has a gene allowing the tolerance of over-the-top applications of glyphosate, eliminates the use of glyphosate as a potential control herbicide for seedling volunteer Roundup Ready[®] cotton. As a result, alternative

herbicides that control the volunteers but do not have residual effects on subsequent crops, including cotton, will need to be utilised. Table 1. provides a list of herbicides that were screened for efficacy against seedling volunteers. These herbicides were selected on their likely efficacy of controlling seedling cotton with minimal residual carryover to either cotton or rotation crops. Glyphosate and mixtures that utilised glyphosate as the main active ingredient were excluded from testing so that results could be inferred for Roundup Ready[®] volunteers as well.

The results of this experiment suggest that Spray.Seed[®], Hammer[®] and bromoxynil would be effective in controlling seedling cotton (including Roundup Ready[®] volunteers) at both 4 and 8 leaf growth stages. Surpass[®], Basta[®], Starane[®] and MCPA Amine are also options but are likely to be less reliable. In addition (excluding Basta[®]), there are spray management considerations with these herbicides, including drift and plant-back times to cotton (refer to Managing Weeds in Cotton, section B3). The results outlined are preliminary and no attempt was made to ascertain the most appropriate herbicide rate or the effects of combinations of herbicides. The results reported here are NOT recommendations

Both Spray.Seed[®] and Hammer[®] are contact herbicides, with no residual carryover and their use patterns have been designed as pre-emergent crop knockdowns. The active components of Spray.Seed[®] (paraquat and diquat) are from the bipyridyl group of herbicides which inhibit photosynthesis at photosystem I (group L). Hammer[®] (carfentrazone) is a member of the aryl triazoline group which inhibits protoporphyrinogen oxidase (group G). The differences in modes of action from glyphosate, which inhibits EPSP synthase (group M) are important, as they allow these herbicides to control glyphosate tolerant cotton and also control other weeds using a different herbicide group. Rotating herbicide chemistry is an important component of preventing herbicide resistance. Hammer[®] can also be mixed with glyphosate or Spray.Seed[®], improving the weed spectrum it controls. In theory, a mixture of Hammer[®] (at an adequate rate) and glyphosate would control Roundup Ready[®] seedling volunteers, as well as the usual weeds glyphosate is targeted against.

With all contact herbicides, excellent spray coverage is essential for adequate control. This often means high (e.g. 100L/ha) water volumes per hectare.

Table 1. Effect of herbicides on seedling cotton at St George (4 true leaves) and Narrabri (8 true leaves) in 2001-02.
Main headings in **bold** are tentative classes.

Herbicide	Trade Name	Rate/ha (kg or L)	Active Ingredient (g/ha)	Percentage Control# St George 4 true leaves	Percentage Control# Narrabri 8 true leaf
Unsprayed	-	-	-	0	0
Effective control					
Bromoxynil	Buctril 200	4	800	100	100
Carfentrazone	Hammer 240 EC	0.15	36	100	100
Paraquat + Diquat	Spray.Seed 250	2	270 + 230	100	100
Incomplete control					
2,4-D Amine	Surpass	2	450	0	95
Glufofenate-ammonium	Basta	3	600	92	96
Fluroxypyr	Starane 200	1	200	25	95
MCPA Amine	MCPA 500	2	1000	30	88
No control					
Clpyralid	Lontrel	0.15	45	0	0
Dicamba	Banvel 200	1.4	280	2	0
Diuron	Diuron DF	1.9	1710	0	0
Fluometuron	Nu-Tron 900 DF	1.9	1710	0	0
Oxyfluorfen	Goal CT	0.25	60	15	0
Prometryn	Gesagard 500 SC	3	1500	19	10
Triclopyr	Garlon	0.15	90	0	0

Plants were still considered alive if they had green foliage or stems and if they regrew at any stage.

Control of Established Cotton

Occasionally, the control of established cotton is required due to unforeseen circumstances such as:

- Adverse weather
- Hail
- Poor plant establishment
- Major insect problems
- Unmanageable weeds
- Disease problems
- Changing economics

When these situations occur the cotton grower

may wish to abandon the field and replant with another crop in summer or a winter crop. Conventional mechanical methods of destroying the cotton would involve mulching, root cutting and cultivation. These methods are very effective at controlling established cotton, however, in some circumstances the use of cultivation is undesirable. Examples of this could include dryland crops that need to be controlled without cultivation due to the increased risk of soil erosion and the need to conserve moisture. Herbicide control may be an option provided the *Helicoverpa* pupae have not started diapausing under the crop.

Herbicides

Established cotton is difficult to control with herbicides alone, although the large leaf area does provide an opportunity to attain good leaf coverage. Table 2 provides a list of herbicides that were screened for the control of established cotton. These herbicides were initially applied as a 100% over-the-top band. This initial application did not appear to work due to poor spray coverage and penetration, with only the tops of the plants being affected. A second application was applied using side directed spray nozzles on droppers and one nozzle over the top.

The results suggest that Starane® and glyphosate + 2,4-D amine (Surpass®) mixtures can provide control of established cotton. The glyphosate + 2,4-D amine mix is also very effective at controlling a large range of broadleaf and grass weeds at the same time. None of these options are registered and the information provided in this section is only experimental. It is important to remember with 2,4-D Amine that up to 28 days is required before replanting some crops and 15mm of rain is required in dry soils before the commencement of this plant back period. Starane® has a plant back period of 7-28 days depending on the crop. As with all *Phenoxy* herbicides the risk of spray drift onto susceptible crops must be prevented and thorough decontamination of all spray equipment must also be ensured.

Control of Regrowth or 'Ratoon' Cotton

'Ratoon' cotton is cotton that has regrown from left over root stock from a previous season. The control of ratoon cotton is important for the management of insects and diseases. The pathogens that cause the diseases black root rot, verticillium wilt, alternaria leaf spot, fusarium wilt and bunchy top are all capable of transferring easily from one season to the next via ratoon cotton. In addition ratoon plants can act as over winter hosts for aphids, spider mites, whitefly and early food for *Helicoverpa*.

In theory ratoon cotton should not occur due to the requirement of harvested cotton to be controlled with adequate cultivation and soil disturbance as soon as practical after picking. This usually involves some sort of mulching (Photo 3.) and/or root cutting (Photo 4.) followed by cultivation to destroy the cotton root system. In conducting this cultivation an additional aim is to destroy over-wintering *Helicoverpa* pupae. This pupae control is a frontline strategy in managing insecticide resistance for the cotton industry and is mandatory if growing Ingard® cotton (refer to ENTopak and MACHINEpak for information on pupae busting).



Photo 3. Mulching harvested cotton.



Photo 4. Root cutting prior to cultivation to stop cotton ratooning.

However, in some seasons, fields may become flooded or adverse weather may make cultivation undesirable. In these scenarios, the use of a herbicide would seem appropriate. Unfortunately no herbicides are registered for the control of ratoon cotton. A limited range of herbicides have been evaluated for the control of ratoon cotton (Table 3), however none were found to be effective. It is possible that double applications may be more successful, but it is clear that ratoon cotton is extremely difficult to control with herbicides alone. It is believed that the main reason for herbicide failures is the small leaf area available for herbicide absorption compared to the large root system available for carbon and nutrient supply that allows the plant to continue growing.

Table 2. Percentage of dead cotton plants after applying two applications of herbicides.

Herbicide treatments	% Dead cotton plants
Starane® (4L/ha)	100
Roundup CT Xtra (2L/ha) + Surpass® (4 L/ha)	94
Roundup CT Xtra (2L/ha) + Surpass® (2 L/ha)	80
Roundup CT Xtra (2L/ha) + Glean (25g/ha) + BS1000# (200ml/ha)	22

A non-ionic surfactant

Table 3. The effect of selected herbicides on ratoon cotton. Herbicides applied 25 days before the first irrigation and first assessment 10 days before irrigation and second assessment 20 days after.

Herbicide treatments		1 st assessment % regrowth	2 nd assessment % regrowth
Unsprayed		80%	95%
Roundup CT Xtra	4.6 L/ha	47%	93%
Basta	5 L/ha	53%	92%
Starane	2 L/ha	7%	91%
Starane	4 L/ha	5%	92%
Bromoxynil	3 L/ha	37%	93%
Prometryn 6 L/ha + DC trate	2 L/ha	47%	94%

Summary

Cultivation is an effective and efficient method of controlling all types of volunteer cotton including, seedling, established and ratoon. Herbicide options to control seedling cotton include Spray.Seed® and Hammer®, both of which are also capable of controlling Roundup Ready® volunteers. Established cotton can be controlled with twin applications of glyphosate + 2,4 D amine or Starane®. Ratoon cotton will still need to be controlled with mechanical methods, as no effective herbicides have been identified.

PLANT PROTECTION INTERACTIONS WITH WEEDS

Stephen Johnson and Leah MacKinnon
(University of New England)

Introduction

Weeds may act as hosts for both insects and pathogenic organisms that have adverse impacts on cotton production. Integrated weed management practices will assist in managing these problems.

The interaction between weeds and insects has been examined in the articles *Integrated pest management guidelines for Australian cotton*, and in particular, *Support document 4. Cotton insect pests and their weed hosts*, both in ENTOpak.

The interaction between weeds, pathogens and cotton diseases is outlined below. For more details on weeds and diseases, the reader is referred to the *Integrated Disease Management Guidelines*. Details of all these publications are given below.

Weeds, pathogens and cotton diseases

Apart from the obvious effects of weeds on cotton production and yield, weeds may also harbour pathogenic organisms responsible for many of the diseases associated with cotton production. Weeds may act as alternative hosts for some cotton pathogens (Table 1) and enable the survival of the pathogen during the period between subsequent cotton crops. For example, bladder ketmia may act as an alternative host for the pathogens that cause Verticillium wilt, Fusarium wilt and Alternaria leaf spot of cotton.

The presence of a pathogen on a weed host is not always obvious and it is possible that the symptoms normally associated with the disease may not be apparent (a symptomless weed host). Sesbania pea, bladder ketmia and dwarf amaranth are known to be symptomless hosts of the Fusarium wilt pathogen.

An infected weed can also contribute to the dispersal of a plant pathogen. The burrs of Noogoora burr carry the Verticillium wilt pathogen, enabling wide dispersion of the pathogen by animals or through irrigation channels, rivers and streams, and flood waters.

Similarly, volunteer cotton plants and cotton regrowth must also be considered as significant pathogen hosts in and around cotton crops. Control of volunteers and ratoon cotton is essential to prevent the further spread of disease (see **Controlling Volunteer Cotton** in section F, WEEDpak).

Further reading

Evans, G. (1971). Influence of weed hosts on the ecology of *Verticillium dahliae* in newly cultivated areas of the Namoi Valley, New South Wales. *Annals of Applied Biology*, **67**, 169 - 175.

Mensah, R., Dillon, M., Kahn, M., Tann, C. and Wilson, L. (1999). *Support document 4. Cotton insect pests and their weed hosts*. ENTOpak, Australian Cotton CRC, Narrabri.

Mensah, R. and Wilson, L. (1999). *Integrated pest management guidelines for Australian cotton*. ENTOpak, Australian Cotton CRC, Narrabri.

Integrated Disease Management Guidelines (2002). Australian Cotton CRC, Narrabri.

Acknowledgments

We would like to acknowledge the advice of Dr. Stephen Allen and Dr. David Nehl in the preparation of the weeds, pathogens and cotton diseases information and list.

Table 1. Weeds known to be hosts of cotton pathogens

WEED SPECIES		PATHOGEN			
Common Name	Scientific Name	<i>Alternaria macrospora</i>	<i>Verticillium dahliae</i>	<i>Fusarium oxysporum</i> f. sp. <i>vasinfectum</i>	Black Root Rot
Amaranth dwarf	<i>Amaranthus macrocarpus</i>		✓✓	✓✓	
Amaranth redroot	<i>Amaranthus retroflexus</i>		✓		
Anoda weed	<i>Anoda cristata</i> (m)	maybe	✓		
Bathurst burr	<i>Xanthium spinosum</i>		✓✓		
Bellvine	<i>Ipomoea plebeia</i>		*		
Bindweed Australian	<i>Convolvulus erubescens</i>		✓✓		
Bindweed black	<i>Fallopia convolvulus</i>		*		
Blackberry nightshade	<i>Solanum nigrum</i>		✓		
Bladder ketmia	<i>Hibiscus trionum</i> (m)	✓✓	✓✓	✓✓	
Burr medic	<i>Medicago polymorpha</i>		✓✓		maybe
Cobbler's pegs	<i>Bidens pilosa</i>		*		
Common joyweed	<i>Alternanthera nodiflora</i>		*		
Cotton regrowth	<i>Gossypium hirsutum</i> (m)	✓	✓✓	✓✓	✓✓
Cowvine/Peachvine	<i>Ipomoea lonchophylla</i>		✓		
Dead nettle	<i>Lamium amplexicaule</i>		✓		definitely not
Dock curled	<i>Rumex crispus</i>		✓✓		
Gooseberry wild/Chinese lantern	<i>Physalis minima</i>		*		
Groundcherry perennial	<i>Physalis virginiana</i>		*		
Groundcherry/Annual ground cherry	<i>Physalis ixocarpa</i>		✓✓		
Mallow small flowered	<i>Malva parviflora</i> (m)	maybe	✓		
Malvastrum spiked	<i>Malvastrum americanum</i> (m)	maybe			
Medic	<i>Medicago</i> spp.		✓✓		maybe
Mintweed	<i>Salvia reflexa</i>		✓✓		
Noogoora burr	<i>Xanthium occidentale</i>		✓✓		
Nutgrass	<i>Cyperus rotundus</i>				definitely not
Pigweed red	<i>Portulaca oleracea</i>		✓✓		
Purpletop	<i>Verbena bonariensis</i>		✓✓		
Saffron thistle	<i>Carthamus lanatus</i>		✓		
Sesbania pea	<i>Sesbania cannabina</i>			✓✓	
Sowthistle common/Milkthistle	<i>Sonchus oleraceus</i>				
Sunflower volunteer	<i>Helianthis annuus</i>		✓✓		
Thornapple common	<i>Datura stramonium</i>		✓		✓✓
Thornapple fierce	<i>Datura ferox</i>		✓✓		
Tobacco wild	<i>Nicotiana</i> spp.		✓✓		maybe
Turnip weed	<i>Rapistrum rugosum</i>		✓✓		
Turnip wild	<i>Brassica</i> spp.		✓		
Variegated thistle	<i>Silybum marianum</i>		✓		
Velvetleaf	<i>Abutilon theophrasti</i> (m)		✓✓		✓✓
Verbena trailing	<i>Verbena supina</i>		*		

Key

✓✓ HOST - definite

✓ HOST - indications

blank unknown

* in other species of the same genera

(m) weeds related to cotton (Malvaceae family)

BEST BET MANAGEMENT GUIDE

Ian Taylor, Stephen Johnson, and Leah MacKinnon

(NSW Agriculture & University of New England)

Introduction

Currently there are over 200 weed species (see WEEDpak Section J3) known to be present on cotton farms in Australia, many of which are problematic. While a few of these weed species have received in depth research, most weed species remain poorly researched and are difficult to control. In addition, the broad climatic regions over which cotton production occurs in Australia, the differing agronomic practices, as well as the widely varying soil types, often mean that control measures effective in one region, are less effective in others. While some weed types are similar and can be controlled using comparable techniques, others, which are quite close botanically eg. caltrop and spineless caltrop (yellow vine) do not respond in the same manner to some control methods. Unless accurate identification of the species occurs, control methods employed may not be effective.

The best bet management guide is a compilation of management options derived from a series of focus group discussions and interviews with growers and consultants from all of the major growing regions. The aim was to pass on the experiences of a range of people and to determine effective control methods for some of the more common, difficult-to-control weeds. The herbicide options listed in this document are those recommended by consultants and growers who participated in the focus groups and interviews.

Some of the options given may be off-label. They may not necessarily be in accordance with label directions. Neither the Cotton CRC nor any of the departments represented in the production of WEEDpak supports the off-label use of herbicides.

By documenting meaningful approaches for problem weeds, we hope to encourage growers to re-assess their current methods, and provide some useful alternative strategies that may assist them in their weed management strategies. It is worth highlighting that there is a great deal of variation between fields and between farms. Growers should not seek to use a prescriptive weed management approach but instead tailor an integrated weed management strategy to their own agronomic practices and farming system.

The weeds included in the Best Bet Management section of WEEDpak are:

Annual ground cherry	(<i>Physalis ixocarpa</i>)	Flax-leaf fleabane	(<i>Conyza bonariensis</i>)
Anoda weed	(<i>Anoda cristata</i>)	Grey raspwort	(<i>Haloragis glauca</i>)
Awnless barnyard grass	(<i>Echinochloa colona</i>)	Hairy wandering Jew	(<i>Commelina benghalensis</i>)
Barnyard grass	(<i>Echinochloa crus-galli</i>)	Liverseed grass	(<i>Urochloa panicoides</i>)
Bathurst burr	(<i>Xanthium spinosum</i>)	Mintweed	(<i>Salvia reflexa</i>)
Bellvine	(<i>Ipomoea plebeia</i>)	Noogoora burr	(<i>Xanthium occidentale</i>)
Blackberry nightshade	(<i>Solanum nigrum</i>)	Nutgrass	(<i>Cyperus rotundus</i>)
Bladder ketmia narrow-leaf	(<i>Hibiscus trionum</i> var. <i>trionum</i>)	Perennial ground cherry	(<i>Physalis virginiana</i>)
Bladder ketmia wide-leaf	(<i>Hibiscus trionum</i> var. <i>vesicarius</i>)	Pigweed	(<i>Portulaca oleracea</i>)
Caltrop	(<i>Tribulus terrestris</i>)	Polymeria annual	(<i>Polymeria pusilla</i>)
Canadian fleabane	(<i>Conyza canadensis</i>)	Prickly paddy melon	(<i>Cucumis myriocarpus</i>)
Caustic weed	(<i>Chamaesyce drummondii</i>)	Rhynchosia	(<i>Rhynchosia minima</i>)
Common sowthistle	(<i>Sonchus oleraceus</i>)	Rough raspwort/Raspweed	(<i>Haloragis aspera</i>)
Common thornapple	(<i>Datura stramonium</i>)	Scurvy weed/Wandering Jew	(<i>Commelina cyanea</i>)
Couch	(<i>Cynodon dactylon</i>)	Spineless caltrop/Yellow vine	(<i>Tribulus micrococcus</i>)
Cowvine/Peach vine	(<i>Ipomoea lonchophylla</i>)	Swamp Chinese lantern/Velvetleaf	(<i>Abutilon theophrasti</i>)
David's spurge	(<i>Euphorbia davidii</i>)	Wild gooseberry/Chinese lantern	(<i>Physalis minima</i>)
Devil's claw	(<i>Martynia annua</i> and <i>Ibicella lutea</i>)	Wild melon	(<i>Citrullus lanatus</i> var. <i>lanatus</i>)
Downs nutgrass	(<i>Cyperus bifax</i>)		
Fierce thornapple	(<i>Datura ferox</i>)		

BEST BET MANAGEMENT GUIDE

Ian Taylor, Stephen Johnson, and Leah MacKinnon

(NSW Agriculture & University of New England)

Introduction

Currently there are over 200 weed species (see WEEDpak Section J3) known to be present on cotton farms in Australia, many of which are problematic. While a few of these weed species have received in depth research, most weed species remain poorly researched and are difficult to control. In addition, the broad climatic regions over which cotton production occurs in Australia, the differing agronomic practices, as well as the widely varying soil types, often mean that control measures effective in one region, are less effective in others. While some weed types are similar and can be controlled using comparable techniques, others, which are quite close botanically eg. caltrop and spineless caltrop (yellow vine) do not respond in the same manner to some control methods. Unless accurate identification of the species occurs, control methods employed may not be effective.

The best bet management guide is a compilation of management options derived from a series of focus group discussions and interviews with growers and consultants from all of the major growing regions. The aim was to pass on the experiences of a range of people and to determine effective control methods for some of the more common, difficult-to-control weeds. The herbicide options listed in this document are those recommended by consultants and growers who participated in the focus groups and interviews.

Some of the options given may be off-label. They may not necessarily be in accordance with label directions. Neither the Cotton CRC nor any of the departments represented in the production of WEEDpak supports the off-label use of herbicides.

By documenting meaningful approaches for problem weeds, we hope to encourage growers to re-assess their current methods, and provide some useful alternative strategies that may assist them in their weed management strategies. It is worth highlighting that there is a great deal of variation between fields and between farms. Growers should not seek to use a prescriptive weed management approach but instead tailor an integrated weed management strategy to their own agronomic practices and farming system.

The weeds included in the Best Bet Management section of WEEDpak are:

Annual ground cherry	(<i>Physalis ixocarpa</i>)	Flax-leaf fleabane	(<i>Conyza bonariensis</i>)
Anoda weed	(<i>Anoda cristata</i>)	Grey raspwort	(<i>Haloragis glauca</i>)
Awnless barnyard grass	(<i>Echinochloa colona</i>)	Hairy wandering Jew	(<i>Commelina benghalensis</i>)
Barnyard grass	(<i>Echinochloa crus-galli</i>)	Liverseed grass	(<i>Urochloa panicoides</i>)
Bathurst burr	(<i>Xanthium spinosum</i>)	Mintweed	(<i>Salvia reflexa</i>)
Bellvine	(<i>Ipomoea plebeia</i>)	Noogoora burr	(<i>Xanthium occidentale</i>)
Blackberry nightshade	(<i>Solanum nigrum</i>)	Nutgrass	(<i>Cyperus rotundus</i>)
Bladder ketmia narrow-leaf	(<i>Hibiscus trionum</i> var. <i>trionum</i>)	Perennial ground cherry	(<i>Physalis virginiana</i>)
Bladder ketmia wide-leaf	(<i>Hibiscus trionum</i> var. <i>vesicarius</i>)	Pigweed	(<i>Portulaca oleracea</i>)
Caltrop	(<i>Tribulus terrestris</i>)	Polymeria annual	(<i>Polymeria pusilla</i>)
Canadian fleabane	(<i>Conyza canadensis</i>)	Prickly paddy melon	(<i>Cucumis myriocarpus</i>)
Caustic weed	(<i>Chamaesyce drummondii</i>)	Rhynchosia	(<i>Rhynchosia minima</i>)
Common sowthistle	(<i>Sonchus oleraceus</i>)	Rough raspwort/Raspweed	(<i>Haloragis aspera</i>)
Common thornapple	(<i>Datura stramonium</i>)	Scurvy weed/Wandering Jew	(<i>Commelina cyanea</i>)
Couch	(<i>Cynodon dactylon</i>)	Spineless caltrop/Yellow vine	(<i>Tribulus micrococcus</i>)
Cowvine/Peach vine	(<i>Ipomoea lonchophylla</i>)	Swamp Chinese lantern/Velvetleaf	(<i>Abutilon theophrasti</i>)
David's spurge	(<i>Euphorbia davidii</i>)	Wild gooseberry/Chinese lantern	(<i>Physalis minima</i>)
Devil's claw	(<i>Martynia annua</i> and <i>Ibicella lutea</i>)	Wild melon	(<i>Citrullus lanatus</i> var. <i>lanatus</i>)
Downs nutgrass	(<i>Cyperus bifax</i>)		
Fierce thornapple	(<i>Datura ferox</i>)		

Annual ground cherry (*Physalis ixocarpa*)

Introduction

Wild gooseberry is an Australian native species belonging to the tomato family. It grows very rapidly during the summer months, producing up to 20 000 seeds per plant. Annual ground cherry is a native of south America and is used as a food source in Mexico. The two species are very difficult to tell apart, however the fruits of annual ground cherry are circular in cross section and

tend to be sticky. Very little is known about the seed biology of these species, particularly in Australian cotton production systems. The perennial ground cherry is similar in appearance to the two species already mentioned, however it has an extensive root system from which new plants develop for many seasons.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	Planting	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5 kg/ha Staple 60g/ha 30% band
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide Diuron 1.6 kg/ha
Cultivation	1-2 Inter-row cultivations per season.	
Chipping	Manual chipping is essential to control <i>Physalis</i> in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants.
Cultivation	Cultivation is very effective for <i>Physalis</i> control when plants are young, however a cautionary approach needs to be adopted when using cultivation as a control method, for perennial ground cherry as small plant sections are capable of establishing elsewhere in the. Cultivation should only be used when the soil is dry, to prevent the spread of this weed.

Anoda weed (*Anoda cristata*)

Introduction

Anoda weed is an annual species that germinates throughout the cotton season but produces the bulk of its mature seed from February onwards. Seeds are readily spread on machinery, harvesting equipment, in harvested cotton, and probably in water. There are limited means of managing this weed in-crop. One on-farm agronomist stated that

you cannot even see it until it comes up above the cotton. You do not know you have got it until the seed is maturing. Another consultant stated that *it has the ability to spread rapidly.* An investigation into the biology and management of anoda weed is currently in progress. Contact Stephen Johnson at ACRI for further information.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Zoliar applied at label rates.
	Planting	Staple 60 g/ha is effective on young plants. Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Staple at 60 g/ha is effective on small plants, particularly those that germinate prior to December and January. Anoda weed continues to emerge throughout the season. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Cotogard/Stomp or Diuron applications. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Normal inter-row cultivation will remove plants in the furrows and on the edges of hills.	
Chipping	The most effective means of removing small infestations of anoda weed is hand chipping. Anoda weed is difficult to distinguish in cotton because the plants have a similar colour. Manual chipping on two occasions is recommended, one pre-Christmas to remove vegetative plants and the other, before mid February, to remove plants that have developed seed heads.	
Farm hygiene	Good farm hygiene will reduce the movement of this weed both on farm and between farms.	
Rotation crops	An Atrazine/Starane mix is effective for control in dryland sorghum crops.	

Management in fallow situations

Herbicides	Roundup or Zoliar are effective in reducing the numbers of this weed in fallow.
Cultivation	Broadacre cultivation will help prevent this weed from going to seed.

Awnless barnyard grass (*Echinochloa colona*) Barnyard grass (*Echinochloa crus-galli*)

Introduction

Both barnyard grass species are annual grasses that germinate quickly after heavy rainfall and irrigation in late spring and summer. Growth is rapid and profuse, seeding occurring within a few weeks. A single barnyard grass plant can produce as many as 40 000 seeds and several generations

of plants may occur per year. These weeds are particular problems of irrigation channels and storage banks. One consultant stated that *when barnyard grass is small, all the selective herbicides do the job, but Select is best on barnyard grass.* The management of both species is similar.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Treflan 2.3–3 L/ha applied broad acre, or Stomp 3 L/ha.
	Planting	Mixtures of Cotogard and Stomp 3 L/ha, or Cotoran and Stomp 3 L/ha. Cotogard and Cotoran banded at 40%.
	In-crop	Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops. All selective grass herbicides are useful for managing seedling barnyard grass. These include Select 375 mL/ha, Verdict 150 mL/ha, Falcon 180 g/ha or Sertin Plus. Select will control barnyard grass very well. These herbicides may be applied on a banded (30–40%) or broadacre basis. Remember that all these selective grass herbicides belong to herbicide group A and care should be taken to ensure resistance does not develop.
	Lay-by	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops. Diuron or a mixture of diuron and Spray.Seed.
Cultivation	Plants in furrows will be cultivated out effectively by standard inter-row cultivations.	
Chipping	Chipping is effective in removing small numbers of plants.	

Management in fallow situations

Herbicides	Selective grass herbicides as outlined above.
Cultivation	Broadacre cultivation will remove plants.

Bathurst burr (*Xanthium spinosum*)

Introduction

Bathurst burr while problematic, is less of a problem in Australian cotton systems than Noogoora burr. The plants are smaller and less competitive but nevertheless can cause a significant decline in lint quality. Bathurst burr is susceptible to the same herbicides as Noogoora burr but is easier to control. Little research has been conducted on the seed characteristics of

Bathurst burr but they are thought to remain viable in the soil for 10-15 years. Typically Bathurst burr plants produce fewer seeds than Noogoora burr although like Noogoora burr there is tremendous variation between plants. From a practical point of view, Bathurst burr should be managed in the same fashion as Noogoora burr, with every effort made to prevent plants from seeding.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	2 L/ha Diuron flowable + Trifluralin 2.5 L/ha
	Planting	2-3 L/ha Stomp + Roundup Ready herbicide 40% band Cotoran/Cotogard 4 L/ha + 3 L/ha Stomp Dual Gold 1 L/ha + Cotogard 3.5 L/ha
	In-crop	2 applications of 1-1.5 kg/ha Roundup Ready herbicide MSMA 800 2.8 L/ha Staple 120 g/ha
	Lay-by	Roundup Ready herbicide 1.5 kg/ha applied as a directed or shielded application Cotogard 2.5 L/ha + Stomp applied as a directed or shielded application Diuron 3.6 L/ha + Stomp applied as a directed or shielded application
Cultivation	1-2 inter-row cultivations per season	
Chipping	Manual chipping is essential to control burrs in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 2-3 L/ha on small plants
Cultivation	Cultivation is very effective for burr control when plants are young.

Bellvine/Cowvine

(*Ipomoea plebeia*)(*Ipomoea lonchophylla*)

Introduction

Cowvine is emerging as one of the most troublesome weeds in Australian cotton systems. A comprehensive guide to cowvine management is included in WEEDpak (see section H2 'Managing cowvine in cotton') and is essential reading for a complete understanding of the dynamics and control of this troublesome weed. Cowvine is tolerant of the majority of herbicides used in cotton systems, especially when plants are greater than 15cm in length. Cowvine flowers very early (at around the three true leaf stage) and seed can be set within a few weeks of emergence. Mature plants produce approximately 800 seeds where competition is low, and under ideal conditions plants can produce thousands of seeds. The seeds have a hard coat and may remain dormant

for six to seven years in agricultural situations.

Control measures should be aimed at preventing seed set and should preferably target seedlings as they emerge, or very soon after emergence.

"Peach vine is our biggest problem, Roundup Ready herbicide is good to start with; later prometryn as a layby"

Bellvine is as difficult to control as cowvine, primarily for the same reasons. Bellvine, however, is a more aggressive climber and more competitive than cowvine and thus will have a greater impact on the yield of cotton. Bellvine does not flower until late summer/autumn, therefore seed production may be prevented by chipping or removing plants late season. The control measures for both species are currently the same.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1 kg/ha
	Planting	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5kg/ha Staple 120 g/ha over-the-top Two applications of Staple 60 g/ha for suppression
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide/shielded applications of Roundup Diuron 1.6 kg/ha Staple 60 g/ha 30% band 0.8 kg Diuron + 3 L/ha Stomp + 2.5L/ha Gesagard Diuron + Zoliar
Cultivation	1-2 inter-row cultivations per season.	
Chipping	Manual chipping 1-2 times per season to control single plants, but can be really expensive for dense infestations.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants. MCPA after defoliation of cotton. Winter laybys of prometryn or Cotogard. Rotate into sorghum and control with Starane and Atrazine.
Cultivation	Cultivation can be effective for cowvine control when plants are young. Larger plants however, can become densely entangled in cultivation equipment, reducing the effectiveness of control and necessitating constant stoppages to clear the implement.

Blackberry nightshade

(*Solanum nigrum*)

Introduction

Blackberry nightshade is an annual or short-lived perennial weed that goes to seed throughout spring, summer and autumn. The berries produced contain many seeds and can stain the cotton lint if harvested. The weed is increasingly difficult to control under current management regimes, particularly in the cooler cotton growing areas. One frustrated consultant recommended *pulling them out by hand and carting them out of the paddock*. The weed is a problem around channels, in fields, and appears to be spread by irrigation water.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broad acre.
	Planting	Cotogard 4 L/ha with Stomp 3 L/ha.
	In-crop	Glyphosate 1–1.5 L/ha applied through shields. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha. Staple 120 g/ha, particularly on seedlings.
	Lay-by	Applications of Diuron are recommended. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Inter-row cultivation will remove plants that grow in the furrow.	
Chipping	Either chipping or hand pulling helps remove plants, particularly in the plant line.	
Channels and head ditches	2,4-D amine applied as a spot spray.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Bladder ketmia narrow-leaf (*Hibiscus trionum* var. *trionum*)

Introduction

Bladder ketmia is a summer-flowering annual weed. It belongs to the same family as cotton (Malvaceae) and is very difficult to control in crop with herbicides alone. While individuals are not overly competitive, bladder ketmia plants often occur in dense stands that can cause considerable localised yield losses. In recent surveys conducted from Hillston in southern NSW to Emerald in Queensland, bladder ketmia was found to be the most troublesome and widespread

weed, infesting nearly 85% of the cotton properties surveyed. Bladder ketmia has a rapid growth rate, is a prolific seeder, and can produce seeds just 48 days after emergence. Bladder ketmia is extremely difficult to control for two reasons, the seeds germinate continuously throughout the season and being closely related to cotton restricts the range of herbicides that can be used due to the risk of also damaging the cotton.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

<i>Herbicides</i>	<i>Pre-plant</i>	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	<i>Planting</i>	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	<i>In-crop</i>	Two applications of Roundup Ready herbicide 1.5 kg/ha
	<i>Lay-by</i>	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide Diuron 1.6 kg/ha
<i>Cultivation</i>	1-2 inter-row cultivations per season.	
<i>Chipping</i>	Manual chipping is essential to control bladder ketmia in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

<i>Herbicides</i>	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants.
<i>Cultivation</i>	Cultivation is very effective for bladder ketmia control when plants are young.

Bladder ketmia wide-leaf (*Hibiscus trionum* var. *vesicarius*)

Introduction

Wide leaf bladder ketmia is very similar to narrow leaf bladder ketmia, except the leaves are 3 lobed rather than 5 and not as deeply notched. The flower colour is different, with the centre either being a pale yellow or a deep crimson (for the ecotype found in central Queensland). It is a prolific seeder and appears to be more susceptible to herbicides than is the narrow leaf variety.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha+ Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	Planting	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5 kg/ha
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide Diuron 1.6 kg/ha
Cultivation	1-2 inter-row cultivations per season	
Chipping	Manual chipping is essential to control bladder ketmia in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants.
Cultivation	Cultivation is very effective for bladder ketmia control when plants are young.

Caltrop

(*Tribulus terrestris*)

Introduction

Caltrop is an annual or perennial plant that has successive germinations after rainfall or irrigation. It grows rapidly during the cotton season, producing burrs within six weeks and a deep root system in a similar time. Burr production continues throughout summer and autumn and the seeds are easily spread on machinery or shoes. Management of this weed is particularly difficult, with one consultant stating that *if you expect a high occurrence of it then don't even think of reducing pre-emergent herbicide rates.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadcast or Diuron flowable 2 L/ha.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Two Roundup Ready herbicide sprays 1.5kg/ha in Roundup Ready crops.
	Lay-by	Mixtures of Diuron 0.8 kg/ha, Stomp 3 L/ha and Gesagard 2.5 L/ha. Cotogard 1–1.3 kg/ha, and Cotogard and Diuron mixtures. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Inter-row cultivation will help remove plants that grow in the furrow.	
Chipping	Chipping should aim to remove as much of the taproot as possible so that reshooting does not occur.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Canadian fleabane (*Conyza canadensis*)

Introduction

The fleabanes are newly emerging weeds of cotton and their presence is primarily thought to be due to changes in farming practices, most notably a reduction in conventional tillage operations. Once principally thought of as cool season weeds, the fleabanes are able to grow readily in warm to very warm conditions. Emergence however, is still restricted to cooler spring temperatures. Mature

plants may produce over 250 000 seeds per plant but these are generally short lived, with few surviving greater than one year. Most seeds are not able to germinate from deeper than one centimetre. The fleabanes are more easily controlled at the rosette stage, however, once main stem elongation begins to occur they are very difficult to control.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Roundup CT 3 L/ha Roundup Ready Herbicide 1.5 kg/ha (at the rosette stage only) Roundup 7-10 days prior to planting
	Planting	Roundup 3 L/ha Roundup Ready herbicide 1.5 kg/ha
	In-crop	Roundup (shielded spray) or Roundup Ready herbicide 1.5 kg/ha
	Lay-by	Roundup Ready herbicide 1.5 kg/ha
Cultivation	Inter-row cultivation may control small plants and burial of seed on the soil surface will prevent seed from germinating. Larger plants can be quite woody, with a deep robust taproot and may not necessarily be controlled by inter-row cultivation. Additionally, plants may break off close to the ground and re-grow.	
Chipping	Manual chipping is effective in control if the plants are very small. Unfortunately, many plants will set seed by the time chippers enter the field.	

Management in fallow situations

Herbicides	2,4-D amine or ester + Roundup Dicamba + Roundup
Cultivation	Cultivation is effective for control of fleabane in fallow situations.

Caustic weed

(*Chamaesyce drummondii*)

Introduction

Caustic weed is an annual or short-lived perennial species that grows mainly during spring and summer. Flowering occurs during this time and the weed spreads by seeds. Germination can take place at any time of the year given adequate moisture. Caustic weed is difficult to control and is sometimes not treated in a timely fashion, as the following consultant comment outlines. *We have got a couple of growers where it has been building up over the years and they have never seen it as a problem but now...it is nearly a mat within their cotton.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadacre or Diuron flowable 2 L/ha.
	Planting	Cotogard 4 L/ha with Stomp 3 L/ha.
	In-crop	Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Gesagard applied at label rates. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Inter-row cultivation will help remove plants that grow in the furrow.	
Chipping	Chipping will help remove small numbers of this plant.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Common sowthistle (*Sonchus oleraceus*)

Introduction

Common sowthistle is an annual species that grows throughout the year. One consultant stated that *it is a winter/early spring weed that tends to be creeping further into spring*. This weed is an increasing problem for many reasons. These include the seeds being easily spread by wind and

water, it being *hard to remove, especially when it becomes larger or when it is in a fallow situation*, and populations of the weed collected from wheat fields in the Darling Downs, Macintyre and Gwydir valleys have developed resistance to chlorsulfuron.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Roundup, Roundup Ready herbicide or 2,4-D amine applied broadcast six weeks before planting have been shown to be effective on this weed.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	The weed is readily removed by early season cultivation.	
Chipping	Chipping may remove any plants that continue to grow in cotton crops through to late spring.	

Management in fallow situations

Herbicides	2,4-D amine applied broad acre will control common sowthistle in winter. Express was also suggested as a useful, albeit slightly more expensive option.
Cultivation	Common sowthistle is readily removed by broad acre cultivation.

Common thornapple

(*Datura stramonium*)

Introduction

Both fierce and common thornapple are annual species that grow vigorously over summer. Plants compete strongly with cotton plants, are allelopathic, and obstruct harvest machinery when left to grow unchecked. Seeds are able to germinate from depths of eight centimetres in the soil. These seeds are produced in summer and

autumn and are easily dispersed by machinery or irrigation water. The management of both species is similar. One consultant stated that *where there is Datura on farms, or on fields that have bad Datura problems, we use Staple. We believe it is most effective on that weed.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadacre or Diuron flowable 2 L/ha.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Staple 30–90 g/ha in the rows as a 50% band. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	The application of Roundup Ready herbicide applied at 1.5 kg/ha. Diuron flowable applied at 3.6 L/ha.
Cultivation	Cultivation removes the plants missed by herbicide applications.	
Chipping	Spot chipping should be used to remove small infestations of plants.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help prevent this weed.

Couch (*Cynodon dactylon*)

Introduction

Couch is a mat-forming perennial grass that grows throughout the year. Seeds are produced in late summer and early autumn. The species primarily spreads vegetatively through stolons and small sections of the plant that are easily transplanted. The plant is particularly troublesome around irrigation channels where it may be difficult to control. Despite this, one consultant stated that *Fusilade* has good activity on it.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 3 L/ha or Stomp 3 L/ha applied broadcast.
	Planting	Mixtures of Cotogard and Stomp 3 L/ha, or Cotoran and Stomp 3 L/ha. Cotogard and Cotoran banded at 40%.
	In-crop	Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops. Selective grass herbicides, in particular Fusilade are effective. Others have suggested Select or Sertin Plus. Because these selective grass herbicides belong to herbicide group A, care should be taken to ensure resistance does not develop.
	Lay-by	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Cultivation is not generally recommended in-crop, as this is likely to spread the species, increasing the area of infestation.	
Chipping	Chipping is not recommended for dense infestations but may be useful to prevent spread of single plant stands.	

Management in fallow situations

Herbicides	The use of Roundup and selective grass herbicides is recommended.
Cultivation	Cultivation is very useful in fallow after the profile has been dried down. It should be timed to occur in mid-summer when there is little chance of rain.

Cowvine/Peach vine/Bellvine (*Ipomoea lonchophylla*)(*Ipomoea plebia*)

Introduction

Cowvine is emerging as one of the most troublesome weeds in Australian cotton systems. A comprehensive guide to cowvine management is included in WEEDpak (see section H2 'managing cowvine in cotton') and is essential reading for a complete understanding of the dynamics and control of this troublesome weed. Cowvine is tolerant of the majority of herbicides used in cotton systems, especially when plants are greater than 15cm in length. Cowvine flowers very early (at around the three true leaf stage) and seed can be set within a few weeks of emergence. Mature plants produce approximately 800 seeds, where competition is low and under ideal conditions plants can produce thousands of seeds. The

seeds have a hard coat and may remain dormant for 6-7 years in agricultural situations. Control measures should be aimed at preventing seed set and should preferably target seedlings as they emerge or very soon after emergence.

"Peach vine is our biggest problem, Roundup Ready herbicide is good to start with; later prometryn as a layby"

Bellvine is as difficult to control as cowvine, primarily for the same reasons. Bellvine, however, is a more aggressive climber and more competitive than cowvine and thus will have a greater impact on the yield of cotton. The control measures for both species is currently the same.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	Planting	Cotogard 4L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5 kg/ha Staple 120 g/ha over the top Two applications of Staple 60 g/ha for suppression
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide/shielded applications of Roundup Diuron 1.6 kg/ha Staple 60 g/ha 30% band 0.8 kg Diuron + 3 L/ha Stomp + 2.5 L/ha Geasagard Diuron + Zoliar
Cultivation	1-2 inter-row cultivations per season.	
Chipping	Manual chipping 1-2 times per season to control single plants, but can be really expensive for dense infestations.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants. MCPA after defoliation of cotton. Winter laybys of prometryn or Cotogard. Rotate into sorghum and control with Starane and Atrazine.
Cultivation	Cultivation can be effective for cowvine control when plants are young. Larger plants however, can become densely entangled in cultivation equipment, reducing the effectiveness of control and necessitating constant stoppages to clear the implement.

David's spurge (*Euphorbia davidii*)

Introduction

David's spurge is a recent incursion onto cotton farms, showing up in the lower Namoi and Gwydir regions. It is a very competitive, fast growing annual, capable of setting seed within a few weeks of emergence. David's spurge is tolerant of all herbicides currently used in production systems. The best results to date have been achieved using Roundup Ready technology.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Roundup Ready herbicide 1.5 kg/ha
	Planting	Roundup Ready herbicide 1.5 kg/ha
	In-crop	Roundup Ready herbicide 1.5 kg/ha
	Lay-by	Roundup Ready herbicide 1.5 kg/ha
Cultivation	Inter-row cultivation is effective in controlling plants in the furrows.	
Chipping	Chipping may be useful in controlling plants in small density stands, however most infestations become quite dense in a short period of time and hence manual chipping is not cost effective.	

Management in fallow situations

Herbicides	Roundup Ready herbicide has so far proved to be the most effective herbicide for controlling David's spurge. Bromoxynil and Paraquat may also provide effective control of this weed in fallow although reports have been conflicting.
Cultivation	Cultivation is effective for control.

Devil's claw

(*Martynia annua* and *Ibicella lutea*)

Introduction

The common name 'devil's claw' can be used to describe at least two species, these being *Martynia annua* and *Ibicella lutea*. The first is common in the Macintyre valley, with one grower describing his property as the *home of devil's claw*. The other can be found in the Namoi and Darling Downs and

is also known as yellow-flowered devil's claw. Both species germinate during spring and summer, with one grower stating that *devil's claw* (*Martynia annua*) is a really smart weed. It waits until it hears the rattle of the planter before it sticks its head up. Management of both species may be difficult.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadcast.
	Planting	Mixtures of Cotogard and Diuron, Cotoran and Diuron, with Stomp 3 L/ha
	In-crop	Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha. Cotoran (post cotton flowering) or Roundup applied through shields.
	Lay-by	Applications of Diuron. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Inter-row cultivation will remove plants that grow in the furrow.	
Chipping	Chipping will remove small numbers of plants, although on large infestations the cost can be prohibitive.	
Rotation crops	Starane 1 L/ha in sorghum crops.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will control this weed.

Downs nutgrass (*Cyperus bifax*)

Introduction

Downs nutgrass is an Australian native species and reproduces readily from seed. Downs nutgrass also produces a large number of viable nuts. Downs nutgrass is not as competitive as nutgrass, grows at a lower density and is more easily controlled than nutgrass.

"We have some anecdotal evidence that Staple also suppresses nutgrass. We only found that when chasing another weed. We have seen that it is useful on Downs nutgrass in particular." A comment from one consultant during meetings.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	2 L/ha Diuron flowable + 2.5 L/ha Trifluralin Zoliar 2.5-3.5 kg/ha mix with Trifluralin
	Planting	Roundup Ready herbicide 1.5 kg/ha Roundup 3 L/ha + total N or Safe N
	In-crop	Roundup Ready herbicide 1.5 kg/ha Semptra split applications 65g each time Shielded applications of Roundup 3 L/ha MSMA 800 2.8 L/ha directed spray
	Lay-by	Roundup Ready herbicide 1.5 kg/ha MSMA 800 2.8 L/ha directed spray
Cultivation	Spray prior to cultivating to reduce the spread of nutgrass. Cultivation is not generally recommended in-crop, as this is likely to spread the nuts, increasing the area of infestation.	
Chipping	Chipping is not recommended for dense infestations, however it may be useful to prevent the spread of single plant stands. It is essential to chip deeply enough to dig out the nuts and expose them to desiccation.	

Management in fallow situations

Herbicides	Roundup Ready herbicide 1.5 kg/ha Roundup 3 L/ha + total N or Safe N
Cultivation	Cultivation is very useful in fallow after the profile has been dried down and should be timed to occur in mid-summer and when there is little chance of rain. Deep cultivation will bring nuts to the surface where they will desiccate.

Fierce thornapple (*Datura ferox*)

(See page G2.13)

Introduction

Both fierce and common thornapple are annual species that grow vigorously over summer. Plants compete strongly with cotton plants, are allelopathic, and obstruct harvest machinery when left to grow unchecked. Seeds are able to germinate from depths of eight centimetres in the soil. These seeds are produced in summer and

autumn and are easily dispersed by machinery or irrigation water. The management of both species is similar. One consultant stated that *where there is Datura on farms, or on fields that have bad Datura problems, we use Staple. We believe it is most effective on that weed.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadacre or Diuron flowable 2 L/ha.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Staple 30–90 g/ha in the rows as a 50% band. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	The application of Roundup Ready herbicide applied at 1.5 kg/ha. Diuron flowable applied at 3.6 L/ha.
Cultivation	Cultivation removes the plants missed by herbicide applications.	
Chipping	Spot chipping should be used to remove small infestations of plants.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help prevent this weed.

Flax-leaf fleabane (*Conyza bonariensis*)

(See page G2.10)

Introduction

The fleabanes are newly emerging weeds of cotton and their presence is primarily thought to be due to changes in farming practices, most notably a reduction in conventional tillage operations. Once principally thought of as cool season weeds, the fleabanes are able to grow readily in warm to very warm conditions. Emergence however, is still restricted to cooler spring temperatures. Mature

plants may produce over 250 000 seeds per plant but these are generally short lived, with few surviving greater than one year. Most seeds are not able to germinate from deeper than one centimetre. The fleabanes are more easily controlled at the rosette stage, however, once main stem elongation begins to occur they are very difficult to control.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Roundup CT 3 L/ha Roundup Ready Herbicide 1.5 kg/ha (at the rosette stage only) Roundup 7-10 days prior to planting
	Planting	Roundup 3 L/ha Roundup Ready herbicide 1.5 kg/ha
	In-crop	Roundup (shielded spray) or Roundup Ready herbicide 1.5 kg/ha
	Lay-by	Roundup Ready herbicide 1.5 kg/ha
Cultivation	Inter-row cultivation may control small plants and burial of seed on the soil surface will prevent seed from germinating. Larger plants can be quite woody, with a deep robust taproot and may not necessarily be controlled by inter-row cultivation. Additionally, plants may break off close to the ground and re-grow.	
Chipping	Manual chipping is effective in control if the plants are very small. Unfortunately, many plants will set seed by the time chippers enter the field.	

Management in fallow situations

Herbicides	2,4-D amine or ester + Roundup Dicamba + Roundup
Cultivation	Cultivation is effective for control of fleabane in fallow situations.

Grey raspwort (*Haloragis glauca*)

Introduction

Both raspwort species are perennial, with stems that arise annually from a woody root system. The most common means of spread of these weeds is vegetative, with cultivation spreading root sections. Very few new plants arise from seed. The main growth period of the species is during spring and summer. Effective management is difficult to achieve, or as one grower stated *the Haloragis species are hard to control in cotton*.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

<i>Herbicides</i>	<i>Pre-plant</i>	Trifluralin 2.5 L/ha applied broadcast or Diuron flowable 2 L/ha.
	<i>Planting</i>	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	<i>In-crop</i>	Rough raspwort may be controlled with Roundup or mixtures of Roundup and Cotogard, or Roundup and Cotoran.
	<i>Lay-by</i>	Cotogard/Stomp or Diuron applications.
<i>Cultivation</i>	The raspweeds can be suppressed in the early stages by cultivation but, care is needed not to spread the weed via small root sections.	
<i>Chipping</i>	Chipping is ineffective in removing this weed, as rapid reshooting will occur.	

Management in fallow situations

<i>Herbicides</i>	Roundup, or Roundup and hormone mixtures are recommended at the end of cotton picking. Glean is a good option when used in a winter cereal rotation.
<i>Cultivation</i>	Broadacre cultivation will suppress this weed in the early stages, but care is needed not to spread this weed via small root sections.

Hairy wandering Jew (*Commelina benghalensis*)

Introduction

Both *Commelina* species are perennial weeds that can reproduce either from seed or vegetatively from transplanted sections of the adult plant. Flowering occurs anytime during the cotton season. The species are troublesome in channels and other wet areas. The weeds appear to be tolerant to glyphosate and are difficult to manage effectively.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Roundup after pre-watering. Trifluralin 2.5 L/ha applied broadacre or Diuron flowable 2 L/ha.
	Planting	A mixture of Cotogard and Stomp applied in a 40-50% band. Dual Gold applied at label rates.
	In-crop	Staple may reduce infestations of the weed. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Cotogard/Stomp or Diuron applications. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Cultivation may help remove plants in the furrows but care should be taken so as not to transplant sections of the plant.	
Chipping	The weed may be chipped, but care should be taken not to leave any section of the plant, including rhizome material, that may reshoot.	

Management in fallow situations

Cultivation	Broadacre cultivation may help remove plants but care should be taken so as not to transplant sections of the plant.

Liverseed grass

(*Urochloa panicoides*)

Introduction

Liverseed grass is an annual species that grows over spring and summer. The species spreads by producing a large number of seeds and is particularly troublesome for this reason.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

<i>Herbicides</i>	<i>Pre-plant</i>	Trifluralin 2.3–3 L/ha applied broadcast, or Stomp 3 L/ha.
	<i>Planting</i>	Mixtures of Cotogard and Stomp 3 L/ha, or Cotoran and Stomp 3 L/ha. Cotogard and Cotoran banded at 40%.
	<i>In-crop</i>	Selective grass herbicides such as Select, Sertin Plus or Verdict are useful to control this weed. Because these selective grass herbicides belong to herbicide group A, care should be taken to ensure resistance does not develop. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	<i>Lay-by</i>	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
<i>Cultivation</i>	Inter-row cultivation is effective for controlling plants in the furrows.	
<i>Chipping</i>	Chipping is effective in removing small numbers of plants, but the cost is prohibitive on large numbers of plants.	

Management in fallow situations

<i>Herbicides</i>	Selective grass herbicides as outlined above.
<i>Cultivation</i>	Broadacre cultivation will remove plants.

Mintweed

(*Salvia reflexa*)

Introduction

Mintweed is an annual plant that germinates from late winter through to summer and flowers from late spring onwards. Mintweed seeds profusely and this often results in dense stands, particularly under minimum tillage conditions. The weed is also very competitive and has been shown to be allelopathic. Mintweed is *bad on previous sheep country* and there is a *higher incidence in fields*

where there have been very poor Cotogard applications. The advent of Roundup Ready cotton has helped control this weed. For example, one consultant stated that *where we might have spent \$200 to \$300 a hectare on chipping for Mintweed...we put Roundup Ready in...and we might have spent \$20 a hectare.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadacre or Diuron flowable 2 L/ha.
	Planting	Stomp 2–3 L/ha. Some people recommend Dual Gold over applications of Stomp.
	In-crop	Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha. Staple appears to work particularly well, especially up to Christmas.
	Lay-by	Mixtures of Stomp with Cotogard, Cotoran and Diuron. A mixture of Dual and Cotoran was also recommended. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Mintweed is readily removed by cultivation, particularly in the furrow.	
Chipping	Manual chipping late in the season will help remove small infestations of mintweed.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Noogoora burr (*Xanthium occidentale*)

Introduction

In Australia there are four closely related species recognised by some taxonomists that form the Noogoora burr complex. Three of these are problematic within Australian cotton production systems. These are Noogoora burr (*Xanthium occidentale*), Italian cocklebur (*Xanthium italicum*) and Californian burr (*Xanthium orientale*). Control of the Noogoora burr complex is difficult, primarily due to the seed characteristics of the species. High numbers of seeds are often produced (greater than (See page 208) 1000 seeds per plant and up to 11 000 for some individuals) that may remain viable for up to 20 years, although in agricultural situations less than 1% of seeds usually remain after six years. Further complicating the control of Noogoora burr is the ability of some seeds to produce a second seedling in the year following primary germination. Seeds are generally quite large and have relatively large energy reserves. This enables seedlings to emerge

from quite deep, often below herbicide layers, resulting in poor control of the seedlings. Additionally, the nature of cotton production, results in the provision of ideal germination conditions (optimum moisture conditions, elevated temperatures and an adequate supply of nutrients) on a number of occasions throughout the season, resulting in several germination flushes. Pre-plant and pre-emergent herbicides break down over time, and therefore the protection offered by these herbicides is often insufficient to prevent some seedlings from emerging, hence the necessity of chipping.

It is essential that control measures are aimed at preventing seed set. Seeds remain viable for long periods of time (up to 20 years) and are easily transported by water thus they can infest large areas very quickly.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	2 L/ha Diuron flowable + Trifluralin 2.5 L/ha
	Planting	2-3 L/ha Stomp + Roundup Ready herbicide Cotoran/Cotogard 4 L/ha in a 40% band + 3 L/ha Stomp Dual Gold 1 L/ha + Cotogard 3.5 L/ha
	In-crop	2 applications of 1- 1.5 kg/ha Roundup Ready herbicide MSMA 800 2.8 L/ha Staple 120 g/ha
	Lay-by	Roundup Ready herbicide 1.5 kg/ha Cotogard 2.5 L/ha+ Stomp Diuron 3.6 L/ha + Stomp
Cultivation	1-2 inter-row cultivations per season	
Chipping	Manual chipping is essential to control burrs in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 2-3 L/ha on small plants
Cultivation	Cultivation is very effective for burr control when plants are young.

Nutgrass (*Cyperus rotundus*)

Introduction

Nutgrass is one of the major weeds infesting cotton fields in the eastern parts of Australia and indeed throughout many cotton production systems worldwide. It is a very aggressive competitor and to date has proven very difficult to control. A comprehensive article on the management of nutgrass has been included in WEEDpak (See section H3). Nutgrass is a perennial species that forms underground nuts contributing to its success as a weed. These nuts are a reserve of carbohydrates that provide energy for the plant to re-shoot after its dormant winter

period. The nuts, however, also provide energy for re-growth following herbicide applications and consequently numerous herbicide applications and other management techniques may be required to deplete the carbohydrate reserve. Additionally, the efficacy of herbicides applied for nutgrass control appear to be humidity and temperature dependent. The stomata (small openings on the surface of the leaf, which control water flow through the plant) close when temperatures are elevated or humidity is low, reducing the uptake of herbicides.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	2 L/ha Diuron flowable + 2.5 L/ha Trifluralin Zoliar 2.5-3.5 kg/ha mix with Trifluralin
	Planting	Roundup Ready herbicide 1.5 kg/ha Roundup 3 L/ha + total N or Safe N
	In-crop	Roundup Ready herbicide 1.5 kg/ha Sempra split applications 65g each time Shielded applications of Roundup 3 L/ha MSMA 800 2.8 L/ha directed spray
	Lay-by	Roundup Ready herbicide 1.5 kg/ha MSMA 800 2.8 L/ha directed spray
Cultivation	Spray prior to cultivating to reduce spread of nutgrass. Cultivation is not generally recommended in-crop, as this is likely to spread the nuts, increasing the area of infestation.	
Chipping	Not recommended for dense infestations, however may be useful to prevent spread of single plants. It is essential to chip deeply enough to dig out the nuts and expose them to desiccation.	

Management in fallow situations

Herbicides	Roundup Ready herbicide 1.5 kg/ha Roundup 3 L/ha + total N or Safe N
Cultivation	Cultivation is very useful in fallow after the profile has been dried down and should be timed to occur in mid-summer and when there is little chance of rain. Deep cultivation will bring nuts to the surface where they will desiccate.

Perennial ground cherry (*Physalis virginiana*)

(See page G2.1)

Introduction

Wild gooseberry is an Australian native species belonging to the tomato family. It grows very rapidly during the summer months, producing up to 20 000 seeds per plant. Annual ground cherry is a native of south America and is used as a food source in Mexico. The two species are very difficult to tell apart, however the fruits of annual ground cherry are circular in cross section and

tend to be sticky. Very little is known about the seed biology of these species, particularly in Australian cotton production systems. The perennial ground cherry is similar in appearance to the two species already mentioned, however it has an extensive root system from which new plants develop for many seasons.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	Planting	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5 kg/ha Staple 60 g/ha 30% band
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide Diuron 1.6 kg/ha
Cultivation	1-2 inter-row cultivations per season.	
Chipping	Manual chipping is essential to control <i>Physalis</i> in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants.
Cultivation	Cultivation is very effective for <i>Physalis</i> control when plants are young. A cautionary approach needs to be adopted when using cultivation as a control method, for perennial ground cherry as small plant sections are capable of establishing elsewhere in the field. Cultivation should only be used when the soil is dry, to prevent the spread of this weed.

Pigweed

(*Portulaca oleracea*)

Introduction

Pigweed can be an annual or perennial species. Mature seed shed during autumn aids in the spread of the weed. Small sections of the stem are also readily broken off and transplanted elsewhere (vegetative reproduction). Pigweed is difficult to control and appears to be Roundup tolerant to some degree. One consultant stated that *in dryland cotton it is particularly bad because it makes the ground so hard that you cannot cultivate it out.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 3 L/ha and Diuron are recommended. Roundup mixtures with Cotogard, Cotoran and Diuron.
	Planting	Stomp 2–3 L/ha.
	In-crop	Roundup Ready herbicide 1.5 kg/ha
	Lay-by	Diuron 1.4 L/ha.
Cultivation	Care should be taken with cultivation not to transplant segments of the plant.	
Chipping	Chipping may be of some use in removing small numbers of this weed.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Care should be taken with cultivation not to transplant segments of the plant.

Polymeria annual

(Polymeria pusilla)

Introduction

Despite its name, annual polymeria is in fact a perennial species. The plant grows over the summer and often forms small circular patches. It may be difficult to manage in cotton crops but as one consultant stated *Staple gets it very early when it is young.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadcast or Diuron flowable 2 L/ha.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Staple 90 g/ha on young plants. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Mixtures of Cotogard and Roundup are effective.
Cultivation	Inter-row cultivation will help remove plants that grow in the furrow.	
Chipping	Chipping will help remove small numbers of this plant.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Prickly paddy melon (*Cucumis myriocarpus*)

Introduction

Prickly paddy melon is an annual species that germinates after summer rains and grows rapidly thereafter. It appears to be difficult to control, with one respondent stating that *it is a weed that is increasing in numbers*.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha. Roundup 3-4 L/ha + Goal 75 mL/ha. Roundup Ready herbicide 1 kg/ha .
	Planting	Cotogard 4 L/ha on a 40% band. 40% band Cotogard/Cotoran + 3 L/ha Stomp. Roundup Ready herbicide 1.5 kg/ha.
	In-crop	Shielded applications of Roundup are effective on larger plants. Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops.
	Lay-by	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Plants may be removed by inter-row cultivation.	
Chipping	Small numbers of plants may be removed by chipping.	

Management in fallow situations

Herbicides	The application of Roundup and Garlon in cotton areas is effective on larger plants.
Cultivation	Broadacre cultivation is an effective means of controlling the weed, but care needs to be taken that seeds are not spread when stems with mature fruit attached become caught around cultivation tines.

Rhynchosia

(*Rhynchosia minima*)

Introduction

Rhynchosia is a twining perennial plant that is a particularly troublesome in winter and summer. Seeds often germinate in summer after rain, and plants grow rapidly, producing many further seeds. Rhynchosia is difficult to control in both irrigated and dryland summer cropping and in fallow situations. One grower stated that rhynchosia is *never totally controlled, but is kept at manageable levels* by the in-crop (cotton) management program outlined below.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	A knockdown application of Goal and Roundup.
	Planting	Cotogard 4 L/ha.
	In-crop	Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	Lay-by	Diuron 1.6 kg/ha.
Cultivation	Cultivation will help remove plants in the furrows.	
Chipping	Chip for <i>rhynchosia</i> one to two times per season for good control.	

Management in fallow situations

Herbicides	To control rhynchosia in fallow situations or post-harvest (cotton), mixtures of glyphosate, or Express at 20g/ha and glyphosate were suggested. Another consultant suggested using either Starane or high rates of Roundup to control the problem.
Cultivation	Broadacre cultivation will help control this weed.

Rough raspwort/Raspweed (*Haloragis aspera*)

(See page G2.21)

Introduction

Both raspwort species are perennial, with stems that arise annually from a woody root system. The most common means of spread of these weeds is vegetative, with cultivation spreading root sections. Very few new plants arise from seed. The main growth period of the species is during spring and summer. Effective management is difficult to achieve, or as one grower stated *the Haloragis species are hard to control in cotton*.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Trifluralin 2.5 L/ha applied broadcast or Diuron flowable 2 L/ha.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Rough raspwort may be controlled with Roundup or mixtures of Roundup and Cotogard, or Roundup and Cotoran.
	Lay-by	Cotogard/Stomp or Diuron applications.
Cultivation	The raspweeds can be suppressed in the early stages by cultivation, but care is needed not to spread the weed via small root sections.	
Chipping	Chipping is ineffective in removing this weed, as rapid reshooting will occur.	

Management in fallow situations

Herbicides	Roundup, or Roundup and hormone mixtures are recommended at the end of cotton picking. Glean is a good option when used in a winter cereal rotation.
Cultivation	Broadacre cultivation will suppress this weed in the early stages, but care is needed not to spread this weed via small root sections.

Scurvy weed/Wandering Jew (*Commelina cyanea*)

(See page G2.22)

Introduction

Both *Commelina* species are perennial weeds that can reproduce either from seed or vegetatively from transplanted sections of the adult plant. Flowering occurs anytime during the cotton season. The species are troublesome in channels and other wet areas. The weeds appear to be tolerant to glyphosate and are difficult to manage effectively.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

<i>Herbicides</i>	<i>Pre-plant</i>	Roundup after pre-watering. Trifluralin 2.5 L/ha applied broadcast or Diuron flowable 2 L/ha.
	<i>Planting</i>	A mixture of Cotogard and Stomp applied in a 40-50% band. Dual Gold applied at label rates.
	<i>In-crop</i>	Staple may reduce infestations of the weeds. Two Roundup Ready herbicide sprays in Roundup Ready crops 1.5 kg/ha.
	<i>Lay-by</i>	Cotogard/Stomp or Diuron applications. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
<i>Cultivation</i>	Cultivation may help remove plants in the furrows but care should be taken so as not to transplant sections of the plant.	
<i>Chipping</i>	The weed may be chipped, but care should be taken not to leave any section of the plant, including rhizome material, that may reshoot.	

Management in fallow situations

<i>Cultivation</i>	Broadacre cultivation may help remove plants but care should be taken so as not to transplant sections of the plant.

Spineless caltrop/Yellow vine (*Tribulus micrococcus*)

Introduction

Caltrop is an annual or perennial plant that has successive germinations after rainfall or irrigation. It grows rapidly during the cotton season, producing burrs and a deep root system in a short time. Burr production continues throughout summer and autumn, and the seeds are often spread on machinery or shoes. Management of this weed is far easier than caltrop (*Tribulus terrestris*), with one grower stating that *we will put Stomp down...anywhere there is Yellow vine and we find that it works pretty well.*

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Stomp in a planting band or broadacre application. Trifluralin is substituted for Stomp in some cases.
	Planting	Cotogard 4 L/ha with Stomp 3 L/ha.
	In-crop	Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops. Roundup applied in shielded sprayers.
	Lay-by	Diuron flowable 3.6 kg/ha. Mixtures of Diuron 0.8 kg/ha, Stomp 3L/ha and Gesagard 2.5 L/ha Cotogard 1–1.3 kg/ha, and Cotogard and Diuron mixtures. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Inter-row cultivation will help remove plants that grow in the furrow.	
Chipping	Plants may be chipped, but care should be taken to remove as much taproot as possible to prevent plant regrowth.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation will help to control this weed.

Swamp Chinese lantern/Velvetleaf (*Abutilon theophrasti*)

Introduction

Swamp Chinese lantern/Velvetleaf is an annual species that germinates throughout the cotton season and produces seeds from mid-December. Seeds are readily spread in irrigation water or via overland flows, and probably on machinery. The weed is a large problem in summer cropping in the USA but is, as yet, isolated in distribution in NSW. One consultant stated that *it is only sticking its*

head up a little bit now. We use spot chipping and it is not a huge concern. An investigation into the biology and management of swamp chinese lantern is currently in progress. Contact Stephen Johnson at ACRI for further information. Other details on the importance of farm hygiene in managing this weed can be found in the case study (Section F2).

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Glyphosate applied as a broadacre application.
	Planting	Cotogard or Cotoran 4 L/ha with Stomp 3 L/ha.
	In-crop	Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops.
	Lay-by	Roundup Ready herbicide and Cotogard applied at 2.5 L/ha. Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Care should be taken when cultivating through swamp Chinese lantern patches so as not to spread seeds of this weed.	
Chipping	Chipping can be used to effectively control small infestations in crop. A late or spot chip should be used to remove any large plants late in the season.	
Farm hygiene	Good farm hygiene is required to prevent swamp Chinese lantern from spreading. For example, storages and channel banks should be kept free of the weed to prevent the spread of seeds in irrigation water.	

Management in fallow situations

Herbicides	High rates of Roundup Ready herbicide, or a mixture of glyphosate applied at 1.5 L/ha mixed with 2,4-D amine applied at 2.4 L/ha with added wetter are effective. The wetter is needed to ensure adequate penetration of the herbicide mixture into the large hairy/velvet-like leaves.
Cultivation	Care should be taken with cultivation through swamp Chinese lantern patches so as not to spread seeds of this weed.

Wild gooseberry/Chinese lantern (*Physalis minima*)

(See page G2.1)

Introduction

Wild gooseberry is an Australian native species belonging to the tomato family. It grows very rapidly during the summer months, producing up to 20 000 seeds per plant. Annual ground cherry is a native of south America and is used as a food source in Mexico. The two species are very difficult to tell apart, however the fruits of annual ground cherry are circular in cross section and

tend to be sticky. Very little is known about the seed biology of these species, particularly in Australian cotton production systems. The perennial ground cherry is similar in appearance to the two species already mentioned, however it has an extensive root system from which new plants develop for many seasons.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha Roundup 3-4 L/ha + Goal 75 mL/ha Roundup Ready herbicide 1.0 kg/ha
	Planting	Cotogard 4 L/ha on a 40% band 40% band Cotogard/Cotoran + 3 L/ha Stomp Roundup Ready herbicide 1.5 kg/ha
	In-crop	Two applications of Roundup Ready herbicide 1.5 kg/ha Staple 60 g/ha 30% band
	Lay-by	Gesagard 3 L/ha 1.5 kg/ha Roundup Ready herbicide Diuron 1.6 kg/ha
Cultivation	1-2 inter-row cultivations per season.	
Chipping	Manual chipping is essential to control <i>Physalis</i> in the plant line and prevent replenishment of seeds into the soil seed bank.	

Management in fallow situations

Herbicides	Roundup 3-4 L/ha + Goal 75 mL/ha on small plants.
Cultivation	Cultivation is very effective for <i>Physalis</i> control when plants are young. A cautionary approach needs to be adopted when using cultivation as a control method for perennial ground cherry, as small plant sections are capable of establishing elsewhere in the field. Cultivation should only be used when the soil is dry, to prevent the spread of this weed.

Wild melon

(*Citrullus lanatus* var. *lanatus*)

Introduction

Wild melon is an annual species that germinates after rainfall and irrigation, and grows rapidly over summer. The melons are produced from summer onwards and the seeds are readily dispersed in water, by wind or on machinery. The species is commonly found along channels.

Disclaimer: This section contains recommendations from consultants and growers and may include off-label uses that are not endorsed by the Australian Cotton CRC.

Management in cotton crops

Herbicides	Pre-plant	Diuron 3 L/ha + Trifluralin 2.3 L/ha. Roundup 3-4 L/ha + Goal 75 mL/ha. Roundup Ready herbicide 1 kg/ha .
	Planting	Cotogard 4 L/ha on a 40% band. 40% band Cotogard/Cotoran + 3 L/ha Stomp. Roundup Ready herbicide 1.5 kg/ha.
	In-crop	Staple 120 g/ha on young seedlings. Shielded applications of Roundup on larger plants. Two Roundup Ready herbicide sprays 1.5 kg/ha in Roundup Ready crops.
	Lay-by	Roundup Ready herbicide 1.5 kg/ha in Roundup Ready crops.
Cultivation	Plants may be removed by inter-row cultivation.	
Chipping	Small numbers of plants are easily removed by chipping.	

Management in fallow situations

Herbicides	Many of the above options are relevant for fallow applications.
Cultivation	Broadacre cultivation is an effective means of controlling the weed, but care needs to be taken that seeds are not spread when stems with mature fruit attached become caught around cultivation tines.

MANAGING PROBLEM WEEDS

Introduction

While all weeds that occur in cotton are problems that must be dealt with, some weeds are far more difficult to control than others. Nevertheless, most of these difficult weeds can be adequately managed in the cotton farming system with an integrated management system, using herbicides, cultivation and chipping in conjunction with other management tools. These weeds are often problems in newly developed cotton blocks, but become less of a problem over time. However, there is a group of problem weeds that are not controlled with normal farming practices. These weeds can spread and become progressively worse year after year, in spite of the cotton grower's efforts.

Specific management strategies are required to manage these problem weeds.

Contents:

H2. Managing Cowvine in Cotton

H3. Managing Nutgrass in Cotton

H4. Managing Polymeria (Take-all) in Cotton

H5. Managing Bellvine in Cotton

H6. Managing Caustic Weed in Cotton

H7. Managing Mintweed in Cotton

H8. Managing Lippia in the Cotton Farming System

H9. Managing Flaxleaf Fleabane in Cotton

H2. Managing Cowvine in Cotton

Cowvine is an annual weed that is a problem both in crops and in fallows. It is not easy to control in a farming system due to a number of characteristics including: strong seed dormancy; long seed life in the seedbank; ability to germinate rapidly after rain, all year round; rapid seedling growth; and a twining growth habit.

Post-emergence applications of diuron and prometryn consistently give the best control of cowvine of the herbicides normally used in cotton. Glyphosate can be effective in controlling cowvine seedlings in conventional and Roundup Ready cotton. Glyphosate is most effective on actively growing cowvine seedlings. Good control of older, actively growing plants is possible with glyphosate.

An effective cowvine management system will use all the available control options (cultivation, chipping and herbicides) in combination. Management of this weed will be an on-going process over many seasons.

H3. Managing Nutgrass in Cotton

Eight different nutgrass species are commonly found in or around cotton fields. These species are quite different in their ability to spread from seed or rhizomes, and consequently require specific management strategies. Positive identification of the problem species is essential as the first step in management. Identification material for these species is given.

A range of management tools is available to manage these weeds. These tools include residual and contact herbicides, cultivation, and crop competition. There are also some management practices that can exacerbate a nutgrass problem and should be avoided whenever possible. Management of nutgrass needs a long-term approach, as these weeds will not be eliminated by any single management option. A successful management program will include all the management tools, used in combination as opportunity arises.

Glyphosate and Zoliar® herbicides have given the most effective control over time. Glyphosate should ideally be applied in-crop twice each season. Attention to machinery hygiene can be pivotal in a successful management program.

H4. Managing Polymeria (Take-all) in Cotton

Polymeria is a deep rooted, rhizomatous, perennial weed that spreads from seeds and rhizomes. It tolerates and can be spread by normal cultivation practices.

No herbicides are registered for controlling polymeria. A permit must be obtained from the Australian Pesticides & Veterinary Medicines Authority before using a herbicide to control polymeria in any situation.

Polymeria can best be managed in cotton with repeated applications of glyphosate on actively growing polymeria, applied through well constructed shields, used under appropriate conditions. Glyphosate should be spot-applied to the polymeria patches to improve crop safety. The addition of Pulse Penetrant or a non-ionic surfactant may improve spray efficacy. Good crop agronomy is also important, resulting in competitive, strong cotton.

Polymeria growing in fallow can be controlled with glyphosate on actively growing patches and with fluroxypyr (eg. Starane) in autumn. Grazon may be useful for controlling polymeria in fallows that are not going back to cotton. Imazapyr (eg. Arsenal) may be useful for controlling polymeria on non-cropping and waste areas.

H5. Managing Bellvine in Cotton

Bellvine is an annual weed that is difficult to control in cotton. It is an aggressive, highly competitive weed that can grow through and over a cotton crop and can tangle inter-row and harvesting equipment. Very high densities of bellvine seedlings can emerge with the cotton crop, and successive germinations may occur throughout the season.

None of the pre-emergence residual herbicides were effective in controlling bellvine. Best results were achieved with trifluralin, diuron and Zoliar. The 4-leaf stage Roundup Ready Herbicide application was effective in controlling bellvine seedlings in Roundup Ready cotton. Moderate infestations of bellvine can be managed with the combination of pre-planting residuals and in-crop applications of Roundup.

Directed applications of diuron and prometryn were relatively effective in controlling bellvine seedlings later in the season in-crop. Both mid-season and lay-by applications of residuals may be required in combination with the 4-leaf Roundup Ready Herbicide application to control bellvine in a heavy infestation. Directed applications of Roundup were not effective in controlling bellvine seedlings later in the season.

An effective bellvine management system will use all the available control options (cultivation, chipping, herbicides, rotation and fallows) in combination, with both contact and residual herbicides used in-crop.

Note. Roundup Ready Herbicide is not registered for controlling bellvine in cotton.

H6. Managing Caustic Weed in Cotton

Caustic weed is an annual weed of cotton that competes for nutrients and water, and at high densities can reduce yields. It is a persistent weed that may become more problematic in reduced input systems.

Stomp and diuron gave the best control of the residual herbicides, with diuron giving good post-emergence control as well as some pre-emergence control of caustic weed. Glyphosate (Roundup CT) also gave good post-emergence control of caustic weed in an irrigated field.

An integrated weed management system including inter-row cultivation, residual herbicides and glyphosate should effectively control this weed. A mid-season directed application of diuron may be a useful tool in fields where no pre-planting residual herbicides are used.

H7. Managing Mintweed in Cotton

Mintweed is a minor annual weed of cotton that can emerge in large numbers at or soon after crop emergence. Mintweed seedlings grow more rapidly than cotton seedlings in spring conditions and can compete for sunlight, nutrients and water.

A pre-planting combination of Dual and Diuron gave the best residual control of mintweed. Atrazine and simazine also gave good residual control of mintweed, although they can not be safely used in cotton.

Glyphosate gave good post-emergence control of mintweed in cotton, and should be an effective management option for this weed in Roundup Ready Flex cotton crops.

H8. Managing Lippia in the Cotton Farming System

Lippia is a highly undesirable, invasive weed that is negatively impacting the grazing industry and the riparian zone. Once established, lippia competes very strongly with all other species, often resulting in almost pure lippia stands. Lippia should not be allowed to establish in the cotton industry. Particular care must be taken to ensure that lippia doesn't establish on irrigation structures as its presence is likely to lead to the failure of these structures.

Lippia should be controlled with cultivation where appropriate, or repeated applications of Lantana 600 on non-crop areas, or glyphosate on fallows. Glyphosate plus metsulfuron is the preferred option on fallows on non-alkaline soils, where cotton will not be a following crop.

2,4-D amine may be used to control lippia in pastures provided that there is no risk of spray drift to sensitive crops such as cotton.

H9. Managing Flaxleaf Fleabane in Cotton

The success of fleabane in the cotton system can be attributed to its ability to emerge in different seasons, relative tolerance to glyphosate and its prolific fecundity. Flaxleaf fleabane seedlings can establish in fallows and under crops at any time of year, running up to head in the warmer months. This weed is most problematic in zero-tillage situations.

A long term (2 - 3 years), whole farm, integrated approach is needed for its effective control. It can be controlled using a combination of contact and residual herbicides, together with crop competition, cultivation and spot-spraying. Control can be improved by using a double-knock approach. The best control was observed with a tank-mix of glyphosate and Tordon 75-D followed by Spray.Seed (double-knock) in combination with a residual herbicide. However, Tordon 75-D can't be used in or around cotton.

The cotton herbicides, diuron, prometryn and Convoy all gave effective residual control of fleabane and could be used in cotton in combination with cultivation.

Fleabane should be managed in all crop and fallows as well as non-crop areas, such as roads, irrigation channels and fence lines, to prevent re-infestation into the cropping area.

MANAGING COWVINE IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
The morning glory family in cotton	H2.1
The cowvine plant	H2.1
Strategies for managing cowvine	H2.3
Herbicides for controlling cowvine	H2.3
Residual herbicides for cowvine control in cotton	H2.4
Post-emergence control of cowvine with residual herbicides in cotton	H2.5
Controlling cowvine with non-residual herbicides	H2.6
Herbicide combinations for controlling cowvine in cotton	H2.8
Alternative residual herbicides for managing cowvine in fallows and rotation crops	H2.10
Managing cowvine in the farming system	H2.11
Summary	H2.12

The morning glory family

Cowvine (*Ipomoea lonchophylla*), also known as peachvine, is a member of the Convolvulaceae family. It is a native Australian plant, closely related to sweet potato (*Ipomoea batatas*). Other morning glories that are problems in cotton include bellvine (*Ipomoea plebeia*) and common morning glory (*Ipomoea purpurea*).

The cowvine plant

Cowvine is a common weed throughout the cotton industry, although it tends to be a far bigger problem in some areas than others.

Cowvine is an annual weed that grows over the warmer months. Seedlings emerge all year round following rain, but are killed by frosts. A flush of cowvine seedlings normally occurs after every rainfall and irrigation event, even in mid-winter.

Cowvine seedlings have unusual, very strongly lobed, "V" shaped cotyledon leaves. The plant is easily identified from the cotyledon shape at this stage. Seedlings grow rapidly after emergence during warm weather, and develop long, twining branches. Large plants may be 3 or 4 m in diameter. Flowering can start early in plant growth, when plants have only 2 or 3 true leaves. Under

hot conditions, flowering can commence within a week of seedling emergence. Flowers continue to be produced throughout the plant's life. Three or four seeds are produced in each seed capsule.

Observations on small and larger plants found 206 seeds on a cowvine plant 0.2 m in diameter, and 791 seeds on a plant 2.8 m in diameter. Larger and older plants could produce many more seeds.



Cowvine is a member of the morning glory family. It is a vine weed, which can be a major problem in cotton, tangling amongst cotton plants, causing problems for inter-row cultivation and harvesting machinery.

Cowvine seeds have a strong dormancy mechanism and can remain viable in the soil for many years (Table 1).

Table 1. Emergence of cowvine seeds grown in a glasshouse at 15 – 35 °C.

Seed age at planting	Emergence %			
	0 - 100 days	100 - 300 days	300 - 600 days	600 - 900 days
Fresh	9	0	0	1
58 days	14	3	1	5
1 year	5	25	13	10
3 years	6	21	16	2

Large numbers of cowvine seeds may be present in the soil seedbank. Soil cores on a heavily infested field found between 1000 and 2500 cowvine seeds/m² in the 0 - 30 cm soil zone. Seeds occur predominantly in the 0 - 30 cm soil zone (80%) in a cultivated field, corresponding to the plow-zone, although some seeds were found down to 1 metre (Table 2).

Table 2. Distribution of cowvine seeds in the soil. Samples were taken from the hill and furrow areas of an irrigated cotton field.

Soil depth zone	Distribution %	
	Hill	Furrow
0 - 10 cm	40	50
10 - 20 cm	24	18
20 - 30 cm	16	11
30 - 40 cm	0	4
40 - 50 cm	4	4
50 - 100 cm	16	13

Few cowvine seeds are able to emerge from more than 5 cm depth in the soil, although a small proportion may emerge from as deep as 15 cm (Table 3).

Table 3. Cumulative emergence of cowvine seedlings from seeds placed at varying depths in the soil. Seeds were mechanically scarified to promote germination.

Soil depth	Emergence %		
	1 month	6 months	1 year
0 cm	25	25	30
1 cm	30	35	60
2 cm	45	50	50
3 cm	35	50	50
4 cm	30	50	55
5 cm	5	5	20
7.5 cm	0	0	0
10 cm	0	0	10
15 cm	0	5	5
20 cm	0	0	0

Cowvine seedlings are slow to emerge from depth and will be vulnerable to cultivation and drying cycles. Seeds may also emerge through soil cracks, or emerge after re-distribution in the soil profile following deep cultivation or re-listing of a field as these seeds may remain viable in the soil for many years. Seed samples taken from the 10-20 cm and 20-30 cm soil zones of a heavily infested field had similar viability to seeds from the 0-10 cm soil zone, showing that these seeds were viable and seedlings could emerge if opportunity arose.

This distribution of seeds in the soil profile means that less than 25% of the cowvine seeds present in an infested field are likely to germinate at any one time. In a field infested with 1500 seeds/m² for example, this would equate to less than 375 seedlings/m² being able to emerge at any time. However, far fewer than 375 seedlings actually emerge due to the strong seed dormancy characteristic already discussed. Population dynamics and seed density from a typical irrigated cotton field are shown in Figure 1.

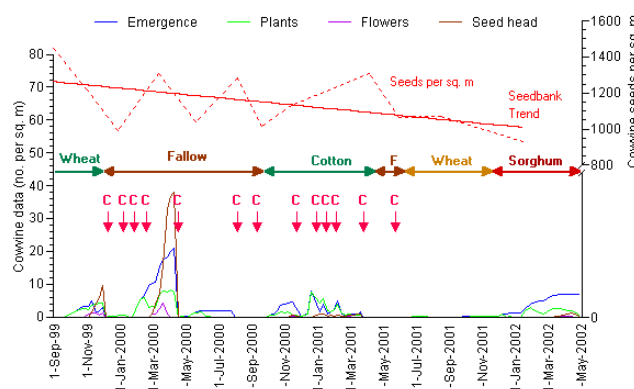


Figure 1. Population dynamics of cowvine in an irrigated cotton field. The cropping sequence over the 3 seasons is indicated. The sorghum crop was grown to allow the use of atrazine herbicide to manage the cowvine problem. Cultivation events are indicated by a "C" with an arrow.

In this field (Figure 1), the density of cowvine seeds in the soil (0 - 30 cm zone), decreased by 36% (or 12% per year), from 1447 to 930 seeds/m² over the three seasons. A total of only 62 cowvine seedlings emerged during this time. The remaining seeds were lost through predation by insects and microbial breakdown. The highest level of emergence was 22 seedlings/m², in the cotton crop in mid-December, 2000. The cowvine plants that established from these seedlings produced a total of 176 new seeds/m² over the three seasons, with most seeds produced during a summer fallow in March and April 2000.



Strategies for managing cowvine

Small cowvine plants are readily controlled by shallow cultivation (to 5 cm) and herbicides in fallows, cereal and sorghum crops, but can be difficult to control in broad-leaf crops such as cotton.

The primary difficulty with managing cowvine, both in-crop and in-fallow, is the tendency for small numbers of cowvine seedlings to emerge continuously, all year round, when soil moisture is adequate, coupled with a short generation period and strong seed dormancy. While a single generation of cowvine seedlings can easily be managed in most situations, most growers find it difficult to manage new germinations every few weeks throughout the summer. In the example of Figure 1, the field was cultivated 5 times over 4 months, between December 1999 and April 2000, yet cowvine plants still established and produced 38 new seeds/m² during this period. Cowvine was a problem in all cropping phases in this field (cotton, wheat and sorghum), as well as in the fallow.

Consequently, while cowvine can be managed with shallow cultivation or non-residual herbicides alone, an integrated approach, using cultivation, non-residual and residual herbicides in combination is necessary for managing this weed. The use of more disruptive, deep cultivation is problematic, as it will bury many of the cowvine seeds already at the soil surface, but may also bring up large numbers of viable seeds that were previously too deeply buried to be of any importance.

The aim of all management programs must be to reduce the size of the cowvine seedbank by ensuring that cowvine plants are always controlled before they produce viable seed.

Herbicides for controlling cowvine

A wide range of herbicides and herbicide combinations were assessed on cowvine growing in a fallow situation in autumn 2000. Many of these herbicides could not be used in cotton, but might be used in fallow or rotation crops. The herbicides were applied to emerged cowvine plants.

The best post-emergence control was observed with Atrazine, Diuron, Gesagard, Simazine, Basta and Oxytril (Table 4), and herbicide combinations that included these herbicides (Table 5). Of these herbicides, only diuron and prometryn can be safely used in cotton. Atrazine and simazine may be used with some rotation crops.

Table 4. Percentage kill of cowvine plants that emerged on the border of a field following rain in March 2000. Control was assessed on May 1, 28 days after spraying.

Treatment	% Weed kill
Diuron 1 L/ha	100
Oxytril 2.0 L/ha	100
Oxytril 1.0 L/ha	97
Diuron 2 L/ha	97
Atrazine 4 L/ha	97
Atrazine 2 L/ha	97
Basta 2.0 L/ha	93
Grazon 1.0 L/ha	90
Oxytril 0.5 L/ha	90
Gesagard 1 L/ha	87
Gesagard 2 L/ha	87
Simazine 2L/ha	80
Basta 1.0 L/ha	80
Basta 0.5 L/ha	63
Grazon 0.25 L/ha	57
Roundup CT 4 L/ha	53
Simazine 1L/ha	50
Starane 1.0 L/ha	43
Grazon 0.5 L/ha	40
Zoliar 1.5 kg/ha	30
MSMA (800 g/L) 2 L/ha	27
Roundup CT 2 L/ha	20
Starane 0.25 L/ha	20
Starane 0.5 L/ha	20
MSMA (800 g/L) 1 L/ha	7
Untreated	7

Note. Cowvine seedlings emerged over the following weeks and a range of ages and sizes were present at spraying, most plants were between 2 leaves and 60 cm in diameter. Most plants were actively growing but some were moisture stressed at the time of spraying on April 3.

Table 5. Percentage kill of cowvine plants in a fallow using herbicide combinations. Details are given in Table 4.

Treatment	% Weed kill
Basta 1 L + Diuron (800 g/L) 2 L/ha	97
Diuron 2 L + MSMA 1 L/ha	97
Gesagard 1 L + Grazon 100 ml/ha	97
Gesagard 2 L + MSMA 1 L/ha	93
Basta 0.5 L + Gesagard 1 L/ha	90
Roundup CT 2 L + Diuron 2 L/ha	90
Basta 1 L + Grazon 100 ml	87
Roundup CT 2 L + Gesagard 2 L/ha	87
Basta 1 L + Zoliar 1 kg/ha	80
Zoliar 1 kg + Grazon 100 ml/ha	23
Zoliar 1 kg + Starane 0.25 L/ha	17
Roundup CT 1 L + Grazon 100 ml/ha	13
Untreated	7

Atrazine was used in the sorghum crop shown in Figure 1. The grower was very satisfied with the resulting control of cowvine, although some cowvine seedlings still emerged, grew and set seed. Cotton growers should always be aware of the plant-back from these products to cotton. Atrazine, in particular, has a very slow breakdown rate in dry soils, and can persist for long periods in dry conditions.



A fallow field heavily infested with cowvine and bladder ketmia. The cowvine plants were very small (below) but some had already flowered and set seed.



Residual herbicides for cowvine control in cotton

While diuron and prometryn are effective in controlling cowvine post-emergence, none of the residual herbicides that can be used in cotton were effective in controlling cowvine pre-emergence. Gesagard, trifluralin and diuron have some residual pre-emergent activity on cowvine but a high proportion of cowvine seedlings still emerged through maximum label rate applications of these herbicides (Table 6).

Table 6. Cumulative emergence of cowvine seedlings following applications of pre-emergent herbicides in pots.

Treatment	Emergence %		
	4 weeks	8 weeks	12 weeks
Gesagard 4.5 L/ha	18%	20%	20%
Trifluralin 2.8 L/ha	22%	27%	28%
Diuron 3.5 L/ha	22%	28%	29%
Dual 2 L/ha	27%	32%	33%
Cotoran 5.6 L/ha	29%	30%	31%
Zoliar 2 kg/ha	31%	34%	36%
Zoliar 4 kg/ha	31%	34%	36%
Cotogard 5 L/ha	31%	34%	38%
Stomp 3 L/ha	41%	43%	45%
Untreated	30%	32%	34%

Not all seedlings that emerge survive, even in the absence of herbicides. Zoliar didn't affect the emergence of cowvine seedlings, but did reduce the survival of the seedlings after emergence, killing around 64% of emerged seedlings soon after emergence (Table 7). However, the efficacy of Zoliar is highly affected by soil moisture level. Consequently, its effectiveness in the field is likely to be quite variable, depending on the soil moisture level following cowvine seedling emergence.

Table 7. The survival of cowvine seedlings following applications of residual herbicides applied pre-emergence in pots. Establishment percentage should be compared with the emergence percentage in Table 6.

Treatment	Establishment %		
	4 weeks	8 weeks	12 weeks
Zoliar 4 kg/ha	10%	11%	14%
Gesagard 4.5 L/ha	16%	17%	18%
Diuron 3.5 L/ha	17%	20%	21%
Zoliar 2 kg/ha	20%	24%	25%
Trifluralin 2.8 L/ha	21%	24%	26%
Dual 2 L/ha	23%	28%	29%
Cotoran 5.6 L/ha	26%	28%	29%
Cotogard 5 L/ha	27%	30%	33%
Stomp 3 L/ha	36%	39%	41%
Untreated	25%	27%	28%

Zoliar also gave the best suppression of cowvine in the field in cotton, but the results were variable and less than ideal (Table 8).

Table 8. Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicides. Emergence of cowvine seedlings was recorded during the cotton season (planting to mid-January, 2002). The results are an average from experiments, at Moree and Dirranbandi.

Treatments	Seedlings/m ²
Untreated	12.2
Dual 2 L/ha	11.8
Gesagard 2.5 L/ha	11.1
Gesagard 5 L/ha	10.3
Diuron 1.5 L/ha	10.3
Cotogard 5 L/ha	9.3
Cotogard 2.5 L/ha	8.8
Cotoran 2.5 L/ha	8.2
Cotoran 5 L/ha	6.6
Diuron 3 L/ha	6.5
Zoliar 1 kg/ha	6.3
Zoliar 4 kg/ha	4.1
Zoliar 2 kg/ha	3.1

Zoliar at 2 kg/ha reduced cowvine seedling density by 74% in experiments in irrigated cotton at Moree and Dirranbandi (Table 8), but this still left 3 seedlings/m², more cowvine plants than can be tolerated in cotton. Diuron and Cotoran gave the best results of the other herbicides. Best results were observed early in the season, with poorer control on all treatments later in the season, as the effective herbicide levels in the fields declined.

Cowvine control improved with all herbicides as the herbicide rates increased, but high herbicide rates are not always safe in cotton. No herbicide damage to the cotton was observed at Moree, but significant damage occurred following rain early in the cotton season at Dirranbandi. The worst damage was with the 2 and 4 kg/ha rates of Zoliar and the 3 kg/ha rate of diuron. The cotton plant stand was reduced by these herbicide applications, especially in the tail-ditch end of the field, where water had backed up.

Results from a range of herbicide combinations at the same experimental sites gave the best cowvine control with a combination of diuron and Zoliar, or prometryn and Zoliar (Table 9). These combinations gave similar levels of cowvine control, but with improved crop safety, compared to the results from the high levels of diuron or Zoliar alone.

Table 9. Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicide combinations. Cowvine emergence was recorded from cotton planting to mid-January 2002, on experiments, situated at Moree and Dirranbandi.

Treatments	Seedlings/m ²
Gesagard 2.5 L/ha + Diuron 1.5 L/ha	8.80
Cotogard 2.5 L/ha + Dual 2 L/ha	7.36
Gesagard 2 L/ha + Diuron 1.5 L/ha + Zoliar 1 kg/ha	6.41
Cotogard 2.5 L/ha + Diuron 1.5 L/ha	6.39
Diuron 1.5 L/ha + Dual 2 L/ha	6.36
Cotoran 2.5 L/ha + Dual 2 L/ha	6.31
Cotoran 2.5 L/ha + Diuron 1.5 L/ha	6.26
Gesagard 2.5 L/ha + Dual 2 L/ha	5.64
Cotogard 2.5 L/ha + Zoliar 1 kg/ha	5.46
Gesagard 2 L/ha + Diuron 1.5 L/ha + Dual 2 L/ha	5.31
Cotogard 2 L/ha + Cotogard 2.5 L/ha	5.19
Cotoran 2.5 L/ha + Zoliar 1 kg/ha	4.87
Diuron 1.5 L/ha + Zoliar 1 kg/ha	3.99
Gesagard 2.5 L/ha + Zoliar 1 kg/ha	3.84

Post-emergence control of cowvine with residual herbicides in cotton

Diuron and prometryn were both effective for controlling emerged cowvine seedlings and small plants in cotton, but gave less than 100% control on some occasions, especially with larger plants (compare Tables 10 and 11, for example). Generally, the addition of a surfactant is necessary to get the best control of emerged cowvine seedlings.

MSMA (Daconate) was commonly tank mixed with residual herbicides for post-emergence control of morning glory seedlings in the US, but is not necessary or desirable for controlling cowvine with diuron or prometryn. MSMA itself has little activity on cowvine (Table 4).

Table 10. Control of cowvine growing in pots using post-emergence herbicides applied to plants at 4 and 11 leaves.

Herbicide	% Weed kill	
	4 leaves	11 leaves
Cotoran (500 g/L) 2.8 L/ha	0	25
Diuron (500 g/L) 1.8 L/ha	95	94
Gesagard (500 g/L) 2.2 L/ha	40	100
Staple 120 g/ha	0	0
Untreated	0	0

Diuron and prometryn must be applied as shielded or directed sprays in cotton, applied to avoid contact with the crop foliage. Most product labels only allow diuron application in crop after the cotton is 30 cm high. Prometryn may be able to be applied after the crop reaches 15 cm. Check the product labels for specific use directions. Always

follow the label directions. Fluometuron did not adequately control cowvine when applied at 2.8 L/ha, but was more effective at the higher rate (5.6 L/ha, Table 11). The level of control was improved when MSMA was tank mixed at 1 or 2 L/ha, but the level of control was still inferior to that achieved with diuron or prometryn.

Table 11. Cowvine control with herbicides applied post-emergence to plants with 2, 4, 6 and 12 leaves, growing in pots.

Herbicide	% Weed kill 6 weeks after spraying			
	2 leaves	4 leaves	6leaves	12 leaves
Cotoran (500 g/L) 2.8 L/ha	25	27	75	50
Cotoran (500 g/L) 5.6 L/ha	75	100	100	62
Diuron (500 g/L) 2 L/ha	75	62	100	50
Diuron (500 g/L) 4 L/ha	75	100	100	75
Gesagard (500 g/L) 2.2 L/ha	100	100	100	100
Gesagard (500 g/L) 4.4 L/ha	100	100	100	100
Staple 30 g/ha	0	0	0	0
Staple 60 g/ha	0	0	0	12
Staple 120 g/ha	0	25	0	0
Roundup CT 1 L/ha	0	50	12	12
Roundup CT 2 L/ha	0	50	12	87
Roundup CT 4 L/ha	100	87	87	100
Untreated	0	4	0	0

Controlling cowvine with non-residual herbicides

With the commercial release of Roundup Ready[®] cotton, many growers have found that Roundup Ready Herbicide[®] can be effective for controlling cowvine seedlings in young Roundup Ready cotton even though this weed is not on the product label. Growers have generally found that Roundup at the maximum label rate is effective on cowvine seedlings at the cotyledon stage and up to 2 or 3 true leaves, but is much less effective on older plants.

Glyphosate can be equally effective for controlling cowvine seedlings growing in conventional cotton, but glyphosate is difficult to apply to small cowvine plants in conventional cotton, without risking damage to the cotton plants from herbicide drift or off-target spray. Glyphosate can not be applied as a shielded or directed spray in conventional cotton before the crop reaches 20 cm in height. (Check specific use directions on the product label). Crop safety is much better with shielded applications in conventional and Roundup Ready cotton later in the season, but cowvine plants may be too large to be controlled by glyphosate by this time.

However, the window for glyphosate application to cowvine seedlings may be larger than has often appeared to be the case. The 2 L/ha application of glyphosate (Table 11) gave no control on seedling cowvine, but 87% control of larger plants (12-leaf stage). Glyphosate applications at 2 L/ha also gave good control of cowvine plants at 10 leaves (Table 12) and 22 leaves (Table 13).

Table 12. Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2 and 10 leaves. At the 10-leaf stage, the centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray.

Herbicide	%Weed kill after 6 weeks		
	2 Leaves full spray	10 Leaves full spray	centre covered
Roundup CT 1 L/ha	87	25	0
Roundup CT 2 L/ha	100	100	62
Roundup CT 3 L/ha	100	100	75
Basta 2 L/ha	100	100	12
Basta 4 L/ha	100	100	37
Bromoxynil 2 L/ha	100	75	0
Bromoxynil 4 L/ha	100	100	0
Untreated	0	0	0

Table 13. Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2, 9 and 22 leaves. The centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray at the 22-leaf stage.

Herbicide	%Weed kill after 8 weeks			
	2 Leaves full spray	9 leaves full spray	22 Leaves full spray	centre covered
Roundup CT 1 L/ha	62	12	25	0
Roundup CT 2 L/ha	50	87	87	12
Basta 1 L/ha	100	100	100	12
Basta 2 L/ha	100	100	100	25
Bromoxynil 1 L/ha	12	12	12	25
Bromoxynil 2 L/ha	0	37	75	12
Untreated	0	0	12	12

The problem of poor control of cowvine with glyphosate sometimes observed in the field probably relates to two factors; the growing conditions of the plants, and incomplete spray coverage. Glyphosate is most effective on actively growing plants and never as effective on weeds that are stressed. The most likely cause of stress to cowvine plants growing in cotton is moisture stress, as small cowvine seedlings compete for moisture with larger, established cotton plants. Cowvine plants of any size will be difficult to control with glyphosate in cotton in hot, dry conditions,

when the plants are not actively growing. Small cowvine plants sprayed soon after an irrigation or rainfall event should be much more easily controlled with glyphosate. Incomplete spray coverage is more difficult to avoid, as some cowvine plants emerge in the cotton row, where they are partially shielded by the cotton plants, and are difficult to spray when using a directed spray or a shielded sprayer. Larger plants may also be difficult to control when some branches are twined in the cotton row, and so avoid the spray.

Although glyphosate does translocate in plants away from the point of spray contact, translocation of glyphosate in cowvine plants appears to be quite limited. The percentage kill of cowvine plants was much lower on plants that were partially sprayed (Table 12 and 13), compared to the kill of plants that were fully sprayed.

Some growers have raised the possibility of using spray additives or different glyphosate formulations to improve the control of cowvine. Data from a glasshouse study showed few differences between glyphosate formulations, although there was an improvement in cowvine control from adding 0.2% of a non-ionic surfactant (Turbo Plus) to Roundup CT (Table 14).

Table 14. Control of cowvine in a pot experiment using Roundup CT with spray additive or a different glyphosate formulation. Plants were at 4 and 6 leaves at spraying.

Herbicide	Additive	% Weed kill 6 weeks after spraying	
		4 leaves	14 leaves
Roundup CT 2.2 L/ha		25	25
Roundup CT 2.2 L/ha	0.2% Turbo Plus	37	50
Roundup CT 2.2 L/ha	1% Turbo Plus	50	12
Roundup CT 2.2 L/ha	0.2% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	1% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	2% Boost	25	0
Roundup CT 2.2 L/ha	5% Boost	25	12
Roundup CT 2.2 L/ha	2% Urea	25	0
Roundup CT 2.2 L/ha	5% Urea	25	0
Roundup Max 2 L/ha		12	0
Roundup Ready 1.4 kg/ha		25	0
Credit & Bonus 1.9 L/ha		12	0
Untreated		0	0

The overall control rate was quite poor in this experiment. The reason for this is not understood, but is typical of the variability of results sometimes observed in the field with glyphosate and some other herbicides on this weed. Nevertheless, the cowvine plants were strongly affected by the glyphosate applications. Most plants that were not killed by the herbicides had only 2 or 3 live leaves

6 weeks after spraying. Unsprayed plants were much larger.

A similar effect was observed with Staple and Envoke, with a reduction in cowvine growth following an over-the-top applications (Table 15). These herbicides did not reliably kill cowvine seedlings but did suppress regrowth for up to 6 weeks after application.

Table 15. Control of cowvine in a pot experiment using non-residual, over-the-top herbicides sprayed at 4, 8 and 16 leaves. The number of alive leaves per plant was observed 4 weeks after spraying

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	16 leaves	4 leaves	8 leaves	16 leaves
Roundup Ready 1.5 kg/ha	100	100	75	0	0	2
Staple 120 g/ha	0	37	12	33	21	51
Envoke 15 g/ha	12	0	12	27	10	15
Untreated	0	0	0	60	81	104

Table 16. Control of cowvine in a pot experiment using Envoke applied over-the-top at 3 and 17 leaves. The number of alive leaves per plant was observed 6 weeks after spraying.

Herbicide	% Weed kill		Leaf number after 4 weeks	
	3 leaves	17 leaves	3 leaves	17 leaves
Envoke 5 g/ha	0	0	41	70
Envoke 10 g/ha	0	80	29	16
Envoke 15 g/ha	0	75	20	5
Envoke 20 g/ha	12	100	14	0
Untreated	0	0	74	57

Envoke was more effective at higher rates and a broadcast application gave good suppression even on larger cowvine plants (Table 16). However, this result on larger plants was not duplicated in the field where it was not possible to get full spray coverage of larger cowvine plants in a cotton crop.

Similarly variable results were observed with diuron, Cotoran and Gesagard (Tables 10 and 11). Growers should be prepared to use an alternative control strategy, such as cultivation, to manage cowvine seedlings in case of an unsatisfactory spray result.

Basta and bromoxynil are two other non-residual herbicides that might become available for over-the-top use with transgenic, herbicide tolerant cotton varieties, should varieties with these tolerances become commercially available. Basta tolerant cotton varieties are currently being developed, but will not be commercially available for several years. Both these herbicides are effective for controlling cowvine; Basta at 1 L/ha and bromoxynil at 4 L/ha. Oxytril® could be used instead of bromoxynil on the bromoxynil tolerant cotton and is effective on cowvine at lower rates (Table 4).

These two herbicides have the advantages that they are safe to use at any growth stage on tolerant cotton varieties and that they are equally effective on seedling and larger cowvine plants. They have the disadvantage that they are both relatively expensive, and they do not translocate well, needing full plant coverage to be fully effective. The control of cowvine plants partially sprayed with Basta and bromoxynil was much lower than the control of fully sprayed plants (Tables 12 and 13).



Glyphosate can be applied through spray shields to the area between the cotton rows in conventional and Roundup Ready cotton varieties. The spray shields prevent the herbicide contacting the foliage of the crop.

Herbicide combinations for controlling cowvine in cotton

A range of pre- and post-emergence herbicides and herbicide combinations for cowvine control were assessed in 5 field experiments over 3 seasons. No single herbicide or herbicide combination was able to give season long cowvine control, but excellent results were achieved using a range of management tools in combination.

The exact mix of weed management tools needed in any given field depends on a range of factors, including season conditions, weed pressure (density and sequential germinations) and the range of other weeds present in the field.

WEEDpak

section **H2**

Of the residual planting herbicides, Zoliar and diuron gave the best early-season control of cowvine (28 Oct, Table 17). However, the control achieved by these herbicides declined rapidly as the season progressed, and large numbers of cowvine seedlings were generally present by mid- to late-November.

Control of these seedlings was most readily achieved using an over-the-top Roundup Ready Herbicide application to Roundup Ready cotton at the 4-leaf stage. The decline in activity of the pre-planting residual herbicides was such that they had little effect on the emergence of cowvine seedlings following the Roundup Ready Herbicide application. Consequently, these residual herbicides were of little value where a 4-leaf Roundup application was made, with similar densities of cowvine seedlings following the Roundup application regardless of the presence or absence of pre-planting residual herbicides (16 Nov, Table 17). The pre-planting residual herbicides would be of much more value in a non-Roundup Ready field.

Table 17. Early-season control of cowvine in a field experiment. The Roundup Ready crop was planted on 1 October and Roundup Ready Herbicide® was applied over-the-top of the crop on 28 October 2004.

Pre-planting herbicide		Seedlings/m ²	
23 Sep 04	4-leaf spray on 28 Oct 04	28 Oct	16 Nov
Diuron 2 kg/ha +			
Zoliar 1 kg/ha	Roundup 1.5 kg/ha	0.4	0.03
Diuron 2 kg/ha	Roundup 1.5 kg/ha	0.4	0.05
Cotogard 2 kg/ha	Roundup 1.5 kg/ha	0.5	0.06
Zoliar 2 kg/ha	Roundup 1.5 kg/ha	0.6	0.09
Untreated	Roundup 1.5 kg/ha	1.1	0.07



Cowvine can be very difficult to manage in conventional or Roundup Ready UNR (ultra narrow row) cotton which does not allow inter-row cultivation, or shielded or directed spray applications.

It is important that the emergence of cowvine seedlings in the crop is monitored following the 4-leaf Roundup application. Few seedlings are likely to emerge until rainfall or irrigation occurs, and most emerging seedlings can be controlled by inter-row cultivation or a Roundup applications during this window. However, seedlings that do emerge and remain untreated will be difficult to control once they are at the 6 - 8 leaf stage or larger. Large germinations of cowvine can occur following rainfall events and the management of the crop should be driven by the observed cowvine pressure, with treatments scheduled as required.

Applications of glyphosate, prometryn and diuron can all be effective in controlling cowvine seedlings later in crop life, provided the seedlings are actively growing and good spray coverage is achieved. Staple and Envoke can also give useful suppression of cowvine seedlings. In the experiment in Table 17, rainfall occurred following the Roundup Ready application and cowvine numbers steadily increased. A mid-season herbicide application was applied in mid-December with combinations of diuron, Roundup and Envoke. All herbicides and combinations reduced the cowvine density by at least 75%, with the combinations including diuron giving better than 95% control (Table 18).

Table 18. Mid-season control of cowvine in a field experiment. The field was assessed on 16 December, herbicide was applied as a directed spray on 17 December, and the cowvine density was again assessed on 12 January 2005. The % reduction in the cowvine density is shown

Mid-season spray 17 Dec	Seedlings/m ²		% Reduction
	16 Dec	12 Jan	
Diuron 2 kg/ha	0.5	0.02	95
Roundup Ready 1.5 kg/ha +			
Diuron 2 kg/ha + Envoke 5 g/ha	0.8	0.03	96
Roundup Ready 1.5 kg/ha +			
Diuron 2 kg/ha	0.8	0.03	97
Roundup Ready 1.5 kg/ha	0.7	0.15	80
Roundup Ready 1.5 kg/ha +			
Envoke 5 g/ha	0.8	0.18	77

The value of these herbicide combinations is not clear. Combinations are often used to improve the spectrum of weeds controlled with a single application, or to improve efficacy on difficult to control weeds. With Roundup Ready cotton, the temptation is to add something to the Roundup to improve its control on those weeds on which it is less effective. Often, however, the addition of another herbicide to glyphosate will reduce the efficacy of the glyphosate and may damage the crop. A reduction in glyphosate efficacy almost

always occurs when herbicides such as diuron and prometryn are added to glyphosate, regardless of the formulations used. The addition of ammonium sulphate may improve glyphosate efficacy in these combinations, but is of limited value.

The herbicide combinations in this experiment improved the cowvine control compared to using Roundup Ready Herbicide alone, but didn't improve control over diuron alone. Results from a pot experiment were inconsistent, but suggested that the combination of residual and Roundup Ready Herbicide could give improved control of cowvine in some situations (Table 19). Nevertheless, this combination may give reduced control of other weeds that might be present. Factors that could improve the result with a combination of Roundup Ready Herbicide and a residual are:

- Addition of a suitable spray adjuvant
- High water rates (at least 100 L/ha), and
- Ensuring that the combination is applied to the target as quickly as possible after mixing

Table 19. Control of cowvine in a pot experiment using post-emergence combinations. Plants were sprayed at 2 and 12 leaves and assessed 6 weeks after spraying.

Herbicide	% Weed kill after 6 weeks	
	2 leaves	12 leaves
Roundup Ready 1.5 kg/ha	100	69
Diuron 0.5 kg/ha	87	62
Diuron 1 kg/ha	50	37
Diuron 2 kg/ha	100	62
Diuron 0.5 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Diuron 1 kg/ha + Roundup Ready 1.5 kg/ha	87	87
Diuron 2 kg/ha + Roundup Ready 1.5 kg/ha	100	100
Gesagard 0.5 kg/ha	87	75
Gesagard 1 kg/ha	87	87
Gesagard 2 kg/ha	100	75
Gesagard 0.5 kg/ha + Roundup Ready 1.5 kg/ha	75	75
Gesagard 1 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Gesagard 2 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Untreated	0	0

In most situations it will also be necessary to apply a layby residual herbicide prior to canopy closure to control cowvine seedlings that emerge late in the crop. A combination of prometryn and Roundup Ready Herbicide was applied to all treatments in this experiment in late January and

resulted in 100% control of all cowvine plants. Plants which emerged after canopy closure had no impact on the crop and were controlled immediately after picking.

These results showed that a cowvine management program that combined good farming practices, Roundup Ready and residual herbicides, and inter-row cultivation could effectively control cowvine in a heavily infested commercial field where management inputs were able to respond to weed pressure.



Inter-row cultivation is a valuable component of an integrated weed management system for controlling cowvine and other weeds.

Alternative residual herbicides for managing cowvine in fallows and rotation crops

Tordon 242 was the only alternative residual herbicide tested which resulted in a long-term reduction in the germination of bellvine seeds (Table 20). Tordon 242 can be applied to cereal and linseed crops, but picloram, one of the constituents of Tordon 242, is toxic to cotton and has a long residual life in the soil (can be up to 300 days half-life). Consequently, there is a minimum 12 month plant-back period to cotton for Tordon 242. None of the other alternative residual herbicides had any effect on cowvine germination

Table 20. Cowvine seedling emergence following applications of residual herbicides.

Herbicide	% Cumulative cowvine germination			
	1 week	2 weeks	4 weeks	1 year
Tordon 242 1 L/ha	3	8	13	17
Spinnaker 400 ml/ha	32	57	62	66
Harmony M 45 g/ha	35	56	59	67
Sencor (750 g/kg) 470 g/ha	47	59	62	67
Lontrel (300 g/L) 500 ml/ha	51	57	60	67
Ally 7 g/ha	47	61	62	69
Simazine (900 g/kg) 2.2 kg/ha	50	63	65	72
Atrazine (900 g/kg) 3.3 kg/ha	44	66	69	77
Untreated	37	61	64	68

Managing cowvine in the farming system

While cowvine can be controlled by cultivation and a range of herbicides, it is not easy to control in a farming system due to:

- strong seed dormancy,
- long seed life in the seedbank,
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Population dynamics of a typical field were presented in Figure 1. Results from a seedbank experiment are shown in Figures 2 and 3. These treatments were designed to simulate the effect of a standard herbicide management system (Figure 2) and a heavier management system (Figure 3) in back-to-back cotton.

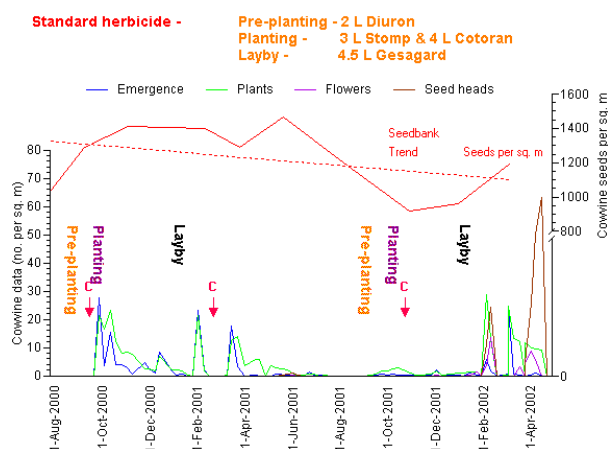


Figure 2. Population dynamics of cowvine under a standard herbicide regime. Cultivation events are indicated by a "C" with an arrow.

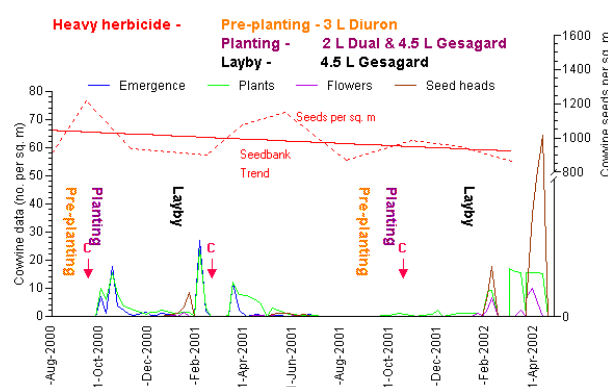


Figure 3. Population dynamics of cowvine under a heavier herbicide regime. Cultivation events are indicated by a "C" with an arrow.

As with the earlier data of Figure 1, there has been a downward trend in the seedbank population of cowvine seeds in both treatments in the two seasons of the experiment. Nevertheless, some cowvine seedlings emerged in both systems, grew, and on several occasions set seed. Totals of 310 and 321 cowvine seeds/m² were produced on the standard and heavy management systems over the two seasons. These seeds were mostly produced towards the end of the cotton season, when the effective levels of the residual herbicide had declined, with most seeds produced in the dry conditions of autumn 2002.

The management of cowvine in these systems should improve over time, provided the number of cowvine seeds in the seedbank continues to decline. Failure to control the cowvine on just one occasion could result in the seedbank increasing back to previous levels. The seedbank is only declining at around 10% per year. It will be many years before cowvine ceases to be a problem in this field.

Cowvine seeds can float and move in irrigation water. However, the number of seeds that do move in irrigation water is quite low, representing

only a small fraction of the number of seeds present in an infested field. Consequently, seed movement in irrigation water is not an issue, except as a source of infestation for previously clean fields.



A heavy infestation of young cowvine plants on an irrigation channel. These plants will produce large numbers of seeds that can move in the irrigation water and spread the weed to previously clean fields.

Summary

Cowvine is an annual weed that is a problem both in crops and in fallows. Cowvine can be controlled by cultivation and a range of herbicides. It is not easy to control in a farming system due to a number of characteristics, including:

- strong seed dormancy
- long seed life in the seedbank
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Typically, around 1000 to 2000 cowvine seeds per m² are present in the seedbank of a heavily infested field. These seeds occur predominantly in the 0 to 30 cm soil zone. Seeds can emerge all year round and plants may flower within a week of germination.

None of the pre-emergence residual herbicides were effective in controlling cowvine. Best results were achieved with combinations of diuron and Zoliar, and prometryn and Zoliar. These combinations reduced the in-field infestation of cowvine by around 75%. Post-emergence, diuron and prometryn consistently give the best control of cowvine of the herbicides normally used in cotton. Glyphosate can be effective in controlling cowvine seedlings in conventional and Roundup Ready cotton. Glyphosate is most effective on actively growing cowvine seedlings. Good control of older, actively growing plants with glyphosate is possible.

An effective cowvine management system will use all the available control options (cultivation, chipping and herbicides) in combination. Management of this weed will be an on-going process over many seasons.

MANAGING NUTGRASS IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
The four steps for weed management	H3.1
The nutgrass (<i>Cyperus</i>) family	H3.2
Nutgrass (<i>C. rotundus</i>)	H3.2
Downs nutgrass (<i>C. bifax</i>)	H3.2
Yelka (<i>C. victoriensis</i>)	H3.3
Tall sedge (<i>C. alterniflorus</i>)	H3.3
Trim sedge (<i>C. concinnus</i>)	H3.3
Dirty Dora (<i>C. difformis</i>)	H3.3
Umbrella sedge (<i>C. eragrostis</i>)	H3.3
Rice flatsedge (<i>C. iria</i>)	H3.3
Understanding nutgrass (<i>C. rotundus</i>)	H3.12
Biological control of nutgrass	H3.12
Treatment options	H3.13
IWM tools for nutgrass control	H3.13
Cultivation	H3.13
Residual herbicides	H3.14
Norflurazon (Zoliar®, Group F)	H3.14
Imazapyr (eg. Arsenal, Group B)	H3.15
Contact herbicides	H3.16
MSMA (eg. Daconate, Group K)	H3.16
Halosulfuron-methyl (Sempra, Group B)	H3.17
Glyphosate (various trade names, Group M)	H3.17
Herbicide efficacy on the major weeds	H3.18
Factors that influence Zoliar efficacy	H3.19

Contents	Page
Factors that influence glyphosate efficacy	H3.20
Nutgrass age	H3.21
Stressed plants	H3.21
Low temperatures	H3.22
Low soil moisture	H3.22
Cultivation	H3.22
Glyphosate rate	H3.22
Water quality	H3.22
Water rate	H3.23
Additives	H3.23
Tank mixing	H3.24
Re-spraying interval	H3.24
Herbicide combinations	H3.25
Spraying equipment	H3.25
Crop competition	H3.25
Developing an IWM program for nutgrass	H3.26
A management program for heavy infestations	H3.29
A management program for light infestations	H3.29
Summary	H3.30
Case studies of grower experiences with nutgrass	
Nutgrass on Kilmarnock	H3.31
Nutgrass control on Norwood	H3.32
Nutgrass control on Auscott Narrabri	H3.33



A heavy “nutgrass” infestation in cotton. The field was infested with four different species. The cotton was infested with downs nutgrass and yelka. Dirty Dora and umbrella sedge infested the head ditch.

The four steps for weed management

A successful weed management program is built in four steps. These are:

- **positive identification** of the weed
- **assessment** of the extent of the problem
- targeted **treatment** of the weed, integrating all available management tools, and
- **evaluation** of the farming system, making modifications as required to ensure success.

The nutgrass (*Cyperus*) family

Positive identification is the first step in managing any problem weed, as different management techniques may be needed to control different weeds, even though the weeds may be closely related.

Nutgrass belongs to the genus *Cyperus*, of which 38 species are reported to occur in the cotton growing areas of Australia. Of these, 19 species are native to Australia and the remaining 19 species have been introduced.¹ Three of these species are commonly found in or around cotton fields (Table 1), while another five species occasionally occur around cotton fields (Table 2).

Table 1. Nutgrass species commonly found in and around cotton fields.

Botanical name	Common name
<i>C. bifax</i> C. B. Clarke	downs nutgrass
<i>C. rotundus</i> L.	nutgrass
<i>C. victoriensis</i> C. B. Clarke	yelka

Table 2. Nutgrass species occasionally found around cotton fields.

Latin name	Common name
<i>C. alterniflorus</i> R. Br.	Tall sedge
<i>C. concinnus</i> R. Br.	Trim sedge
<i>C. difformis</i> L.	Dirty Dora
<i>C. eragrostis</i> Lam.	Umbrella sedge
<i>C. iria</i> L.	Rice flatsedge

This article primarily focuses on the control and management of nutgrass (*C. rotundus*) as by far the most difficult to control of these weeds. Management information for the other species is discussed throughout the article.

Nutgrass (*C. rotundus*) (see p. H3.4)

Nutgrass, called purple nutsedge in the USA, is an introduced, strongly competitive perennial weed that grows from underground tubers. It is an international weed and is a major problem in a range of crops, and especially irrigated farming systems.

Nutgrass favours lighter soil and wetter conditions, but grows well on both dryland and irrigated soils throughout the cotton industry.

It may be relatively short, at 10 - 15 cm, but can grow up to 60 cm high in irrigated cotton. Nutgrass has dark green leaves and stems that are triangular throughout their length. It has a dark purple flower head that is up to 10 cm in diameter and lightens in colour with age. Nutgrass grows in

very dense patches, with little space between shoots. Densities of up to 14000 tubers and 2200 shoots/m² have been recorded in irrigated Australian cotton. It can reduce cotton yields by up to 90% at these densities.

Nutgrass can be positively identified from the purple colouration on the outer leaves at the base of the plant stem, around the basal bulb. This colouration is seen by stripping back one or two leaves from the base of the nutgrass shoot. Purple colouration persists through several layers of outer leaves, while the inner leaves are light green and then white.

Nutgrass produces large numbers of seeds, but the seed has very low viability (only 1 or 2%) and the seedlings are weak and easily controlled by herbicides such as trifluralin and pendimethalin. Nutgrass plants rarely establish from seed; reproduction is almost always by vegetative propagation through new tubers.

A single nutgrass plant can produce up to 2000 new tubers in a single season. The first tubers are initiated about four weeks after the nutgrass shoots first emerge. These new tubers then produce new shoots that produce new tubers etc. Most tubers are in the top 15 cm of the soil, although tubers can emerge from 30 - 40 cm depth.

Nutgrass is frost susceptible and becomes dormant over winter when conditions are sufficiently cool. Plants re-establish in spring from dormant tubers. Nutgrass tubers may remain dormant in the soil for several years, but require moisture to survive. Tubers are easily killed by desiccation in a dry soil.

Downs nutgrass (*C. bifax*) (see p. H3.5)

Downs nutgrass is a native Australian species and is abundant in much of the flood susceptible, watercourse country.

It is similar to nutgrass, but is generally taller at 60 - 80 cm, its leaves and stems are a lighter green in colour, and its seed head is larger (up to 20 cm across) and lighter in colour, starting off brown or orange and fading with age. Its stems are triangular over their full length, but unlike nutgrass, the outer leaves at the base of the stem are light green, and the inner leaves white.

Downs nutgrass produces a large quantity of viable seeds. Typically, it also produces 5 to 20 new tubers per plant each season, and establishes from both seed and tubers. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation. New downs nutgrass infestations can occur from seeds carried in floodwater and fodder.

¹ Lazarides M. Cowley K. and Hohnen P. (1997). CSIRO handbook of Australian weeds, CSIRO Publishing, Collingwood, Vic.

Downs nutgrass grows at much lower density than nutgrass and is much less competitive, although downs nutgrass may be more obvious in cotton due to its greater height.

Yelka (*C. victoriensis*) (see p. H3.6)

Yelka is native Australian species that occurs in the watercourse country and is common on roadsides.

It has erect, dark green stems 100 - 120 cm tall with few leaves. The stems are circular at the base, but become more triangular towards the top. Yelka may have a small, purple flower head, with a few short leaves below the flower, but often the flower head is absent. It grows at low densities, produces few seeds and tubers, and is not very competitive. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation in a dry soil.

Tall sedge (*C. alterniflorus*) (see p. H3.7)

Tall sedge is a perennial native Australian species that occurs sporadically in wet areas such as river and creek banks, lagoons and irrigation ditches.

Mature plants are around 1 m tall and can form large, dense tussocks. The stems are almost circular at the base but become triangular throughout most of their length.

Tall sedge produces rhizomes and masses of seed, but does not spread rapidly. It can be a nuisance in irrigation channels and water storages.

Trim sedge (*C. concinnus*) (see p. H3.8)

Trim sedge is a native Australian species that occurs sporadically on wet areas and table drains.

It grows to around 50 - 60 cm high and produces both seed and rhizomes. Its stems are triangular throughout their length.

Dirty Dora (*C. difformis*) (see p. H3.9)

Dirty Dora is another native Australian species that invades wet areas. It is a major problem weed in rice and cane production in Australia.

Dirty Dora grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. It tends to be relatively short, up to 50 cm, and is a paler, yellowy colour. The stems of dirty

Dora are strongly triangular throughout their length.

Small numbers of small plants may occur throughout cotton fields without being noticeable. Dirty Dora plants have germinated from soil samples taken from fields where the plant has never been observed to occur.

Umbrella sedge (*C. eragrostis*) (see p. H3.10)

Umbrella sedge is an introduced species that invades wet areas and can be a problem in water storages and irrigation channels.

Umbrella sedge grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. Plants are generally around 30 - 50 cm tall, although they can grow to 1 m. The stems are almost circular at the base but become triangular throughout most of their length.

Once established, umbrella sedge plants can grow to form a large tussock.

Rice flatsedge (*C. iria*) (see p. H3.11)

Rice flatsedge is a native annual sedge that occurs in wet areas such as table drains and irrigation channels. It grows to 60 to 80 cm in height and produces large quantities of seed. Its stems are strongly triangular throughout their length.



Nutgrass is a strongly competitive perennial weed that grows from tubers.



Downs nutgrass is a native perennial weed commonly found in the watercourse country. It is not very competitive with cotton, but can be very obvious due to its height and colourful flower heads.



Yelka is a native weed commonly found on roadsides and waste areas. It is tall, but has few leaves and grows at relatively low densities.



Tall sedge is a native weed occasionally found on river and creek banks, irrigation channels and water storages. It can form large, dense tussocks.



Trim sedge occurs sporadically on wet areas and table drains.



Dirty Dora is a native species that invades wet areas. It produces masses of seed and can spread very quickly.



Umbrella sedge is an introduced weed that invades wet areas and spreads rapidly from seed.



Rice flatsedge is a native species that invades wet areas.

Understanding nutgrass (*C. rotundus*)

Nutgrass produces and survives from vegetative tubers in the soil. These tubers are up to 10 mm in diameter and up to 20 mm in length. Tubers are formed at the end of underground rhizomes that develop from each vegetative plant. A new plant develops from each tuber. Tubers appear to be formed in chains, but each tuber gives rise to a vegetative plant, which gives rise to new tubers, and so on.

These tubers can become dormant in winter or during dry conditions and can survive for years in the soil, extracting moisture through their roots. However, they are vegetative plant structures and cannot survive without water. Tubers are rapidly killed if they are exposed to very dry soil or are exposed at the soil surface after their roots are cut. Tubers without roots in moist soil die within a few hours when exposed at the soil surface in the middle of summer.

Tubers can be found throughout the soil profile, but are most common in the 0-10 cm soil layer. The results from 120 soil cores are shown in Table 3. Cores were from heavily infested fields in the Moree and Wee Waa areas. No tubers were detected below 40 cm, although a small number of tubers have been found at up to 1m depth. These tubers probably fell down cracks in the soil and are of no importance, except when they become exposed by deep cultivation, erosion, earth works, or after levelling.

Table 3. Distribution of nutgrass tubers down the soil profile (0 to 100 cm). Percentage found in each soil layer.

	Soil depth (cm)			
	0 - 10	10 - 20	20 - 30	30 - 40
Field 1	66	25	7	1
Field 2	50	38	10	2
Field 3	42	42	14	3
Average	53	35	11	2

Emergence from tubers placed at depth in a sandy soil and a black soil are shown in Table 4. Nutgrass shoots emerged readily from tubers down to 20 cm in depth, with some emergence from 40 cm in the sandy soil. Emergence was slower from the lower depths and was much slower in the black soil. The results from the sandy soil show that shoots could emerge from at least 40 cm in a black soil, where shoots emerge through cracks in the soil. Poor emergence was observed from tubers placed on the soil surface, which were probably killed by desiccation.

Table 4. Percentage emergence and days to emergence from tubers placed at depth in sandy and black soils in pots.

Depth (cm)	Sandy soil		Black soil	
	Emergence	Days	Emergence	Days
0	43	13	0	
2.5	100	9	100	7
5	100	9	75	18
7.5	100	12		
10	100	12	100	41
12.5	100	11		
15	100	14	100	54
20	100	18	75	51
25			0	
30	0		0	
40	25	38	0	
50			0	

Post-emergence observations indicated that the depth of the tuber did not affect subsequent plant growth.

Biological control of nutgrass

A range of organisms attack nutgrass, including rust, head smut, scale insects and a caterpillar that bores down through the stem (*Bactra trunculenta*). Feral pigs and other animals will also dig for and eat nutgrass tubers. These organisms normally have little impact on nutgrass infestations, attacking only a small proportion of plants, but can be found in large numbers in heavy nutgrass infestations.

The possibility of biological control of nutgrass has been examined in a number of countries, but has not been effective in significantly reducing weed numbers.



Leaf rust on nutgrass (top left), and downy rot (bottom left) and stem rust on yelka plants (right).



Nutgrass affected by smut. This is of little importance, however, as nutgrass spreads primarily by tubers not from seeds.



Nutgrass tubers and shoots parasitised by a scale insect (white spheres).

Treatment options

Nutgrass can only be managed using a long-term, integrated weed management (IWM) approach. There are a number of tools that help control nutgrass, and practices that enhance control. These tools need to be used in combination. There are also a number of practices that should be avoided whenever possible.

One of the key components of an effective IWM strategy for nutgrass is to develop a 'whole-farm' approach. It is essential that nutgrass infestations are managed not just in-field, but also on roadways, channels, storages, non-cotton fields and waste areas. Strict field hygiene protocols are needed, especially where large areas of nutgrass are present in non-cotton areas and it is not practical to control the nutgrass on these areas. Nutgrass rarely establishes from seed. Most infestations are caused by tubers being spread from field to field and farm to farm by machinery. It is common to see nutgrass plants initially establish at the end of a field, where they have fallen from cultivators that were previously operating in

infested fields. Subsequent cultivation passes spread the infestations throughout the fields.

More information on IWM is covered in the **Integrated Weed Management (IWM) Guidelines for Australian Cotton Production** in **WEEDpak**.

IWM tools for nutgrass control

Nutgrass can be controlled using:

- cultivation,
- residual herbicides,
- contact herbicides, and
- crop competition.

Cultivation

Mechanical cultivation can be very effective in controlling nutgrass, but it is also the most common means of spreading nutgrass. All too often nutgrass tubers and plants are lifted by a cultivator only to be transplanted further down the field.

Cultivation is effective in controlling nutgrass when it severs all the roots from the tubers, provided that the soil is sufficiently dry to kill the tubers. If the soil is not dry, nutgrass plants will rapidly re-establish after cultivation, and may be spread by the cultivator to new parts of the field or to new fields.

Inter-row cultivation is usually ineffective in controlling nutgrass in cotton, as cultivation generally occurs at relatively high soil moisture content to avoid excessively damaging the cotton, and is not deep enough to fully sever the roots of nutgrass plants and tubers.



Inter-row cultivation can be useful for suppressing very heavy nutgrass infestations, but has the major limitation that it can't control nutgrass in the cotton plant line.

Inter-row cultivation in lightly infested fields will often spread nutgrass and exacerbate the problem. Cultivation of lightly infested fields should

be avoided where possible, or the cultivator should be lifted over nutgrass patches or cleaned down after passing through nutgrass patches. A small amount of time spent in cleaning down cultivation machinery can save large costs in time and money required to control the weed in the future.

Multiple inter-row cultivation passes can be used to suppress nutgrass in heavily infested fields, where the spread of tubers is of no importance. Multiple cultivation passes will help the cotton to establish and produce a crop. There will, however, be no lasting reduction in the nutgrass population, which will need to be controlled by another means at a later date.



A trailing ripper set up for heavy cultivation of nutgrass after picking. Note the steel cable across the rippers (top photo) designed to cut the nutgrass roots during ripping.

Heavy cultivation (cultivation to at least 30 cm) is most effective in controlling nutgrass when the soil is completely dry following a cotton or rotation crop. A crop such as lucerne is ideal for completely drying out the soil in the nutgrass root zone. Cultivation should be timed to occur in mid-summer when no rain is forecast and the lucerne crop has dried the soil as much as possible. Heavy cultivation in these conditions can almost completely eliminate a nutgrass infestation from a field. The main limitation to control is the cost of the operation and the practical depth of cultivation.

Cultivation that disturbs the hills prior to planting can also be useful, as it appears to delay nutgrass emergence.

Residual herbicides

Norflurazon (Zoliar[®], Group F)²

Zoliar is the only residual herbicide currently registered for controlling nutgrass (*Cyperus* sp.) in cotton. It is highly persistent, with a half-life of up to 180 days³. Zoliar requires thorough soil incorporation and needs to be used over at least 3 consecutive seasons.



Nutgrass affected by Zoliar, as indicated by the white leaves. Most plants have been severely affected by Zoliar, and some plants in the background have been killed by the herbicide.

Zoliar is registered for application at 2.8 to 4.2 kg/ha, depending on soil type and whether Zoliar was applied in the previous season. Zoliar should be applied at the higher rate in the first season (depending on soil type), but the rate can be reduced in following years. Ideally, it is applied to nutgrass patches in autumn prior to a cotton crop planted in spring. Lower rates should be used if application occurs closer to planting.

Zoliar is readily adsorbed to clay and organic matter in the soil and is relatively immobile. Its efficacy is affected by soil pH and clay content. High rates are required on heavy, alkaline clay soils, but much lighter rates should be used on sandy and acid soils.

² Herbicides are grouped according to mode of action and the risk of weeds developing resistance to the herbicide. Always try to avoid using repeated applications of herbicides belonging to the same herbicide group.

More information on herbicide groups is covered in **Managing Herbicide Resistance in Cotton in WEEDpak**.

³ Technical information for all products was compiled from label information and from information from the Herbicide Handbook (1994) Seventh Edition. Ed. William H. Ahrens, Weed Science Society of America, Champaign, Illinois, USA.

WEEDpak

section **H3**

Zoliar's activity is triggered by a rainfall or irrigation event. It is readily absorbed through plant roots when the soil is wet (near or above field capacity), but is not absorbed from a dry soil.

Zoliar acts on the plant's photosynthetic pathways and destroys chlorophyll and lipids in the cell membranes, and cell proteins. This has the effect of turning affected leaves white. The affected leaves and plants die if this effect lasts sufficiently long.

It is common under Australian conditions for Zoliar to become less active again within a few days of the triggering rainfall or irrigation event. When this happens, the plant recovers from the herbicidal effect and resumes growing. Sections of white along the length of a leaf can indicate Zoliar activity has occurred in the past. Some suppression of nutgrass does continue at lower soil moisture levels.



This grass plant has been affected by Zoliar, but will probably recover as some leaves are still photosynthesising.

Zoliar has the primary advantage that it needs to be applied only once for the season and is most effective during wetter conditions, when the nutgrass would otherwise be most actively growing, and other control measures are difficult or impossible to implement. Zoliar also has the advantage of being equally effective across both hills and furrows.

In addition to controlling nutgrass, Zoliar controls a broad range of grass and broadleaf weeds. Zoliar is relatively expensive, but the cost can be partly offset by substituting Zoliar for some of the other residual herbicides that would normally be used. For example, the grass herbicides such as trifluralin and pendimethalin should not be required in a field treated with Zoliar.



The wheat in this patch was killed by Zoliar that was applied in an earlier season.

Unfortunately, Zoliar is also active against a range of other crop plants. The plant-back period to cereal crops is 30 months after a single herbicide application; a longer plant-back period is required following multiple applications. Zoliar is best suited to heavily infested fields because of its cost and the limitations with rotation crops.

Imazapyr (eg. Arsenal[®], Group B)

Arsenal is registered for controlling nutgrass (*Cyperus* spp.) in non-crop situations. It inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition rapidly leads to plant death. Arsenal is a residual soil sterilant, effective in controlling most plant species. It is both root and shoot absorbed, and can act as a contact herbicide as well as a residual herbicide.



Arsenal will kill cotton and rotation crops for years after application. It should never be applied in-crop or in an area where soil or water movement could carry the herbicide into a sensitive area.

Arsenal is highly persistent, with a half-life of up to 142 days. It can control weeds for up to 3 years when applied at the registered rate. It is ideal for controlling nutgrass patches on roadways, the outsides of channel banks, and other non-crop areas.

When applying Arsenal to a nutgrass patch, it is good practice to apply the herbicide to an area 1 or 2 metres larger than the obviously infested area. This ensures that all nutgrass plants are controlled by the application. All too often the Arsenal controls the nutgrass in the sprayed patch, but treatment fails because a few plants remain outside the sprayed area and the infestation re-develops from these plants.

Arsenal is weakly adsorbed to soil and can move many metres from the site of application. It should never be applied in-crop or in an area where soil or water movement can carry the herbicide into a sensitive area, such as in the rotobuck area, or on the inside of ditches and channels.

Contact herbicides

MSMA (eg. Daconate[®], Group K)

Daconate can be a useful tool for nutgrass management, as it can be applied over-the-top of cotton, or as a directed spray. It is normally applied to small cotton in spring, although it can be applied up until flowering. Daconate can not be applied after the crop commences flowering.

Daconate is readily absorbed into nutgrass foliage and rapidly affects plants. It does not necessarily kill nutgrass plants but will suppress nutgrass growth, allowing the cotton to establish and shade the weed. Daconate is also effective in controlling a range of other weeds.

Daconate is an arsenical compound (contains arsenic). It has little soil activity but has a half-life of about 180 days in soil. Arsenic build up in the soil is not a problem when it is used in accordance with the label directions.

Table 5. Yield reduction in cotton sprayed over-the-top with Daconate[®] in November and December.

Date	Yield reduction (%)
Late November	2
Early December	13
Late December	18

Daconate is not completely safe to cotton. It can burn cotton leaves and delay cotton growth. To reduce this crop damage, Daconate should be applied as a directed spray to young cotton where possible, rather than an over-the-top application. Daconate should be directed to avoid the growing terminal of the cotton plants.

Damage to older cotton can be more serious as shown in Table 5. Nevertheless, in a field heavily infested with nutgrass, Daconate when properly applied, does far more damage to the nutgrass than it does to the cotton, with the end result that a Daconate application helps the establishing cotton and ultimately improves cotton yields

Daconate should be applied during hot conditions, as the efficacy is temperature related. That is, Daconate is more effective under hotter rather than cooler conditions. Daconate is also more damaging to cotton as temperatures increase. Growers should consider using lower rates when spraying Daconate over-the-top of cotton under very hot conditions, especially later in the season. Label recommendations suggest that Daconate should be applied under hot, dry conditions, at temperatures above 25°C. This temperature requirement means that Daconate should not be applied under cool, cloudy conditions, as it is unlikely to be effective under these conditions.

WEEDpak

section H3

Temperature variation within a day, however, does not have much effect on the efficacy of Daconate as shown in Table 6. Daconate is absorbed into the plant and has its herbicidal effect over time, so that efficacy is more affected by the temperature over a number of hours following spraying, rather than the actual temperature at the time of spraying.

Table 6. Yield reduction on cotton sprayed over-the-top with Daconate® at different temperatures and times on the same days.

	Time		
	6 am	10 am	3 pm
15 December Temperature (°C)	14	22	26.5
Yield reduction (%)	20	22	26
22 December Temperature (°C)	19.9	26	35
Yield reduction (%)	24	22	19

Halosulfuron-methyl (Sempra®, Group B)

Sempra is registered for controlling nutgrass in cotton, but must be applied through a shielded sprayer, to avoid herbicide contact to the cotton. Sempra inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition stops plant growth and plant death occurs 14 to 21 days after application.

Sempra does not persist for long in the soil, with a half-life of up to 34 days. However, most rotation crops are very sensitive to Sempra and the recommended plant-back period to rotation crops is 24 months.

Sempra has the advantage that it kills nutgrass plants reasonably quickly and can be very effective early in the cotton season. However, Sempra does not tend to translocate through the nutgrass rhizomes. Consequently, Sempra does not give good control of tubers attached to sprayed plants and gives little control of unsprayed nutgrass in the plant-line when it is applied through a shielded sprayer, as shown in Table 7.



Sempra® applied through a shielded sprayer (foreground plot) controlled nutgrass in the furrow (sprayed area), but gave little control of the unsprayed plant-line.

Table 7. Reduction in leaf number and tuber number of sprayed and unsprayed nutgrass plants attached to sprayed plants. Plants were grown in divided pots and sprayed 4 or 10 weeks after first shoot emergence. They had on average 59 and 153 leaves at spraying, respectively.

Sempra rate (g/ha)	Nutgrass age	Sprayed	Unsprayed
Reduction in leaf number (%)			
70 g	4 weeks	12	0
	10 weeks	0	0
140 g	4 weeks	56	0
	10 weeks	56	0
Reduction in number of viable tubers (%)			
70 g	4 weeks	58	0
	10 weeks	39	0
140 g	4 weeks	92	0
	10 weeks	79	23

Glyphosate (various trade names, Group M)

Glyphosate is registered for controlling nutgrass in cotton. In conventional cotton, glyphosate must be applied through a shielded sprayer, with the spray nozzles positioned so as to **avoid any spray contacting** the cotton foliage. Glyphosate can be applied pre-cotton emergence, in-crop as a shielded spray, at defoliation, or after picking. Roundup Ready Herbicide® can be applied over-the-top of Roundup Ready® cotton up to the 4th true cotton leaf, but must not be applied to the foliage of older Roundup Ready plants. Glyphosate cannot be applied to Roundup Ready cotton at defoliation. For more information, refer to **Managing Roundup Ready® Cotton** and **SPRAYpak/ Spray Application in WEEDpak**.

Glyphosate inhibits EPSP synthase, which prevents protein synthesis and kills the plant. Glyphosate is effective against most plants, but the herbicidal effect is quite slow, often taking 2 to 3 weeks. Glyphosate is far more effective when applied to rapidly growing plants. Spray failures can occur when glyphosate is applied to stressed plants. This is particularly true with nutgrass, where glyphosate applications to stressed plants are often ineffective.

Glyphosate is rapidly adsorbed and inactivated on contact with the soil. Consequently, it has no residual effect, although its breakdown in the soil is comparatively slow, with a half-life of 47 days.

Glyphosate can be effective in controlling nutgrass. It translocates within the sprayed nutgrass plant and also to attached tubers and plants. This translocation means that glyphosate can kill the nutgrass plants it is sprayed on, but can also kill attached tubers and nutgrass plants in the cotton row that were not sprayed.



Glyphosate applied through a shielded sprayer controlled nutgrass in the furrow and controlled some nutgrass in the unsprayed cotton plant-line.

Herbicide efficacy on the major species

Zoliar is effective against all nutgrass species, as it is effective against both tubers and seedlings. Heavy rates of Zoliar are necessary to control plants growing from tubers, but much lighter rates of Zoliar should be adequate to control seedlings, with application timed to occur prior to expected weed germination. Much shallower soil incorporation should also be used for seedling control, as seedlings will not emerge from more than a few mm depth. Lighter rates, shallowly applied should give good control of species that only grow from seed such as dirty Dora, umbrella sedge and rice flatsedge.

Arsenal is equally effective against all nutgrass species, controlling seedlings and emerging shoots.

The three major species, nutgrass, Downs nutgrass and yelka have differing sensitivities to the contact herbicides. All herbicides are more effective on younger rather than older plants (Tables 8, 9 & 10).

Table 8. Herbicide efficacy of the contact herbicides on nutgrass (*C. rotundus*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	0
		2.8 L	25
	Sempra	70 g	46
		140 g	100
8 weeks	Roundup CTXtra	1 L	96
		2 L	100
	Daconate	1.4 L	0
		2.8 L	0
	Sempra	70 g	8
		140 g	0
	Roundup CTXtra	1 L	81
		2 L	87

Daconate, which suppresses nutgrass, is much more effective on Downs nutgrass and yelka.

Sempra is effective on young nutgrass plants, especially at the higher rate, but is much less effective on older plants. Sempra is more effective on downs nutgrass and yelka, but the same trend occurs with age, being more effective on younger plants.

Table 9. Herbicide efficacy of the contact herbicides on downs nutgrass (*C. bifax*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	29
		2.8 L	50
	Sempra	70 g	67
		140 g	75
8 weeks	Roundup CTXtra	1 L	92
		2 L	100
	Daconate	1.4 L	44
		2.8 L	50
	Sempra	70 g	11
		140 g	25
	Roundup CTXtra	1 L	94
		2 L	100

WEEDpak

section **H3**

Glyphosate gave good control of all species at both growth stages, although results in the field are not always so consistent.

Table 10. Herbicide efficacy of the contact herbicides on yelka (*C. victoriensis*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	100
		2.8 L	75
	Sempra	70 g	69
		140 g	100
8 weeks	Roundup CTXtra	1 L	87
		2 L	100
	Daconate	1.4 L	42
		2.8 L	50
	Sempra	70 g	0
		140 g	37
	Roundup CTXtra	1 L	100
		2 L	87

Factors that affect Zoliar efficacy

Zoliar is best suited to light, acid soils, where it is very effective at relatively light rates. In Arizona (USA), for example, Zoliar is very effective when applied post-cotton emergence at 1.5 kg/ha, but will kill cotton if applied pre-planting at this rate. Lighter rates should be used when applying Zoliar to light acid soils in Australia.



Cotton and nutgrass on a light, acid soil in Arizona severely affected by 1.5 kg of Zoliar.

Zoliar can behave quite unpredictably in alkaline, heavy clay soils, and must be applied at higher rates on these soils to be effective (4 kg/ha in the first season with lower rates used in subsequent seasons). In some situations, it appears that Zoliar is some how “bound-up” in the soil for some weeks after application, apparently becoming effective only six or so weeks after application. The length of this time period is influenced by soil moisture.

Consequently, it is recommended that Zoliar be applied to alkaline, heavy clay soils in about May, prior to a cotton crop. Thorough incorporation is essential for best results. This is most easily achieved by broadcasting Zoliar before listing. Zoliar is then thoroughly incorporated into the hills through listing, although the Zoliar rate in the furrows may be relatively low.

Good results have been achieved by applying very heavy rates of Zoliar to heavily infested nutgrass patches in fields, and on head and tail ditches. These rates could not be safely used on lighter soils.

Results from an experiment using very heavy rates of Zoliar are shown in Table 11. In this experiment Zoliar was applied over-the-top of 4-leaf cotton. Use of these rates is contrary to the pesticide label. To use higher than label rates, growers must first obtain a use permit from the NRA (National Registration Authority).

The combination of Zoliar applied pre-planting and glyphosate applied in-crop gave the most effective control of nutgrass in this experiment. The very high rates of Zoliar did cause significant leaf damage to the cotton (applied over-the-top of young cotton), but did not adversely affect crop yield.

Table 11. Shielded Roundup and heavy rates of Zoliar for nutgrass control applied over 2 seasons. The initial nutgrass infestation averaged 456 tubers/m². Specific permit permission must be obtained from the NRA before pesticides can be used outside the label recommendation.

	Rate/ha	Tubers per m ²	Lint yield (kg/ha)
Untreated	-	1213	1467
Roundup CT	2.4	1076	1674
Zoliar	4	434	1564
Zoliar	16	133	1791
Roundup CT + Zoliar	2.4 + 4	152	1600
Roundup CT + Zoliar	2.4 + 16	35	1759

Factors that influence glyphosate efficacy

Glyphosate seldom gives 100% control of nutgrass in the field, even under the best conditions. One reason for this is that a nutgrass population includes plants at all stages of growth, including dormant tubers, shoots that have not emerged above the soil surface at the time of spraying, and newly emerging shoots. The emerged shoots are difficult or impossible to spray due to their small size and because they are often protected from the spray by other plant material. The problem of spray penetration can be a major limitation to control of a dense stand of nutgrass.

An apparent spray failure with glyphosate may not be caused by poor herbicide efficacy, but by the emergence of new nutgrass shoots from previously dormant tubers and from plants that were not sprayed. This is especially true with early season glyphosate applications, as new shoots may continue to emerge through to early summer. These shoots are connected to previously dormant tubers that were not previously susceptible to treatment. The emergence of new shoots after spraying should not be viewed as a spray failure but as an opportunity to treat a new portion of the nutgrass population. A dense nutgrass infestation can contain up to 14 000 tubers/m², but will have only about 2200 shoots/m². This means that a high proportion of tubers may not be directly connected to live shoots.

Repeated treatments are the only sure way of controlling nutgrass with glyphosate.

Growers should always aim to apply at least two in-crop shielded applications of glyphosate in cotton. These applications should be timed to occur after irrigation in about mid-December and mid-January, before the canopy closes. Ideally the second application should occur about four weeks after new shoots begin to emerge following the first glyphosate application.

Nutgrass age

Nutgrass plants are most susceptible to glyphosate when they are young, and become progressively more tolerant as they age. Freshly emerged shoots are much easier to kill than are mature plants. This is shown in the data in Tables 8 and 13. Flowering has little impact on glyphosate susceptibility, but flowering plants are much less susceptible than are younger plants.

However, except during early spring, or after cultivation or a successful herbicide application, a nutgrass population includes plants at all stages of plant maturity. Almost from the moment the first shoot appears in spring, nutgrass plants produce new tubers that produce new plants, that produce new tubers, and so on. These new tubers are initiated within days of the first shoot emergence. Viable new tubers and new plants can be formed within 4 to 6 weeks of the first shoot emerging. Consequently, at any point in the season, a nutgrass population includes freshly emerged shoots, through to mature plants. The potentially rapid increase in a nutgrass population is shown in Figure 1. Competition from cotton can greatly reduce this rate of reproduction in the cotton row. Vigorously growing cotton may also shade the furrow and compete strongly with the nutgrass.

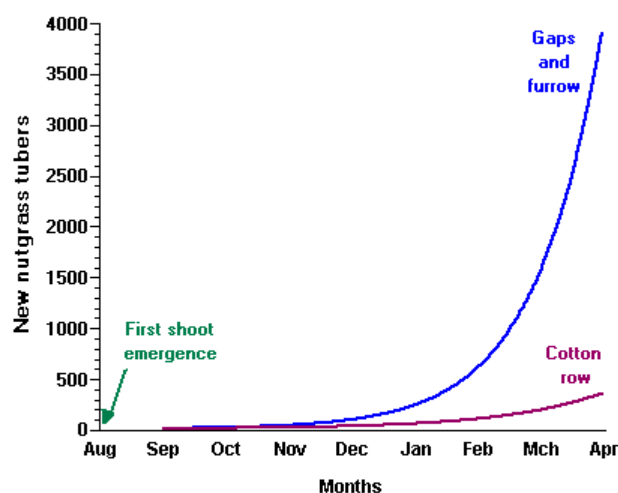


Figure 1. Nutgrass tuber production in cotton starting from a single tuber in spring. Nutgrass is intolerant of shading and produces fewer tubers in the cotton row.

The glyphosate labels generally recommend that spraying be delayed until nutgrass plants reach at least 20% flowering, in about February. This recommendation is based on a misunderstanding of the need for nutgrass to be flowering before herbicide application. This misunderstanding assumes that older nutgrass plants are more sensitive to glyphosate and that nutgrass plants translocate assimilates to their attached tubers after flowering in autumn. Neither of these assumptions is correct.

Unlike many other perennial plants, nutgrass does not predominantly move assimilates (nutrients) down to its roots and tubers in autumn prior to plant dormancy. The movement of assimilates in nutgrass is a continuous process and is more apparent in younger plants than older plants. Almost from initial shoot emergence, nutgrass produces new tubers and assimilates are being continuously moved down to the roots and tubers, to provide for the production of these new roots and tubers. Consequently, glyphosate translocation to attached tubers occurs equally well at all stages of the season, although glyphosate is more effective in killing young plants and tubers than older plants.

Ideally, glyphosate should be applied to nutgrass within 4 to 6 weeks of first shoot emergence. This timing gives the best kill of plants and attached tubers, and ensures that plants are controlled before they reproduce, **provided that plants are not stressed at spraying**. Stressed plants are far less susceptible to glyphosate, and are unlikely to be killed by an application.

Stressed plants

Nutgrass is capable of very rapid growth, but is very easily stressed by factors such as low temperatures, low soil moisture, cultivation and other herbicides. Like most weeds, nutgrass is far more susceptible to glyphosate when the weed is rapidly growing. Even very high rates of glyphosate are likely to be ineffective in controlling nutgrass when it is stressed.

Moisture stressed plants are best controlled by cultivation. Where this is not possible or not practical, spraying should be delayed until after plants have resumed normal growth.

Low temperatures

While early spring may seem to be an ideal time to apply glyphosate to nutgrass, there have been many spray failures at this time caused by the nutgrass being stressed by low temperatures.

Glyphosate applications can be very effective in warm to hot conditions in October and November, but are likely to be ineffective when temperatures drop too soon after application. For effective control, hot conditions must continue for at least a week after spraying. A drop in temperature, or cool nights, may result in a spray failure.

Similarly, cool conditions in autumn are likely to result in spray failures.

Reliable control of nutgrass can generally be achieved from mid-November onwards, although this date will be earlier in the northern regions and can be much later in the cooler areas. Nevertheless, spraying earlier in the season can be very effective when conditions are favourable.

Low soil moisture

Nutgrass has a shallow, fibrous root system that makes it very prone to moisture stress in the cotton system. Experience has shown that nutgrass is most susceptible to glyphosate when the weed is rapidly growing, immediately after irrigation or rainfall. Ideally, glyphosate should be applied to the nutgrass as soon as possible after irrigation or rainfall.

The exception to this is that glyphosate can be very effective when applied to moisture stressed nutgrass, provided that rain or irrigation occurs within hours of the application. Applying glyphosate to nutgrass immediately before irrigation can be a practical way to overcome the difficulty of wet tail ditches etc.

Cultivation

One of the practical difficulties of controlling nutgrass with glyphosate can be the need to delay inter-row cultivation to allow nutgrass to grow sufficiently to be sprayed.

Nutgrass should be allowed to grow for at least four weeks between cultivation and spraying. Cultivation should then be delayed for at least one week after spraying and two weeks if possible. Cultivating within a week of spraying can reduce spray efficacy, as shown in Table 12.

Table 12. Reduction in Roundup CT efficacy from simulated, post-spraying cultivation. Nutgrass plants were sprayed 6 weeks after first shoot emergence of plants growing in pots.

Herbicide rate (L/ha)	Post-spraying cultivation	% Kill	Leaves per plant
-	-	0	125
2.4	-	75	0.3
2.4	2 days	25	7
2.4	4 days	50	3
2.4	8 days	25	14

Glyphosate rate

Most glyphosate labels recommend a split application of herbicide at **1 L active** per ha per application. This rate has generally been adequate to control nutgrass in most situations, with the second application greatly improving the final result.

A range of other glyphosate rates has been used on nutgrass over the years with varying success. Half the recommended rate has been adequate to control nutgrass under ideal conditions, as shown in Tables 13 and 16, but has often lead to spray failures (also shown in Table 13). A higher rate (such as 2 L active/ha) will give better control in some situations, but is not generally needed and may not be cost-effective. Increasing the rate beyond 1 L active/ha will not generally overcome limitations such as the plant being stressed by cool temperatures or lack of soil moisture, but will greatly increase the risk of damage to the crop when applied as an inter-crop spray.

Water quality

One of the desirable characteristics of glyphosate is its ability to be rapidly adsorbed to soil particles and inactivated. This makes glyphosate ideal as a knockdown herbicide prior to planting or even between planting and crop emergence. Glyphosate can also be inactivated by metals and ions in the spray solution, and is very sensitive to zinc, which is present on galvanized surfaces.

These qualities make glyphosate very sensitive to water quality. Glyphosate efficacy can be reduced by dirty water, by hard water, by alkaline water and by metal ions. To avoid problems with water quality, it is important to use the best quality water available and to ensure that glyphosate remains in the spray tank for as short a time as possible.

Under most circumstances, however, water quality should not be a major factor reducing the efficacy of glyphosate on nutgrass, provided the spray mixture is not allowed to sit for an extended period.

Table 13. Herbicide efficacy of two rates of Roundup CT on nutgrass applied 3 or 6 weeks after first shoot emergence of plants grown in pots. The herbicide was applied in 100 L water/ha with 0.4% Turbo P (non-ionic surfactant) added. The spray mix was allowed to sit for 24 hours before spraying. Water quality is shown in Table 14.

Age	Rate (L/ha)	Source	% Kill
3 weeks	1.2 L	Distilled	82
		Bore A	98
		Bore B	76
		River	100
		Channel	58
	2.4 L	Distilled	88
		Bore A	99
		Bore B	77
		River	94
		Channel	100
6 weeks	1.2 L	Distilled	37
		Bore A	5
		Bore B	0
		River	1
		Channel	0
	2.4 L	Distilled	78
		Bore A	42
		Bore B	93
		River	0
		Channel	81

Table 14. Water quality of the sources used in Table 13. The channel water was allowed to sit in storage for an extended period before use.

Source	pH	Conductivity (dS/m)	Hardness (Ca + Mg)	Chloride (mg/L)
Distilled	6.65	0	0	10
Bore A	6.62	0.36	164	15
Bore B	8.18	0.57	157	48
River	9.48	2.59	98	370
Channel	9.21	0.18	67	25

A comparison of glyphosate efficacy using a range of water sources where the mixture was allowed to sit for 24 hours (Table 13) showed that poor water quality could have a large effect on herbicide efficacy, but that the effects were not consistent. Results from a second experiment where the spray was used 3 hours after mixing showed no reduction in efficacy due to water quality.

In both experiments, herbicide rate and nutgrass age had as much impact on herbicide efficacy as did water quality.

Water rate

Most glyphosate labels recommend a maximum water rate at or below 100 L/ha. Common farm use is in the range of 40 to 60 L/ha, well below the maximum recommended rate.

Lower water rates improve spraying efficiency by increasing the area that can be covered by each tank load, but may also reduce the coverage of droplets on the target plant. Coverage and spray penetration into the plant canopy can be improved by using higher nozzle pressure, but this leads to the production of more small spray droplets and more spray drift. Higher water volumes and lower nozzle pressures are desirable when using an in-crop shielded application of glyphosate to reduce spray drift and thereby reduce damage to the crop.

Additives

A large range of wetters, surfactants and other additives is available for use with glyphosate and other herbicides. These additives can improve herbicide efficacy in some situations, but generally are not required with glyphosate. Some additives may have an inconsistent or negative affect in some situations, as shown in Table 15.

The addition of Prep® (ethephon) to glyphosate for example, may improve control in some situations, but Prep is antagonistic to glyphosate, causing the chemicals to come out of solution and may reduce glyphosate efficacy.

Table 15. The effect of some spray additives on glyphosate efficacy on nutgrass, sprayed 8 weeks after first shoot emergence.

	Treatment	% Kill	Leaves per plant
1	Untreated	0	234
2	Roundup 3 L	0	231
3	Roundup 3 L + 3% Agral 600	100	0
4	Roundup 3 L + Herbex 3 L	75	1
5	Roundup 3 L + Prep 0.3 L	0	50

Both percentage kill and leaves per plant data are shown in this and some other tables. Leaves per plant gives an indication of the suppression of plants that survived the treatment. A comparison of treatments 1 and 2, in Table 15 shows that the Roundup application (without additive) not only failed to kill the nutgrass, it failed to even suppress the weed. Treatment 5 (Roundup + Prep) also failed to kill the nutgrass, but did suppress the weed, causing a 79% reduction in leaf number.

Additives are often used to overcome poor application conditions, poor water quality, or antagonism from other tank-mixed herbicides. Generally, these additions do not fully overcome

the problems. No additive will make stressed nutgrass plants receptive to glyphosate.

However, experience in the field has shown that the addition of a non-ionic surfactant at 0.2% will often improve glyphosate efficacy, as shown with Agral 600 in Table 15. Data in Table 16 shows an improvement when using a non-ionic surfactant with low glyphosate rates, but no improvement when using the recommended rate of glyphosate.

Table 16. Nutgrass leaf production and % kill from three rates of Roundup CT with 4 rates of added non-ionic surfactant (Turbo-P).

Roundup CT rate	Surfactant rate (%)	% Kill	Leaves per plant
-	-	0	110
0.6	-	0	133
	0.2	25	80
	0.5	25	43
	1.0	25	75
1.2	-	25	61
	0.2	100	0
	0.5	100	0
	1.0	100	0
2.4	-	100	0
	0.2	100	0
	0.5	100	0
	1.0	100	0

Additives should not be used with over-the-top glyphosate applications to Roundup Ready[®] cotton, except as directed on the product label. The use of other additives could affect the activity of glyphosate and cause damage to the Roundup Ready cotton.

Tank-mixing

Glyphosate can be tank-mixed with a range of other herbicides. However, tank-mixing with some of the more commonly used cotton herbicides is likely to reduce glyphosate efficacy to some extent, as many of these herbicides contain some clay that will inactivate the glyphosate. The amount of reduction of glyphosate efficacy will depend on water volume and quality, the amount of clay in the tank-mixed herbicide, and the length of time the mixture stands in the spray tank.

Tank mixing with clay-based products should be avoided if possible. Ammonium sulfate should be added when tank-mixing with a clay-based product is necessary and higher glyphosate rates should be considered. Always ensure that these mixtures remain in the spray-tank for as short a time as possible.

Re-spraying interval

Glyphosate is frequently used to control other weeds at a lighter rate than the 1 L active/ha used for nutgrass. Ideally, nutgrass patches should be sprayed with a heavier rate at the same time by using a boom spray fitted with a second boom line with larger nozzles or by slowing the tractor to increase spray rate. The additional boom line is likely to give the better result of these two options as it is far easier for the operator to switch on or off an additional boom than to be constantly changing tractor speed.

Table 17. Effect of timing of a 1.4 L/ha (0.63 L active/ha) application of Roundup CT after a 1 L/ha (0.45 L active) application on nutgrass 3 or 6 weeks of age.

Nutgrass age	Initial spray rate	Time to re-spraying with 1.4 L	% Kill	Leaves per plant
3 weeks	-	-	0	108
	1 L	-	50	49
		at spraying	100	0
		1 week after	75	7
		2 weeks after	100	0
		3 weeks after	75	1
		4 weeks after	25	71
6 weeks	-	-	0	166
	1 L	-	0	32
		at spraying	25	1
		1 week after	25	52
		2 weeks after	50	1
		3 weeks after	0	4
		4 weeks after	0	24

However, if the two applications can't occur on the same day, the second application should be delayed for around two weeks, as shown in Table 17.

Herbicide efficacy is reduced when the two sprays are too close together due to the stress on the plant caused by the first spray. Glyphosate applied to a plant with the second spray is unlikely to be readily translocated or to be very effective, as the plant is already stressed and damaged by the first spray. However, if the sprays are too far apart, the affect of the first spray is lost.

For best control, nutgrass should be resprayed approximately four weeks after green shoots emerge.

Herbicide combinations

The best control of nutgrass has been achieved using multiple applications of glyphosate on a field that previously received Zoliar. However, this can be a very expensive option, as unless the nutgrass patches are well defined, the Zoliar must be applied to most or all of the field. GPS mapping of the nutgrass patches may be used to greatly reduce this cost.

An alternative strategy for lighter infestations of nutgrass that has been successfully used by some growers is to apply a tank mix of Zoliar and Semptra as a spot application in December, with a follow-up application of glyphosate in January. Both applications must be made through a shielded sprayer. The combination of Zoliar and Semptra is very expensive on a per hectare basis, but the applications can be very cost-effective when applied through a weed-activated sprayer so that the herbicide is only applied to the weed infestation.

Spraying equipment

In-crop applications of glyphosate must be applied so as to avoid contact with the crop foliage. The only exception to this is Roundup Ready cotton, which can be sprayed over-the-top with Roundup up to the fourth true leaf, in compliance with the product label.

Glyphosate can be applied in-crop as a directed spray or through a shielded sprayer. A range of equipment is available, at a range of prices, ranging from basic rubber or steel shields against the crop, to completely enclosed sprayers. The primary differences between these extremes of design is their ability to be safely operated in windy conditions, their ability to be adjusted to meet a range of requirements and crop size, and their ability to be used in a range of crop sizes without causing excessive physical damage to the crop.

It is essential when using any spray equipment to ensure that the equipment is properly set up and is used only under appropriate conditions. Generally, the more open the equipment design is, the more sensitive it is to windy conditions. Any air movement into the shield area will cause air movement back out of the shield area. This air is likely to carry fine spray droplets that may then be deposited onto the crop. Shields that have open fronts and tops are most prone to this movement, but some air movement is inevitable in even the best designed shields.

Nevertheless, even an open shield design can be used safely in the crop provided that it is used at low tractor speeds and low wind conditions, and with correctly set up and operated spray nozzles. Fine mesh such as shade cloth can be used to enclose the shields, greatly reducing air movement within the shield area and reducing the risk of crop damage from spray drift.

A range of nozzle designs is available, including low drift nozzles. Low nozzle pressure (pressures towards the bottom end of the recommended range for the nozzle) and high water volumes (allowing the use of larger nozzles) will also help reduce the production of fine spray droplets.

Once a shielded sprayer has been set up, it is important that it is regularly checked to ensure that nozzles are operating correctly, and that the operator is aware of the operating conditions. Operating a sprayer in windy conditions will inevitably lead to crop damage.

Crop competition

Although nutgrass can compete very strongly with cotton, nutgrass does not itself tolerate strong competition. Nutgrass has a fibrous, relatively shallow root system. This enables it to compete strongly early in the cotton season and to respond quickly after rain and irrigation, but it does not compete well with irrigated cotton later in the cotton season when soil moisture in the surface soil layers is limiting.



A section of a cotton crop severely infested with nutgrass. No harvestable cotton was present in this portion of the field.

Nutgrass is also relatively intolerant of shading and has a greatly reduced growth rate when shaded by a taller crop.

One of the keys to growing cotton and other crops in a field that is infested with nutgrass is to ensure that the crop establishes as quickly as possible and is able to shade-out the nutgrass. There are a number of management practices that can influence crop competitiveness, including:

- stubble management
- soil conditions
- crop species and variety selection
- sowing date, rate and depth
- seed dressings
- fertilizer type, rate and placement
- irrigation management (pre- and post planting)
- herbicides - residuals and knock-down pre-emergence and post-planting
- cultivations
- weed control (of nutgrass and other weeds)

These practices should be optimised to maximise crop competitiveness. The result of not optimising these factors can be that the crop does not establish vigorously on nutgrass infested areas and competes poorly, allowing the nutgrass to establish and spread. This worst-case scenario can result in a crop failure with no harvestable crop.

One of the most common problems with establishing rotation crops is inadequate soil moisture and nutrition in the nutgrass infested areas. The main part of a field may have good moisture and nutrition following a cotton crop, but both these inputs are likely to be lacking on nutgrass infested areas, as the weed has already used these resources during the cotton season. Consequently, crop establishment is comparatively poor on the nutgrass infested areas. Irrigation at planting and inclusion of a starter fertilizer with the crop can make a large difference to the crop's competitiveness and its impact on nutgrass.

Developing an IWM program for nutgrass

Nutgrass is a perennial weed that will not be controlled with any single treatment. Successful nutgrass management is built on using as many management tools as possible, at every available opportunity, over a number of years.

No one management program is suitable for every field and every season. The management tools can be successfully used in a variety of ways, depending on the extent of the problem and available resources.

The type of nutgrass program required for any individual field will depend on the extent of the problem and the management resources available.

Results from field experiments conducted over a number of seasons and a number of sites are shown in Tables 18 to 21. These results allow comparison of some treatments and treatment combinations.

Of the contact herbicides, multiple glyphosate applications have given the most reliable nutgrass control over a number of sites and seasons. However, glyphosate is only effective on actively growing nutgrass. The combination of glyphosate (applied on actively growing nutgrass) and cultivation (on moisture stressed nutgrass) can be used very effectively (Table 18).

The best results in cotton were achieved using a combination of Roundup and Zoliar (Table 19), with Zoliar incorporated pre-planting and two in-crop shielded applications of Roundup applied each season. This treatment (Treatment 8) resulted in an 88% decrease in the nutgrass population over two seasons, compared to a 5-fold increase in the nutgrass population where no treatment was imposed (Treatment 1).

The Roundup and Zoliar combination also resulted in the best cotton yield, 117% (3 bales/ha) higher than the untreated comparison (Treatment 1). This yield increase of 3 bales would have more than paid for the cost of treating the nutgrass. In addition, use of this treatment would result in a field starting the next season with a lower density of nutgrass than was initially present, potentially resulting in even better yields than were recorded over these two seasons.

Results using a range of herbicides and herbicide combinations on an initially much lighter nutgrass population were similar (Table 20), with the best nutgrass control (an 87% reduction in tuber density) from three in-crop Roundup applications (Treatment 4) and the best yield (a 47%, 1.7 bales/ha increase) from 2 in-crop applications (Treatment 3). The slight reduction in yield associated with the third Roundup application was probably caused by crop damage from the additional herbicide application, as the herbicide



WEEDpak

section **H3**

was applied through a poorly designed shield which allowed some herbicide drift to the crop.

The improvements in crop yields after treatment would probably have been even better if better designed equipment and/or Roundup Ready cotton had been used. Generally, any damage to the cotton from the herbicide application is more than compensated for by the associated reduction in weed competition resulting from the reduction in the nutgrass population. Nevertheless, it is essential to only apply glyphosate through a well designed and properly set-up shielded sprayer, operating in appropriate conditions. This is equally true whether using conventional or Roundup Ready cotton varieties.

Results from a more extensive comparison of Roundup and Zoliar combinations are shown in Table 21. In this experiment, the best nutgrass control was achieved using a single Roundup application in early December (Treatment 4), which resulted in a 97% decrease in the nutgrass density.

However, results from a single Roundup application were highly variable (compare Treatments 2 to 7). This variability reflects the normal variability of results often achieved with glyphosate and was caused by a number of factors including the condition of the nutgrass at the time of spraying. On some occasions, the nutgrass was highly stressed at spraying, resulting in a poor kill. Growers should be able to achieve much better results by targeting conditions that are more suitable for glyphosate when nutgrass is actively growing.

Table 18. Changes in nutgrass density in a fallow with treatments over 2 seasons. The area initially had an average nutgrass infestation of 334 tubers/m².

Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²
Untreated	-	-	3879
Cultivation	-	8	1114
MSMA	2.8	2	2895
MSMA	2.8	4	789
Roundup CT	2.4	2	668
Roundup CT	2.4	4	346
Roundup CT	4.8	4	150
Roundup CT	2.4	8	47
Cultivation + Roundup CT	2.4	4 + 4	118

Table 19. Changes in cotton lint yield and nutgrass density with in-crop and residual herbicide treatments over 2 seasons. The area initially had an average nutgrass infestation of 1348 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			7194	582
2	Roundup CT	2.4	1	3728	547
3	Roundup CT	2.4	2	797	856
4	Roundup CT	2.4	3	611	891
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	741	987
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	1194	873
7	Zoliar + Roundup CT	3 + 2.4	1 + 1	786	660
8	Zoliar + Roundup CT	3 + 2.4	1 + 2	160	1262

Table 20. Changes in cotton lint yield and nutgrass density with in-crop treatments over 2 seasons. The initial nutgrass infestation averaged 338 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1097	819
2	MSMA	1.8	2	577	871
3	Roundup CT	2.4	2	223	1206
4	Roundup CT	2.4	3	43	1173
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	385	930
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	231	1126
7	MSMA + Roundup CT	1.8 + 2.4	1 + 2	108	1018
8	Sempra	0.14	1	552	944
9	Sempra	0.07	1 + 1	367	1047
10	MSMA + Sempra	1.8 + 0.07	1 + 2	386	1061
11	MSMA + Sempra + Roundup CT	1.8 + 0.14 + 2.4	1 + 1 + 1	278	992
12	MSMA + Roundup CT + Sempra	1.8 + 2.4 + 0.14	1 + 1 + 1	278	1143

Table 21. Changes in nutgrass density with in-crop treatments over 2 seasons and cotton lint yield in the first season. The initial nutgrass infestation averaged 456 tubers/m². The Zoliar was applied over-the-top of the cotton after crop emergence and the Roundup CTXtra was applied as a directed spray.

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1213	1467
2	Roundup CTXtra	2	early Nov	615	1588
3	Roundup CTXtra	2	late Nov	210	1661
4	Roundup CTXtra	2	early Dec	39	1486
5	Roundup CTXtra	2	late Dec	685	1532
6	Roundup CTXtra	2	early Jan	1076	1674
7	Roundup CTXtra	2	late Jan	410	1493
8	Roundup CTXtra	2 + 2	early Nov + late Dec	328	1371
9	Roundup CTXtra	2 + 2	late Nov + early Jan	667	1543
10	Roundup CTXtra	2 + 2	early Dec + late Jan	173	1532
11	Zoliar	4	Oct	434	1564
12	Zoliar + Roundup CTXtra	4 + 2	Oct + early Jan	152	1600
13	Zoliar + Roundup CTXtra	4 + 2 + 2	Oct + early Dec + early Jan	226	1573

A management program for heavy infestations

Cotton yields are reduced by nutgrass competition on a field heavily infested with nutgrass.

Consequently, it is important to try to reduce the weed infestation as quickly as possible to improve crop yields. To do this, it is necessary to use a range of treatments in combination, using as many treatments as practical each season. Examples of intensive management plans for conventional and Roundup Ready cotton are shown in Tables 22 and 23. It may not be practical or appropriate to use all of these treatments each season, but it is important to use as many treatments as possible, until the nutgrass population is reduced to a more manageable level.

Table 22. A management plan for back-to-back conventional cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in green type. An additional glyphosate application could replace the deep ripping operation if the soil is wet and the nutgrass is actively growing.

Operations	Crop
September cultivation planting	Cotton
October	
November MSMA application inter-row cultivation	
December glyphosate application	
January glyphosate application lay-by herbicide	
February	
March glyphosate application at defoliation	
April picking slashing	
May deep ripping Zoliar application incorporation	
June listing	
July herbicide or cultivation	Fallow
August	

A management program for lighter infestations

A less intensive nutgrass management program can be used once the weed density on a field has been reduced to a level where the nutgrass is not reducing cotton yield. This program needs to be responsive, allowing for additional treatments should they become necessary, and must include regular field inspection. Failure to adequately treat nutgrass can result in a field becoming rapidly reinfested.

Such a management program would probably not include broadcast applications of Zoliar but may include a spot application of Zoliar to nutgrass patches. The main component of the management program should be in-crop shielded applications of glyphosate, with at least one application each season. Ideally, a second application will be allowed for in case the first application is not effective.

Table 23. A management plan for back-to-back Roundup Ready cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in green type. An additional glyphosate application could replace the deep ripping operation if the soil is wet and the nutgrass is actively growing.

Operations	Crop
September cultivation planting	Cotton
October	
November Roundup application inter-row cultivation	
December Roundup application	
January Roundup application lay-by herbicide	
February	
March Roundup application at defoliation	
April picking slashing	
May deep ripping Zoliar application incorporation	
June listing	
July herbicide or cultivation	Fallow
August	

Summary

Eight different nutgrass species are commonly found in or around cotton fields. These species are quite different in their ability to spread from seed or rhizomes, and consequently require specific management strategies. Positive identification of the problem species is essential as the first step in a management program.

A range of management tools is available to manage these weeds. These tools include residual and contact herbicides, cultivation, and crop competition. There are also some management practices that can exacerbate a nutgrass problem and should be avoided whenever possible.

Management of nutgrass needs a long-term approach, as these weeds will not be eliminated by any single management option. A successful management program will include all the management tools, used in combination as opportunity arises.

Glyphosate and Zoliar® herbicides have given the most effective control of nutgrass over time. Glyphosate should ideally be applied in-crop twice each season. It must be applied through a well constructed, properly set up shielded sprayer, operating under favourable conditions, when applied in conventional cotton. Roundup Ready Herbicide can be applied with much greater safety in Roundup Ready cotton varieties.

Zoliar is a residual herbicide that must be applied in consecutive seasons to be fully effective. It has a long plant-back period to most rotation crops.

Farm machinery can be a major contributor to spreading nutgrass around a farm. Attention to machinery hygiene can be pivotal in a successful management program.

Case studies of grower experiences with nutgrass

Nutgrass on Kilmarnock

John Watson

I remember nutgrass starting to be noticeable on channels in 1975; it was endemic in the dryland cropping paddocks and grazing country. The local pharmacist and then chemical supplier gave me a few mLs of something in a small plastic bottle. It was to be the answer to our potential problem and think it was probably Roundup! I was overseas for three years and by 1978 there were now small patches in some of the fields. Despite all our efforts it got progressively worse.

Many chemical products were tried, all of which gave variable and inconsistent results. Zoliar was effective if thoroughly incorporated on the flat before hilling up. It's extended use lead to problems in rotation crops. Cotton grown in a field with a relatively low population of nutgrass at planting could see it so thick after three months that yield would be affected if no action was or had been taken.

Graham Charles commenced trial work in the 1990's on our worst block, which, at the time, was on the leased property "Nandewar". He tested a number of products over three years and the best results indicated multiple applications of one or more chemicals. Overall, the trials showed that a cost effective result could be obtained from an early application of Zoliar and single in crop spray of Roundup using shielded sprayers.

The nutgrass control program is now largely based on control in the fallow phase, Roundup or chisel ploughing dry soil; rotations, cereal every second or third year; and in crop shielded spraying. It can sometimes be advantageous to do a broadacre application of Roundup after planting but before crop emergence. The result is quite variable, probably because of low temperatures especially here in the upper Namoi.

Roundup Ready® cotton will allow an over the top application after emergence and should therefore give better control as temperatures should be higher. Other than this obvious advantage, we will use much the same practices with Roundup Ready cotton, but will be looking to alternate some of the non-crop sprays with other chemistry to delay the onset of resistance of weeds to Roundup.

Case studies of grower experiences with nutgrass

Nutgrass Control at Norwood

Peter Glennie and Kylie May

Nutgrass has always been present on “Norwood”. Years of flood inundation (prior to development), grazing and cultivation led to the gradual spread of the weed around the farm.

Early control methods consisted of cultivation and herbicides such as MSMA and glyphosate - all to varying degrees of success. The late 80's saw the introduction of Zoliar, which was incorporated into the control program. The worst areas were attacked first. The cost of Zoliar prohibited full field sprays in all but the worst fields, so various methods of spot spraying were tried, including manually turning small tractor mounted booms on and off, a spray boom on the back of a slasher at picking time and spraying with a quad. Zoliar was applied both at planting and picking and it was discovered that it wasn't until about the third year into the Zoliar program, that the nutgrass really started to respond to the applications. The patches were still there, but they were getting smaller and thinner.

The early 90's saw little or no irrigation water from Copeton and not much more rain. Water was conserved in the soil by preparing the hills early then leaving them to sit until planting time. Although this was a good drought strategy, the reduced disturbance saw nutgrass areas increase again.

A very dry winter in 1994 resulted in no winter crops being planted. This left an opportunity to grow a green manure crop the following summer. A lablab/forage sorghum mix was planted in December and left to grow for three months before being rolled and ploughed back into the ground. The following summer saw a marked reduction in the amount of nutgrass in those fields, probably due to a combination of the competition from the lablab/forage sorghum, and the extra cultivations needed to work the high amount of dry matter back into the soil. This result has been repeated in other years with lucerne and again this season with another lablab/forage sorghum mix that was planted last summer. Although this did reduce the amount of nutgrass in the field, other methods of control are necessary to keep the patches from increasing.

Zoliar still forms part of the nutgrass control program on “Norwood”, although it is now mostly applied with a GTS sprayer, which has allowed more accurate targeting of the weed. Other methods of control are continually being trialled, both for better control and to hopefully reduce the amount of Zoliar in the soil, which limits rotation crop choice. Increased seed bed preparation, particularly deep cultivation, is having an affect, although more work still needs to be done.

This season (2001/02), saw the first commercial use of Roundup Ready cotton and herbicide. The herbicide had a dramatic effect on nutgrass patches, at a time of the season, when control is most important. It has allowed the cotton to out compete the nutgrass, without the need for extra cultivations. The wet November possibly helped contribute to the good result, by keeping the nutgrass fresh and more receptive to the Roundup Ready herbicide. It will be interesting to see if the result can be repeated over the next few seasons - here's hoping it will.

Currently we are trialling a more aggressive approach with the use of a large ripper with a wire cable connecting all the tynes. This cable is situated at the back of the tyne and is pulled by a D9N bulldozer, about 1 foot into the ground. The thought is that it will cut off the nuts from below and dry out the nuts above. So far the results are promising.

Case studies of grower experiences with nutgrass

Nutgrass control on Auscott Narrabri

David Wood

Nutgrass has been a problem on Auscott for a long time, but the issue came to a bottleneck over the last couple of years. Some fields were becoming so heavily infested that it was no longer economical to continue growing cotton.

The increase in the nutgrass populations was due to number of factors,

1. Succession of wet winters
2. Lack of effective in crop control options
3. Reduced tillage at depth

The run of wet winters reduced opportunities to use tillage as a control method, and resulted in operations for seedbed preparation being undertaken in less than ideal conditions. This made it very difficult to uproot and expose the tubers to desiccation as the nuts remained in moisture. Consequently, this simply spread the nutgrass from head ditch to tail drain.

In the past Zoliar was used as a broad acre spray across heavy infestations, however, its use was limited because of the restrictions that it imposed on future rotation crops. Due to the rotation issue Roundup was than used as an in crop control through shields. This also provided challenges with drift onto susceptible plants. MSMA was then used because of the greater crop safety, though unfortunately its success was variable. Semptra was also tried but was relatively ineffective. Together they gave reasonable control to continue cotton production, but were unable to stop the population from steadily increasing.

The situation took a turn for the better with the onset of Roundup Ready cotton. The Roundup Ready technology provided the opportunity to attack the nutgrass in the plant line early season, allowing the cotton to grow away and out compete the weed. The results from the Roundup spray are still sometimes variable, however, the successive applications achieve good brown off of the shoots more regularly, which is then followed by cultivation. In some cases it was taking the nutgrass 3-4 weeks to come back.

Zoliar is still an important part of the program on Auscott. Fields with light infestations are spot sprayed with a row weeder to prevent patches from spreading. It is also now sprayed through all rotobuck and tail drains in an attempt to stop cultivators from dragging the nuts down the field.

In combination with the chemical approach, rotation and tillage play an important role. The use of deep rooted crops, such as lucerne or safflower, dry out the soil profile and allow for deep ripping to expose nuts to desiccation. The advantage of lucerne over other crops is that if rains just prior to tillage, then it can be left to continue growing and draw the moisture out again, which is something that safflower or wheat cannot do if they have reached maturity.

At the end of the cotton season a Roundup spray at 2-3L/ha straight after harvest has shown signs of significantly reducing nutgrass populations in the following year. We are not sure if it will work each year, however, the results are encouraging.

MANAGING POLYMERIA (TAKE-ALL) IN COTTON

Graham Charles and Stephen Johnson

(NSW Agriculture & University of New England)

Contents	Page
The polymeria plant	H4.1
Cultivation	H4.2
Herbicides for managing polymeria	H4.3
Imazapyr (eg. Arsenal®)	H4.3
Triclopyr & picloram (eg. Grazon®)	H4.4
Glyphosate (eg. Roundup®)	H4.4
Glyphosate rate	H4.5
Timing of glyphosate applications	H4.6
Additives to enhance glyphosate efficacy	H4.7
Glyphosate formulations	H4.8
Using glyphosate in the field	H4.9
Fluroxypyr (eg. Starane®)	H4.9
2,4-D amine	H4.10
Using 2,4-D in the field	H4.11
Herbicide combinations	H4.11
Summary	H4.11
A grower's experience with polymeria	
Polymeria (Take-all) on Colly Farms	H4.12

The polymeria plant

Polymeria (*Polymeria longifolia*) is a member of the Convolvulaceae (bindweed) family. Polymeria, also known as polymeria take-all and Peak Downs curse, is a native Australian plant, which occurs through many of the Queensland and New South Wales cotton growing areas. It was present in many cotton fields before they were developed, and persists after development.

Polymeria is a deep-rooted, rhizomatous, perennial weed that tends to grow in dense patches. Its rhizomes can extend to 1.5 metres depth in the soil, with roots extending below the rhizomes. Shoots can emerge from 20 cm depth. Once established, its rhizomes form a dense mat that spreads throughout the soil under a polymeria patch. Polymeria spreads from these rhizomes and can rapidly re-establish from the rhizomes if the above ground plant material is removed by cultivation, chipping or herbicides.

Polymeria is an erect plant, 7 – 25 cm tall. Its leaves are green to grey or silver in colour and are covered in fine hairs. Polymeria has a prominent pink or white trumpet-shaped flower, with a yellow centre, 2 – 2.5 cm in diameter. It produces large, brown, velvety seeds, 3 – 5 mm across, with one or two viable seeds per seed capsule. Polymeria spreads from both seeds and rhizomes.



Polymeria is a member of the bindweed family and has prominent, pink flowers. Polymeria plants grow in dense patches.



Polymeria was established on this area in the Moree watercourse prior to the development of the road.

Polymeria can grow all year round in warmer areas, but is frost sensitive and is burnt by frosts. Some shoots will persist through winter and new

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

shoots emerge early in spring. Plants grow rapidly over the warmer months. Flowering normally commences in mid-summer.

Polymeria patches are relatively stable, but spread slowly year after year. Once polymeria becomes established, it competes strongly with cotton, and is resistant to most management approaches. Patches of polymeria with a density of 100 stems/m² or more can reduce cotton yield by 50%. This, and higher densities, are common in many patches. Polymeria competes strongly for soil water and nutrients, depleting the cotton crop of these resources.

Cotton generally establishes poorly on polymeria patches, often resulting in islands of solid green (polymeria) amongst cotton rows. If unchecked, these islands can easily grow to 50 or 100 m across. Eventually, polymeria can spread from small patches to cover a significant proportion of a field. On one field at Twynam North, the area of polymeria increased by approximately 1% per year over an 8-year period, rising from 5.6% of the field area in 1988 to 14% in 1996. No cotton grew to maturity on these patches. In 1996, this represented a yield loss of 158 bales or \$94 000 on this field alone. A number of other fields had smaller infestations.



Polymeria forms dense patches. Cotton generally doesn't grow to maturity in these patches.

Dense infestations of polymeria are established on over 2500 ha of cotton country. Lighter infestations occur on a much greater proportion of the cotton

area. These lighter infestations should be managed, and should be managed to prevent them becoming major problems. Special care should be taken to avoid spreading this weed when developing country infested with polymeria.



Inter-row cultivation delays polymeria growth, but shoots re-emerge from underground rhizomes. Inter-row cultivation doesn't control the weed in the plant row.

Cultivation

Polymeria has been regularly subjected to cultivation operations ranging from light inter-row cultivation in moist fields, through to deep cultivation under dry conditions. Polymeria is not controlled by normal cultivation practices, but cultivation in dry conditions may set polymeria back. Heavy cultivation in dry conditions may assist with controlling polymeria.

Cultivation in moist conditions can spread polymeria, as polymeria can establish and grow from small pieces of rhizome spread by the cultivator. Cultivators can inadvertently carry polymeria pieces into new fields where they may establish.

Polymeria's tolerance to cultivation is due to its deep rooting habit, with rhizomes penetrating well over a metre into the soil. Standard cultivation is at best only trimming surface growth, allowing plants to re-establish from the rhizomes below the cultivated zone.

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

Herbicides for managing polymeria

A range of herbicides has been trialled on polymeria, over a number of seasons with mixed and often poor results. Many herbicides will burn-off the above-ground plant material, but the weed rapidly reinfests from the large mass of rhizomes present under the polymeria patches. These rhizomes act as a continuous source of reinfestation.

No herbicides are registered for controlling polymeria.

Best results have been obtained with applications of Arsenal, Grazon, Roundup, and Starane. A range of other herbicides, including Ally, Atrazine, Basagran, dicamba, Garlon, Glean, and Staple have been trialled, but do not satisfactorily control polymeria. Assessment of the efficacy of 2,4-D is continuing.

A permit must be obtained from the National Registration Authority before using a herbicide to control polymeria in any situation.

Imazapyr (eg. Arsenal®)

Arsenal is a residual soil sterilant, effective in controlling most plant species. Arsenal is both root and shoot absorbed, acting as both a contact herbicide and a residual herbicide. Arsenal is highly persistent, with a half-life of up to 142 days. It can control weeds for up to three years when applied at the registered rate. It is ideal for controlling weeds on roadways, the outsides of channel banks, and other non-crop areas.

Arsenal is weakly adsorbed to soil and can move many metres from the site of application. It should never be applied in-crop or in an area where soil or water movement can carry the herbicide into a sensitive (crop) area.

Arsenal inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition rapidly leads to plant death.

Arsenal gave short-term control of polymeria when applied at 2 L/ha or more (Table 1). Better control was achieved with higher rates (Table 2). However, polymeria persisted in areas sprayed with Arsenal, even when applied at rates as high as 6 L/ha.

Table 1. Polymericia control in cotton using over-the-top applications. The treatments were assessed 63 days after the initial treatment on December 20, 1996.

Treatment	Application(s)		Weed rating ¹ after 63 days
	20 Dec	15 Jan	
Untreated			100
Roundup CT	2.4 L/ha		80
Roundup CT		2.4 L/ha	57
Roundup CT	2.4 L/ha	2.4 L/ha	47
Staple		240 g/ha	100
Staple	120 g/ha	120 g/ha	93
Arsenal	0.5 L/ha		50
Arsenal	1 L/ha		47
Arsenal	2 L/ha		17

Weed rating¹ is a percentage rating from 0 (no live polymericia) to 10 (100% of plot covered in live plants) based on a visual estimation.

Table 2. Polymericia control in fallow, sprayed on October 10, 1996. Treatments were assessed after 97 and 376 days.

Treatment	Weed rating after	
	97 days	376 days
Untreated	100	90
Arsenal 2 L/ha	21	17
Arsenal 6 L/ha	8	1
Starane 2 L/ha	42	64
Starane 6 L/ha	30	35
Garlon 100 mL/ha	83	76
Garlon 300 mL/ha	56	73
Glean 20 g/ha	48	47
Glean 60 g/ha	94	100
Ally 10 g/ha	71	36
Ally 30 g/ha	70	76
Express 30 g/ha	78	76
Express 90 g/ha	64	54

Arsenal must never be used in a crop area.



Arsenal used to control polymericia on a channel bank.

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

Triclopyr & picloram (eg. Grazon®)

Grazon is a mixture of picloram and triclopyr. It is effective on a wide range of difficult-to-kill, broad leaf weeds. Grazon is a residual herbicide, with both shoot and root activity. It is not safe to apply to cotton, and has a plant-back to cotton of many months. Grazon can be used in non-cotton areas and fallow fields. It has a plant-back to wheat and barley of 2 to 4 months (depending on the application rate). Always check the product label before using a herbicide.

Triclopyr is moderately persistent, with a half-life of about 30 days. Picloram is more persistent, with a half-life of about 90 days, although it can break down much more quickly under warm, moist

conditions, and more slowly under cool, dry conditions. Picloram is highly leachable. Both chemicals have the same mode of herbicidal action, acting on the plant's cell walls, causing cell elongation, and affecting cell division, causing plant death.

Grazon gave good control of polymerica when applied at 2 L/ha, with applications in December and February (Table 3), reducing the polymerica population to negligible levels in the first season of application. Nevertheless, some polymerica shoots are still emerging after three seasons of applications. Grazon is suited to spot-applications in fallow fields and non-cotton areas.

Table 3. Polymerica control in a fallow. Herbicides have been applied at the nominated time each season since December 1999. Herbicides were applied regardless of the condition of the polymerica (stressed or actively growing).

Treatment	Initial 10 Dec 99	Visual assessment of weed rating at:		
		208 days 5 Jul 00	678 days 18 Oct 01	861 days 19 Apr 02
Untreated	33	43	40	77
Roundup CTXtra 6 L/ha (Sept)	47	60	50	77
Roundup CTXtra 6 L/ha (Sept & Dec)	87	23	37	43
Roundup CTXtra 6 L/ha (Nov & Jan)	53	3	20	17
Roundup CTXtra 6 L/ha (Mar)	70	30	40	77
Roundup CTXtra 6 L/ha (Sept, Dec & Mar)	47	20	0	1
Roundup CTXtra 18 L/ha (Nov)	23	10	58	53
Roundup CTXtra 18 L/ha (Nov & Jan)	60	3	1	0
Starane 2 L/ha (Mar)	50	32	57	63
Starane 2 L/ha (Dec & Feb)	33	0	2	5
Grazon 2 L/ha (Dec & Feb)	80	3	1	2
Tordon 75D 3 L/ha (Mar)	33	3	2	43



Glyphosate can be an effective tool for in-crop management of polymerica. At this crop stage, glyphosate must be applied using spray shields to prevent the herbicide contacting the crop foliage.

Glyphosate (eg. Roundup®)

Glyphosate kills most plants, including conventional cotton. It can be applied to fallows, but must be applied through a shielded sprayer, set up to avoid any contact with cotton foliage when applied to conventional cotton. Glyphosate can be applied pre-cotton emergence, in-crop as a shielded spray, at defoliation, or after picking.

Roundup can be applied over-the-top of Roundup Ready cotton up to the 4th true cotton leaf stage, but must not be applied to the foliage of older Roundup Ready plants. Roundup must be applied as a directed or shielded spray after the 4th leaf stage. Glyphosate cannot be applied to Roundup Ready cotton at defoliation.

Glyphosate inhibits EPSP synthase, which prevents protein synthesis and kills the plant. Glyphosate is effective against most plants, but the herbicidal effect is quite slow, often taking 2 to 3 weeks. Glyphosate is far more effective when applied to rapidly growing plants. Spray failures can occur

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

WEEDpak – a guide for integrated management of weeds in cotton

when glyphosate is applied to stressed plants.

Glyphosate is rapidly adsorbed and inactivated on contact with the soil. Consequently, it has no residual effect, although its breakdown in the soil is comparatively slow, with a half-life of 47 days.

Glyphosate can be effective in controlling polymeria, with 100% kill observed in some situations. However, the result observed in the field is generally not this good, as:

- glyphosate may not fully translocate throughout the polymeria rhizome mat, leaving some rhizomes alive. Translocation appears to improve as herbicide rates are increased. Polymeria will rapidly regrow from unaffected rhizomes.
- glyphosate is less effective against stressed plants. Moisture and temperature stresses reduce herbicide efficacy.
- thorough spray penetration into a thick polymeria patch is difficult to achieve. Inevitably some plants and shoots are not sprayed.
- glyphosate cannot be effectively applied to the cotton plant-line, as conventional cotton is not tolerant of glyphosate. Roundup can be applied to Roundup Ready cotton up to the 4th true leaf of the crop.
- polymeria can re-establish from seed.

Glyphosate rate

Glyphosate is generally ineffective in controlling polymeria when applied at rates of 1 or 2 L/ha, but control improves as rates are increased (Tables 4). Similar results were observed in the field, where Roundup CT was applied as an in-crop, directed spray (Table 5), and in actively growing polymeria in a fallow (Table 6).

Table 4. Polymeria control using contact and residual herbicides at standard and heavy rates on plants grown in pots. Dry matter regrowth was recorded from 25 to 86 days after treatment.

Treatment	Dry matter regrowth (kg/ha)	% control
Untreated	1773	0
Roundup CT 2 L/ha	1320	26
Roundup CT 4 L/ha	556	69
Roundup CT 8 L/ha	178	90
Roundup CT 16 L/ha	0	100
Starane 2 L/ha	2099	0
Starane 6 L/ha	102	94
Atrazine 5 L/ha	1015	43
Atrazine 10 L/ha	585	77
Basagran 2 L/ha	898	49
Basagran 6 L/ha	551	69

Table 5. Polymeria control in cotton using directed spray applications. Weed density was assessed 19 and 60 days after treatment.

Treatment (applied Jan 17, 1997)	Weed rating after 19 days	Weed rating after 60 days
Untreated	100	100
Roundup CT 4 L/ha	63	43
Roundup CT 8 L/ha	33	37
Roundup CT 16 L/ha	7	17

Glyphosate rates between 3 and 6 L/ha have been effective in the field when other factors such as low temperatures and moisture stress have not been limiting.

Glyphosate is generally ineffective when applied to stressed polymeria and is not well suited to treating polymeria in fallows, unless the weed is actively growing after good rain (as was the case in Table 6).

Results from repeated applications in fallow have been very variable, with multiple applications giving the best results (Table 3). A strategy of multiple glyphosate applications, applied after rain and as required, seems to be the best approach when using this herbicide in a fallow.

Table 6. Control of polymeria in a fallow using increasing rates of glyphosate. Percentage control was visually estimated relative to an unsprayed treatment, 64 days after spraying. Work by Scarsbrick, Auld and Milne, 1979.

Treatment	Rate	% control at 64 days
Glyphosate	1 L/ha	23
	2 L/ha	60
	4 L/ha	73
	6 L/ha	77
	8 L/ha	80

Split applications of glyphosate can also be effective. In one experiment, where multiple applications of Roundup CT at 4 and 8 L/ha were compared, the best result was from a split application of 4 L/ha in November and January (Table 7). Poorer control was observed from 3 applications of 4 and 8 L/ha.

Table 7. Control of polymeria using in-crop directed spray applications of glyphosate. The results were assessed 104 and 364 days after the first herbicide application on October 24, 1997.

Treatment	Application(s) (L/ha)			Weed rating after	
	24 Oct	20 Nov	17 Jan	104 days	364 days
Untreated	-	-	-	97	75
Roundup CT	4	-	-	100	85
Roundup CT	8	-	-	100	85
Roundup CT		4	4	43	22
Roundup CT	4	4	4	53	43
Roundup CT	8	8	4	33	37

The reduction in control caused by the additional herbicide application probably occurred because the first October application was ineffective in controlling the polymeria (possibly due to cool temperatures), but stressed the weed, making it less receptive to the November application.

Aside from the direct effect on the polymeria, the Roundup treatments had an added benefit, in that cotton established on the sprayed plots and was estimated to yield around 5 bales/ha on the best treatments. This result was in marked contrast to previous seasons, when no cotton lint was harvested on the polymeria patches. The additional yield on these plots easily justified the expense of the herbicide application. The degree of polymeria control with Roundup was primarily limited by the need to apply the herbicide as a shielded spray, leaving unsprayed polymeria in the cotton row.

Timing of glyphosate applications

Glyphosate applications during December and January have generally been the most effective, with poorer results from earlier applications (Table 7).

Applications in early spring, before cotton planting, have given variable results. Rates between 3 and 6 L/ha were applied to a number of patches over a one-week period in one spring, with good control observed from about half the applications. There was no obvious correlation between the glyphosate rate and the variable results achieved, with poor control observed on some patches sprayed at 6 L/ha, and good control on some other patches sprayed at 3 L/ha.

Similarly variable results were observed from a second in-crop experiment, where plots were sprayed over two seasons (Table 8). The best results were from applications of 6 L/ha in January and February, and from a single application of 12 L/ha in February.

A single application of 3 L/ha in February also gave a reasonable result. Overall, polymeria density was substantially reduced on the trial area over the 2 seasons, with some evidence of Roundup translocating well beyond the treated areas.



Glyphosate is effective in controlling polymeria in-crop, enabling the crop to establish and yield even in thickly infested patches.

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

Table 8. Control of polymeria using repeated shielded applications of Roundup in the cotton crop. Applications were made in December 1998, and January and February 1999. Weed density was assessed 64, 372 and 483 days after the December 1998 treatment.

Treatment	Application date(s)			Visual assessment of weed rating		
	Dec	Jan	Feb	64 days	372 days	483 days
Untreated	-	-	-	70	62	94
Roundup CTXtra	-	-	3 L/ha	76	38	43
Roundup CTXtra	-	3 L/ha	3 L/ha	80	58	67
Roundup CTXtra	3 L/ha	3 L/ha	3 L/ha	54	48	49
Roundup CTXtra	-	-	6 L/ha	72	43	45
Roundup CTXtra	-	6 L/ha	6 L/ha	32	26	25
Roundup CTXtra	6 L/ha	6 L/ha	6 L/ha	45	56	48
Roundup CTXtra	-	-	12 L/ha	100	39	28
Roundup CTXtra	-	12 L/ha	12 L/ha	43	31	32
Roundup CTXtra	12 L/ha	12 L/ha	12 L/ha	43	50	41

One of the main difficulties encountered in these experiments was unacceptable damage to the cotton, due to imprecise application of the high herbicide rates through a shielded, hand-held sprayer. Even with better spray equipment, the potential risk of damage to the crop from very high rates of glyphosate is too high to be acceptable. Results from applications of 3 L/ha show that useful levels of control of polymeria could be achieved with this rate, without unacceptable risk of damage to the crop. A polymeria management strategy using one or two in-crop glyphosate applications of 3 L/ha could achieve much improved cotton yields and a year-by-year reduction in the polymeria infestation.

Additives to enhance glyphosate efficacy

Use of a spray additive with glyphosate may improve its efficacy for polymeria control. Polymeria has a very hairy leaf surface, which may be a factor contributing to the poor control results observed with lighter rates of glyphosate (3 L and below). A wide range of spray additives is available for use with glyphosate, some of which may improve spray efficacy when used on polymeria.

A small range of spray additives was tested at various rates. The addition of PULSE® Penetrant at 1% improved control (Table 9), while the addition of Turbo® Plus at 5% improved control in a second experiment (Table 10). The control from Roundup CTXtra without additive was also very good in both experiments.



Extreme care should be taken with in-crop applications of glyphosate, as the herbicide can damage conventional cotton plants, as in this photo (crop plants yellow and stunted).

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

Tables 9. *Polymeria control in a pot trial using Roundup CTXtra with extra spray additive. Spray was applied at 100 L/ha. Regrowth was measured from 31 to 164 days after treatment.*

Treatment	Dry matter regrowth (kg/ha)	% control
Untreated	5080	0
Roundup CTXtra @ 3 L/ha	294	94
Roundup CTXtra @ 3 L/ha + 1% Pulse	0	100
Roundup CTXtra @ 3 L/ha + 1% Turbo Plus	898	82
Roundup CTXtra @ 3 L/ha + 1% Bond	3425	33

A lower rate of glyphosate was used in a third experiment (Table 11), where Roundup CT was used at 3 L/ha rather than Roundup CTXtra at 3 L/ha. This gave an 8% reduction in active ingredient and a change in the product surfactant. Turbo Plus at 1% gave a large improvement in spray efficacy in this experiment, although efficacy was further improved by increasing the Roundup rate without including the additive.

Table 10. *Polymeria control in a pot trial using Roundup CTXtra and extra spray additive. Spray was applied at 100 L/ha. Regrowth was measured from 42 to 126 days after treatment.*

Treatment	Dry matter regrowth (kg/ha)	% control
Untreated	6718	0
Roundup CTXtra @ 3 L/ha	208	97
Roundup CTXtra @ 3 L/ha + 0.2% Pulse	426	94
Roundup CTXtra @ 3 L/ha + 1% Pulse	104	98
Roundup CTXtra @ 3 L/ha + 5% Pulse	145	98
Roundup CTXtra @ 6 L/ha + 1% Turbo Plus	544	92
Roundup CTXtra @ 3 L/ha + 5% Turbo Plus	0	100
Roundup CTXtra @ 3 L/ha + 5% Bond	292	96

Table 11. *Polymeria control in a pot trial with Roundup CT*

and Turbo Plus spray additive. Spray was applied at 100 L/ha. Regrowth was recorded from 42 to 167 days after treatment.

Treatment	Dry matter regrowth (kg/ha)	% control
Untreated	9672	0
Roundup CT @ 3 L/ha	2465	75
Roundup CT @ 3 L/ha + 1% Turbo Plus	406	96
Roundup CT @ 3 L/ha + 5% Turbo Plus	542	94
Roundup CT @ 6 L/ha	0	100
Roundup CT @ 6 L/ha + 1% Turbo Plus	0	100
Roundup CT @ 6 L/ha + 5% Turbo Plus	0	100

Glyphosate formulations

A range of commercial glyphosate formulations is available, with differing types and concentrations of wetters. There is little evidence that these formulations vary in their efficacy for controlling polymeria (Table 12).

Table 12. *Comparison of a range of glyphosate formulations for controlling polymeria in a pot trial. Applications were at 1.0 and 1.5 kg a.e./ha, giving equivalent rates of the various formulations. Dry matter regrowth was recorded from 43 to 173 days after treatment.*

Treatment	Rate	Dry matter regrowth (kg/ha)	% control
Untreated	-	10529	0
Roundup CT	2.2 L/ha	542	95
	3.3 L/ha	0	100
Roundup Max	2.0 L/ha	100	99
	2.9 L/ha	0	100
Roundup Ready	1.4 kg/ha	0	100
	2.2 kg/ha	0	100
Credit & Bonus	1.9 L/ha	339	97
	2.8 L/ha	0	100

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

WEEDpak – a guide for integrated management of weeds in cotton

Using glyphosate in the field

Based on these results, glyphosate was applied to polymeria patches on commercial fields, with applications at planting and shielded applications in crop. While the results were not outstanding, there was a general reduction in polymeria density on treated fields and cotton was picked from polymeria patches where there previously was no harvestable cotton. The main lessons learned from these trials were:

- polymeria must be actively growing. Results have been generally poor from applications to moisture stressed polymeria, and in cool spring conditions,
- at-planting applications of glyphosate have enabled cotton to establish in polymeria patches,
- in-crop glyphosate applications must be through well constructed shielded sprayers, with competent operators. High rates of glyphosate can cause unacceptable damage to cotton when poorly applied,
- spot-spraying is the preferred in-crop option, minimising the risk of accidental damage to cotton, and
- attention to crop agronomy is important to enable satisfactory cotton establishment and growth in polymeria patches.

Fluroxypyr (eg. Starane®)

Starane is a contact herbicide, effective on a range of harder-to-kill broadleaf weeds. Starane is primarily shoot absorbed, but there can be some root absorption. Starane is moderately persistent, with a half-life of up to 55 days. Starane is moderately leachable. It is not safe to apply on or near cotton.

Starane's mode of action is not clear, but it has a hormone-like action, altering the integrity of the plant's cell walls and affecting cell division. Starane is most effective on actively growing plants.

Starane has been widely trialled by growers, generally at 2 L/ha, but with variable results. Starane has been useful for controlling smaller infestations of polymeria, but is less satisfactory for controlling larger patches. Applications under optimal (glasshouse) growing conditions gave poor results, with no control with Starane at 2 L/ha (Table 4). Control improved to 94% when Starane was applied at 6 L/ha.

Poor results in the field were observed with Starane at 1 and 2 L/ha sprayed in December (Table 13), and at 2 and 6 L/ha sprayed in October (Table 2). A single application of Starane at 2 L/ha in March also gave poor results, but good control was achieved with repeated applications of 2 L/ha in December and February (Table 3) (both sets of applications were repeated over 3 seasons). Growers report that best results have generally been achieved with applications in February and March.

Table 13. Polymeria control in fallow, sprayed on December 22, 1987, and assessed after 65 days. This trial was conducted by Max McMillan.

Treatment	Weed rating after 65 days
Untreated	90
2,4-D Amine 1 L/ha	78
2,4-D Amine 2 L/ha	56
2,4-DP 1.7 L/ha	88
2,4-D Amine 1 L/ha + Ally 10 g/ha	84
MCPA Amine 1 L/ha	78
Basta 3 L/ha	94
Starane 1 L/ha	46
Starane 2 L/ha	38

As with all herbicide applications, some viable polymeria rhizomes remain after treatment. A polymeria management plan based on Starane will require repeated strategic applications and spot treatments over many seasons.

2,4-D amine

2,4-D amine has been widely trialled for controlling polymerica. It is applied in autumn, after cotton is defoliated and no longer susceptible to the herbicide. 2,4-D must never be applied during the cotton season, as cotton plants are extremely sensitive to the herbicide. Drift onto cotton from an application of 2,4-D can cause a big reduction in cotton yield.

There have been reports of good control of polymerica using 2,4-D, but these reports have not been substantiated. 2,4-D applied in autumn burns-off the polymerica foliage, which then dies off over winter. The 2,4-D appears to have given very good control at this point, as in Table 14.

Table 14. Polymerica control in a fallow using 2,4-D and other herbicides, applied on March 14, 1983 and assessed in July, 112 days after spraying. Work by Neville Strachan.

Treatment	Weed rating at 112 days
Untreated	23
2,4-D Amine 2 L/ha	0
2,4-D Ester 1.25 L/ha	1
Dicamba 1.4 L/ha	24
Roundup 2 L/ha	13
Tordon 50-D 1.4 L/ha	1
Roundup 2 L/ha + 2,4-D Ester 1.5 L/ha	0
Tordon 50-D 1.4 L/ha + 2,4-D Amine 2 L/ha	1
Tordon 50-D 1.4 L/ha + Dicamba 1.4 L/ha	1
Dicamba 1.4 L/ha + 2,4-D Amine 2 L/ha	1
Weedazol TL Plus 5.6 L/ha	13
Glean 30 g/ha	34

However, the weed may re-emerge in spring with little apparent affect from the treatment. 2,4-D amine at 4 L/ha applied in June gave some short-term control (Table 15). 2,4-D amine applied at 1 or 2 L/ha earlier in the season also gave no long-term control of polymerica (Table 13). Further work is being undertaken to evaluate the long-term control of polymerica with 2,4-D.

Table 15. Polymerica control using a range of herbicide combinations in a fallow, sprayed on June 26, 1995.

Treatment	Visual assessment of weed rating	
	104 days	340 days
Untreated	41	51
2,4-D Amine 4 L/ha	27	49
Roundup 4 L/ha	26	64
Starane 2 L/ha	31	60
Roundup 1.5 L/ha + 2,4-D Amine 2 L/ha	38	43
Roundup 3 L/ha + 2,4-D Amine 2 L/ha	35	63
Roundup 1.5 L/ha + 2,4-D Ester 1.5 L/ha	29	52
Roundup 2 L/ha + Goal 0.75 L/ha	62	67
Roundup 1.5 L/ha + Starane 1 L/ha	34	36



Polymerica is a native plant that occurs through much of the cotton industry. Uncontrolled infestations, such as the plants established on this channel bank, produce seed that can spread the weed into cotton fields.

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

WEEDpak – a guide for integrated management of weeds in cotton

Using 2,4-D in the field

The opportunity to apply 2,4-D to cotton fields and fallows is limited by factors including:

- applications in the cotton area can only safely occur in autumn, after defoliation. Applications earlier in the season are not possible due to the extreme sensitivity of cotton to this herbicide,
- 2,4-D must be applied to actively growing polymeria. Polymeria growing in cotton will be moisture stressed, and not likely to respond to herbicide unless rain occurs at picking, and,
- 2,4-D must be applied before frosts in autumn burn off the foliage, stressing the plant.

Herbicide combinations

Combinations of Roundup and 2,4-D, and Roundup and Starane were trialled, but gave no improvement in control (Table 15). It is unlikely that combinations of herbicide with different modes of action will improve control of this weed, as the different herbicides generally stress the plant, reducing herbicide efficacy.

Summary

Polymeria is a deep rooted, rhizomatous, perennial weed that spreads from seeds and rhizomes. It tolerates and can be spread by normal cultivation practices.

No herbicides are registered for controlling polymeria. A permit must be obtained from the National Registration Authority before using a herbicide to control polymeria in any situation.

Polymeria can best be managed in cotton with repeated applications of glyphosate on actively growing polymeria, applied through well constructed shields, used under appropriate conditions. Glyphosate should be spot-applied to the polymeria patches to improve crop safety. The addition of Pulse Penetrant or a non-ionic surfactant may improve spray efficacy. Good crop agronomy is also important, resulting in competitive, strong cotton.

Polymeria growing in fallow can be controlled with glyphosate on actively growing patches and with fluroxypyr (eg. Starane) in autumn. Grazon may be useful for controlling polymeria in fallows that are not going back to cotton. Imazapyr (eg. Arsenal) may be useful for controlling polymeria on non-cropping and waste areas.

NO HERBICIDES ARE REGISTERED FOR CONTROLLING POLYMERIA. A PERMIT MUST BE OBTAINED FROM THE NATIONAL REGISTRATION AUTHORITY BEFORE USING A HERBICIDE TO CONTROL POLYMERIA IN ANY SITUATION.

A grower's experience with polymeria

Polymeria (Take-all) control on Colly Farms

David Moore (Formerly Senior Agronomist, Colly Farms Ltd)

My experiences refer to the control of this weed in the western Gwydir/Collarenebri area. Having seen this weed grow rapidly as a cotton acre utiliser over a number of seasons, I can say its control is not easy to achieve and involves having a large amount of patience and deep pockets.

The key to controlling polymeria revolves around attacking it when it is actively growing, has a large enough leaf mass, and warm temperatures – not unlike controlling nutgrass. The critical time, therefore, is from early December, through to the end of the irrigation cycle in irrigated cotton. In this period, the weed grows very well, being well fed by both nutrients and water. The leaf surface is covered with tiny hairs that can make uptake of any herbicide very difficult. This is why treatment in times of higher temperature/relative humidity is better than in cooler periods.

The aim with all these treatments has been to reduce the number of shoots/m² so that the current, or following crop has a greater chance of producing economically viable cotton yield.

Treatments I have tried are;

1. Phenoxy herbicides in the Autumn.

I have found these applications (of up to 5 L/ha of 2,4-D amine) to be ineffective.

2. Fluroxypyr (Starane®) herbicide applied in summer

Have seen very good results with this product at rates of around 2 L/ha. The drawback is this products volatility and propensity to volatilise and effect nearby crops. It may be an option in a fallow with adequate buffer.

3. Deep ripping/cultivation in a fallow situation.

The mass of rhizomes that are under a patch of polymeria is incredible, as is the depth to which they can be found. Shallow cultivation that minimally disrupts the growth is ineffective, with smaller pieces of rhizomes being transplanted and growing with the next rainfall.

Therefore, any cultivation must be aggressive and the transplanted rhizomes need to dry out for a long time before any water is added to the system.

Unfortunately, when these fields come back into irrigated production, the frequency of watering and warm summers mean that the weed is back with two seasons.

4. Glyphosate in the fallow

Again needs to be actively growing with adequate leaf mass - using rates of applied 450 g/L product need to be around 6 L/ha.

Have seen good reductions in numbers from these applications.

5. Shielded applications of glyphosate in crop.

Have seen up to two applications of high rates of glyphosate in crop via a shielded sprayer give very good results. Again the rate needs to be around 6 L/ha.

6. Industrial residual herbicides in field

Have seen a Imidazolinone product (Arsenal) used in field on heavily infested patches of polymeria. While there was a dramatic decrease in shoots per square metre, there was no total reduction. This accompanied with the fact that these areas will not yield cotton for the following two seasons and the fact that treated soil may move through the field makes this option an unfavoured one.

However, it may be an option in controlling patches in head ditches, roadsides etc. with a back pack application. Needless to say, care in application is critical.

Summary

I favour applications of glyphosate in the fallow or shielded applications in crop. These applications, timed when the weed is actively growing under high humidity, have given good results. These applications followed up by an application of fluroxypyr in early autumn also help to reduce the numbers of shoots per metre in the following crop.

The ability to use GPS to accurately record patches of polymeria and assess the degree of control achieved is advantageous.

The key is to not let your fields get to the stage that areas of your fields are unproductive and require such treatments as mentioned above. If you have some infested fields, isolate them and make rig hygiene a priority.

MANAGING BELLVINE IN COTTON

Graham Charles
(NSW Dept of Primary Industries)

Contents	Page
The morning glory family in cotton	H5.1
The bellvine plant	H5.2
Strategies for managing bellvine	H5.3
Pre-emergent control of bellvine in cotton	H5.3
Non-residual herbicides for post-emergence control of bellvine in cotton	H5.4
Non-residual herbicides for post-emergence control of bellvine in fallows	H5.7
Residual herbicides for post-emergence control of bellvine in cotton	H5.8
Herbicide combinations for the control of bellvine in cotton	H5.8
Herbicide systems for managing bellvine in cotton	H5.10
Pre-harvest glyphosate	H5.11
Alternative residual herbicides for managing bellvine in fallows and rotation crops	H5.11
Summary	H5.12

The morning glory family in cotton

The morning glory family includes over a dozen weedy species that can be found in the cotton growing area of Australia. A number of morning glory species are also major problem weeds in parts of the US cotton industry.

The most commonly found morning glories in Australian cotton are cowvine (also called peachvine, *Ipomoea lonchophylla*), bellvine (*Ipomoea plebeia*), common morning glory (*Ipomoea purpurea*) and desert cowvine (*Ipomoea diamantinensis*). These plants have many similarities but can be distinguished by leaf shape in seedling and older growth stages as shown.

They are aggressive, highly competitive weeds that can grow through and over a cotton crop, tangling inter-row and harvesting machinery. This climbing habit is more apparent in bellvine and common morning glory, which can emerge above even a dense cotton crop later in the season.



Cotyledon and adult leaf shapes can be used to distinguish the morning glory species most commonly found in Australian cotton crops. The plants are (top to bottom): bellvine, peachvine, common morning glory and desert cowvine.



Bellvine (top) and common morning glory (bottom) can climb up through a cotton crop and emerge above the crop later in the season.

The bellvine plant

Bellvine is found throughout much of the Queensland cotton area, and is spreading in northern NSW.

It is an annual weed that emerges following rainfall and irrigation events in spring and summer, and grows rapidly over the warmer months. Bellvine plants are not frost tolerant and are killed by frosts.

Bellvine seeds appear to have little seed dormancy. Seeds germinate readily and high densities of seedlings can establish with cotton in spring. Seedlings grow rapidly after emergence during warm weather and develop long, twining branches. Large plants may be 3 to 4 m in diameter and can form dense clumps, potentially growing over the top of other plants.

Bellvine plants grow vegetatively through spring and early summer and commence flowering when day-length begins to decrease in late summer. Bellvine flowers prolifically over late summer and autumn, each plant producing masses of seed capsules, with 4 seeds per capsule.

Large numbers of bellvine seeds may be present in the soil seedbank. Soil cores from heavily infested cotton fields detected bellvine seed densities in the range of 100 - 3000 seeds/m², with 8800 seeds/m² the highest recorded density. Bellvine seed densities in the soil fluctuated greatly within a small distance, indicating both the

tremendous seed production capacity of this species and its relatively short seedbank life.

Bellvine seeds do not readily germinate from the soil surface, but seedlings are able to emerge from down to 10 cm soil depth, with seedlings most freely emerging from down to 4 cm (Figure 1). Emergence from 1 and 2 cm depth commenced within 4 days of planting, with most seeds emerging from the shallower depths within 5 weeks of planting.

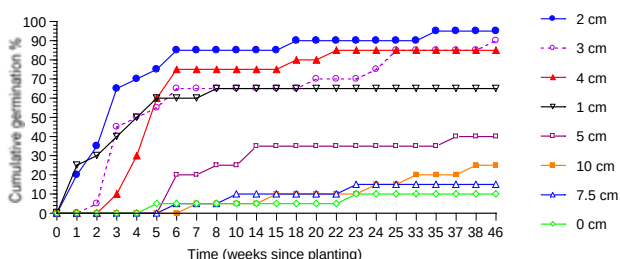


Figure 1. Emergence over time of bellvine seeds planted at 0 – 10 cm depth. No emergence was observed for seeds planted at 15 and 20 cm.



Bellvine, another weedy member of the morning glory family, can be troublesome in Australian cotton. It is a vine weed that can choke cotton plants and cause problems for cultivation and harvesting machinery.



Bellvine plants may form dense clumps and can grow over the top of other plants.

Strategies for managing bellvine

Bellvine is most susceptible to control in fallows and rotation crops such as cereals and sorghum crops. Plants are easily controlled with shallow cultivation to 5 cm. Bellvine seedlings can also be controlled using heavy applications of glyphosate in fallows and with phenoxy herbicides in fallows, cereal and sorghum crops.

Bellvine is difficult to control in cotton and other broadleaf crops. Consequently, this weed is best managed using an integrated weed management approach, managing the weed in cotton using multiple tools and reducing the problem over time by preventing weed set in fallows and rotation crops. Care must be taken to ensure these herbicides do not drift onto susceptible crops such as cotton.

Effective control of bellvine in fallows, cereal and sorghum crops is a practical solution for this weed because the bulk of seed production occurs in late

summer and autumn, giving a wide window of opportunity for control, and bellvine seeds don't have a long seedbank life. Consequently, it should be possible to deplete the seedbank and achieve a large reduction in weed pressure within 2 or 3 seasons if all bellvine plants can be prevented from setting seed for this period. This strategy assumes favourable conditions and a large germination of bellvine seedlings each season.

Nevertheless, it is important to manage bellvine in cotton so that cotton yields are not compromised, and to ensure minimal return of weed seed to the seedbank in each cotton crop.

Pre-emergent control of bellvine in cotton

Of the residual herbicides tested, trifluralin at 2.8 L/ha gave the best residual control of bellvine, reducing emergence 1 week after herbicide application by 77%, and by 67% at 4 weeks (Table 1). Diuron at 3.5 L/ha gave some suppression of bellvine emergence for the first 2 weeks after application, and a small reduction at 8 weeks.

The bellvine seedlings that emerged through these herbicides grew normally, except on the Zoliar treatments, where a high rate of post-emergence seedling mortality was observed (Table 1). Consequently, the high rates of trifluralin and Zoliar both caused reductions in the number of established bellvine seedlings present 8 weeks after treatment, but in both cases, some bellvine seedlings were still able to establish through these treatments. Diuron at 3.5 L/ha and Zoliar at 2 kg/ha also caused small reductions in seedling establishment.

Table 1. Bellvine control (emergence% and establishment) with pre-emergence herbicides applied in pots.

Herbicide	% Cumulative seedling emergence				% establishment	
	1 week	2 weeks	4 weeks	8 weeks	4 weeks	8 weeks
Trifluralin 1.4 L/ha	43	51	52	57	41	43
Trifluralin 2.8 L/ha	10	17	18	22	13	18
Stomp 1.5 L/ha	57	64	66	69	52	59
Stomp 3 L/ha	42	55	62	63	43	46
Dual 1 L/ha	38	50	55	57	45	47
Dual 2 L/ha	42	51	59	62	45	46
Diuron (500 g/L) 1.75 L/ha	40	55	58	60	54	56
Diuron (500 g/L) 3.5 L/ha	22	34	45	46	37	39
Cotoran (500 g/L) 2.8 L/ha	38	56	62	64	53	58
Cotoran (500 g/L) 5.6 L/ha	35	46	55	57	45	49
Cotogard (250+250 g/L) 2.5 L/ha	55	56	66	70	58	61
Cotogard (250+250 g/L) 5 L/ha	38	55	57	59	50	52
Gesagard (500 g/L) 2.25 L/ha	46	58	62	63	56	59
Gesagard (500 g/L) 4.5 L/ha	48	54	55	58	50	51
Zoliar 2 kg/ha	53	55	58	63	39	39
Zoliar 4 kg/ha	40	48	52	53	28	28
Untreated	44	52	55	56	52	53

Better results for these herbicides were observed in the field, although some bellvine seedlings still established in even the best treatments.

Pre-planting applications of Zoliar and diuron gave good control of bellvine in a Roundup Ready cotton crop at Theodore (Table 2). These treatments reduced bellvine densities by 99 and 93% respectively in December, compared to the untreated plots.

Table 2. Bellvine control with pre-emergence herbicides applied in a Roundup Ready cotton crop at Theodore. Roundup was applied over-the-top after the October survey, and the site was inter-row cultivated after the November survey.

Herbicide	Bellvine plants/m ²		
	22 Oct	27 Nov	20 Dec
Zoliar 4 kg/ha	0.0	0.1	0.1
Diuron (800 g/kg) 2 kg/ha	0.4	0.5	0.5
Cotoran (500 g/L) 5.6 L/ha	1.7	2.0	1.0
Convoy DF (440+440 g/kg) 2.9 kg/ha	2.5	3.3	3.2
Prometryn 900 DF 2.5 kg/ha	4.4	8.0	3.5
Untreated	7.5	9.6	6.5

Nevertheless, densities of 0.5 bellvine/m² are still sufficient to cause problems in cotton and need to be controlled. The Convoy, prometryn and untreated plots maintained very high densities of bellvine plants in this experiment and became unmanageable by mid-season.



Residual herbicides applied prior to planting suppressed bellvine seedling growth and reduced bellvine numbers by 50-60% compared to an untreated plot in the foreground, but 5-10 seedlings/m row still established and required control early in crop life.

The residual herbicides were much more effective in a Roundup Ready cotton crop at Emerald, where multiple Roundup Ready Herbicide applications were made during the season (Table 3). The relatively low bellvine density (0.3 plants/m²) on the untreated plots in December showed the importance of using glyphosate as part of a bellvine management system. A high bellvine density had been present on these plots at the start of the season, but was managed by the glyphosate applications even in the absence of residual herbicides. However, bellvine numbers increased by mid-January in the absence of a lay-by residual herbicide, showing the importance of using a combination of weed management tools to manage this weed.

Table 3. Bellvine control with pre-emergence herbicides applied in a Roundup Ready cotton crop at Emerald. Roundup Ready Herbicide was applied twice over-the-top after the October survey, and as a shielded application in early December.

Herbicide	Bellvine plants/m ²			
	23 Oct	26 Nov	20 Dec	21 Jan
Diuron (800 g/kg) 2 kg/ha	0.3	0.3	0.1	0.1
Convoy DF (440+440 g/kg) 2.9 kg/ha	0.4	0.5	0.1	0.1
Zoliar 4 kg/ha	0.5	0.4	0.1	0.1
Prometryn 900 DF 2.5 kg/ha	0.5	0.5	0.1	0.2
Cotoran (500 g/L) 5.6 L/ha	2.1	2.0	0.2	0.4
Untreated	11.2	3.5	0.3	1.1

Non-residual herbicides for post-emergence control of bellvine in cotton

A series of glasshouse experiments was conducted to examine a range of herbicide options and combinations for post-emergence control of bellvine in cotton.

None of the post-emergence herbicides tested gave acceptable and repeatable levels of control

(kill) of bellvine seedlings and plants, with results varying between experiments. Nevertheless, many of the herbicide options did consistently suppress bellvine growth for at least 4 to 5 weeks post-spraying. This level of suppression is far from ideal but could be useful as part of an integrated bellvine management program.

Roundup Ready Herbicide at 1.5 kg/ha and Envoke at 30 g/ha gave the best control of bellvine seedlings and the best suppression of plant growth

as indicated by bellvine leaf number 4 weeks after spraying (Table 4). These herbicides were effective in suppressing the growth of small plants

(3 and 13 leaves), but were less effective on much larger plants (68 leaves at spraying).

Table 4. Bellvine control with non-residual herbicides applied post-emergence to plants with 3, 13 and 68 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	3 leaves	13 leaves	68 leaves	3 leaves	13 leaves	68 leaves
Roundup Ready Herbicide 0.75 kg/ha	50	0	37	4	64	120
Roundup Ready Herbicide 1.5 kg/ha	75	0	12	3	10	110
Basta 1 L/ha	12	0	0	57	128	278
Basta 2 L/ha	37	0	25	47	136	115
Staple 30 g/ha	12	0	0	18	149	283
Staple 60 g/ha	12	0	0	11	133	211
Envoke 15 g/ha	25	0	0	3	83	209
Envoke 30 g/ha	75	0	0	0	28	111
Untreated	0	0	0	106	171	184

Similar results were observed on smaller bellvine plants (Table 5). Roundup at 1.5 kg/ha, Staple at 120 g/ha and Envoke at 15 g/ha all killed some seedlings and gave good suppression of bellvine plants up to 5 weeks after spraying.

Staple and Envoke also have residual activity on some plants, although they are used as non-residual herbicides in cotton. Bellvine seeds were planted into these pots 5 weeks after spraying to test for residual control, but these herbicides had no detectable effect on seedling emergence or growth.

Envoke was less effective in suppressing larger bellvine plants, except at the highest rates, and had little effect on very large plants (Table 6).



These bellvine seedlings were suppressed but not killed by herbicide applied 4 weeks earlier.

Table 5. Bellvine control with non-residual herbicides applied post-emergence to plants with 2, 4, 9 and 17 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill				Leaf number after 4 weeks			
	2 leaves	4 leaves	9 leaves	17 leaves	2 leaves	4 leaves	9 leaves	17 leaves
Roundup Ready 1.5 kg/ha	25	100	37	12	6	0	0	1
Staple 120 g/ha	50	0	12	12	1	3	3	3
Envoke 15 g/ha	0	0	25	12	1	3	9	10
Untreated	0	0	0	0	69	83	123	192

Table 6. Bellvine control with Envoke applied post-emergence to plants with 2, 7, 51 and 143 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill				Leaf number after 4 weeks			
	2 leaves	7 leaves	51 leaves	143 leaves	2 leaves	7 leaves	51 leaves	143 leaves
Envoke 5 g/ha	0	25	0	0	18	67	199	276
Envoke 10 g/ha	0	0	0	0	22	68	169	397
Envoke 15 g/ha	0	0	0	0	7	37	125	313
Envoke 20 g/ha	0	0	0	0	6	12	75	270
Untreated	0	0	0	0	82	155	177	336

A range of herbicide combinations were tested with Roundup Ready Herbicide to improve post-emergence control of bellvine. Combinations of Roundup Ready and Envoke, and Roundup Ready and Staple gave the best control on a field population of actively growing bellvine seedlings (Table 7). Both combinations gave improved control compared to Roundup Ready Herbicide alone, although some seedlings grew through the treatments and required an additional control input.

Table 7. Bellvine control with non-residual post-emergence herbicide combinations applied to bellvine seedlings. % kill was determined by the difference in population prior to and 2 weeks post-spraying.

Herbicide	% kill
Roundup Ready 1 kg/ha + Envoke 30 g/ha	79
Roundup Ready 1 kg/ha + Staple 120 g/ha	50
Daconate 2.8 L/ha + Harvade 450 ml/ha	6
Roundup Ready 1.5 kg/ha	5
Roundup Ready 1 kg/ha + Harvade 450 ml/ha	4
Roundup Ready 1 kg/ha + Daconate 2.8 L/ha	3
Roundup Ready 1 kg/ha	3

Post-emergence control of bellvine with combinations of Roundup Ready and Envoke herbicides was further evaluated in a glasshouse experiment, but did not give consistent improvements over Roundup Ready Herbicide alone (Table 8). Best control was achieved with Roundup Ready Herbicide alone at 1.5 kg/ha.

Bellvine control generally improved as Roundup Ready rates increased, and as Envoke rates

increased, but the trend was not consistent through the combinations. Bellvine control was relatively poor with Roundup Ready Herbicide alone at 0.5 kg/ha, and was improved with the addition of Envoke to this Roundup rate. Roundup Ready Herbicide alone at 1.5 kg/ha gave much better bellvine control, with no improvement from the addition of Envoke to this higher Roundup rate.

As previously observed, Roundup Ready Herbicide at 1.5 kg/ha was reasonably effective in controlling bellvine seedlings in this experiment, and effectively suppressed plant growth for 4 weeks post-spraying.



A tank-mix of Roundup Ready and Envoke herbicides gave the best control of bellvine (foreground), but some seedlings survived this treatment

Table 8. Bellvine control with combinations of Roundup Ready and Envoke herbicides applied post-emergence to plants with 4, 8 and 14 leaves growing in pots. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	14 leaves	4 leaves	8 leaves	14 leaves
Envoke 5 g/ha	0	0	0	63	29	128
Envoke 10 g/ha	0	0	0	66	18	100
Envoke 20 g/ha	12	0	0	24	7	52
Roundup Ready 0.5 kg/ha	0	0	0	162	50	203
Roundup Ready 0.5 kg/ha + Envoke 5 g/ha	12	0	25	42	45	27
Roundup Ready 0.5 kg/ha + Envoke 10 g/ha	37	12	25	13	38	26
Roundup Ready 0.5 kg/ha + Envoke 20 g/ha	37	0	0	18	40	58
Roundup Ready 1 kg/ha	12	25	12	13	17	24
Roundup Ready 1 kg/ha + Envoke 5 g/ha	87	25	50	2	10	7
Roundup Ready 1 kg/ha + Envoke 10 g/ha	62	50	12	5	11	30
Roundup Ready 1 kg/ha + Envoke 20 g/ha	87	25	50	1	19	4
Roundup Ready 1.5 kg/ha	62	62	62	3	6	12
Roundup Ready 1.5 kg/ha + Envoke 5 g/ha	87	12	25	1	14	8
Roundup Ready 1.5 kg/ha + Envoke 10 g/ha	87	12	50	1	21	6
Roundup Ready 1.5 kg/ha + Envoke 20 g/ha	62	62	37	2	5	9
Untreated	0	0	0	176	235	301

Combinations of Staple and Envoke herbicides at lower rates were also examined in an attempt to find a more cost-effective combination for bellvine control and to broaden the spectrum of weeds controlled by a single application (Table 9). Weed control and suppression improved with increasing rates of both herbicides and with increasing rates

of the combinations, although the best control was achieved with the 120 g/ha rate of Staple alone. There was no strong evidence of synergism with these combinations, but the use of a Staple and Envoke combination might be a practical option where a range of other weeds in a field indicate this use.

Table 9. Bellvine control with combinations of Staple and Envoke herbicides applied to bellvine seedlings at 4, 8 and 15 leaves. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	15 leaves	4 leaves	8 leaves	15 leaves
Envoke 5 g/ha	0	0	0	244	116	308
Envoke 10 g/ha	0	0	0	150	98	444
Envoke 20 g/ha	12	0	0	84	115	55
Staple 30 g/ha	0	0	0	95	126	364
Staple 30 g/ha Envoke 5 g/ha	0	0	0	42	111	263
Staple 30 g/ha Envoke 10 g/ha	0	37	0	68	52	120
Staple 60 g/ha	37	25	0	24	77	90
Staple 60 g/ha Envoke 5 g/ha	50	0	0	19	68	108
Staple 60 g/ha Envoke 10 g/ha	75	37	0	1	35	133
Staple 120 g/ha	100	27	100	0	32	0
Untreated	0	0	0	255	251	372

Non-residual herbicides for post-emergence control of bellvine in fallows

A range of herbicide combinations with Roundup Ready Herbicide that might be used to control bellvine and other weeds in fallows were tested on small bellvine plants (Table 10). Good levels of weed suppression were achieved with all combinations, although some reduction in bellvine

control was apparent with some combinations. No combination improved on the result from Roundup Ready Herbicide alone. The poor level of control with Roundup + Harvade and Roundup + Daconate combinations was consistent with the poor results seen earlier in Table 7.

Table 10. Bellvine control with Roundup Ready Herbicide combinations applied to bellvine seedlings at 4, 8 and 15 leaves. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	15 leaves	4 leaves	8 leaves	15 leaves
Roundup Ready 1.5 kg/ha	75	100	87	0	1	1
Roundup Ready 1.5 kg/ha + Pledge 30 g/ha	87	100	75	0	0	2
Roundup Ready 1.5 kg/ha + Oust 500 g/ha	0	62	0	0	1	2
Roundup Ready 1.5 kg/ha + Hammer 75 ml/ha	62	75	37	0	0	3
Roundup Ready 1.5 kg/ha + Goal 75 ml/ha	12	50	0	0	1	2
Roundup Ready 0.5 kg/ha + Harvade 450 ml/ha	0	0	0	1	1	2
Roundup Ready 0.5 kg/ha + Daconate 2.8 L/ha	0	12	0	1	1	2
Untreated	0	0	0	9	17	31

Residual herbicides for post-emergence control of bellvine in cotton

Prometryn and Convoy at maximum label rates were relatively effective in controlling bellvine seedlings in a glasshouse experiment, but were less effective on older plants (Table 11). The residual herbicides also suppressed seedling growth, but had less effect on older plants.

Diuron was less effective than prometryn in this experiment but gave similar or better results when compared to prometryn in two other experiments, effectively controlling bellvine seedlings at 4 - 16 leaves.



Inter-row cultivation is effective in controlling bellvine seedlings in the furrow but can't control weeds in the plant-line.

Table 11. Bellvine control with residual herbicides applied post-emergence to plants with 3, 13 and 68 leaves growing in pots. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	3 leaves	% Weed kill		Leaf number after 4 weeks		
		13 leaves	68 leaves	3 leaves	13 leaves	68 leaves
Diuron (900 g/ka) 1 kg/ha	0	0	0	63	93	177
Diuron (900 g/ka) 2 kg/ha	25	0	25	54	93	191
Prometryn (900 g/ka) 1.25 kg/ha	75	0	12	8	104	187
Prometryn (900 g/ka) 2.5 kg/ha	100	12	37	0	48	61
Convoy (440 + 440 g/kg) 1.45 kg/ha	25	0	25	30	86	108
Convoy (440 + 440 g/kg) 2.9 kg/ha	87	0	0	2	87	158
Cotoran (500 g/L) 2.7 L/ha	0	0	0	54	98	255
Cotoran (500 g/L) 5.4 L/ha	12	0	0	59	94	200
Untreated	0	0	0	106	171	184

Herbicide combinations for the control of bellvine in cotton

A range of pre- and post-emergence herbicides and herbicide combinations for bellvine control were assessed in 6 field experiments in commercial cotton fields over 3 seasons. No single herbicide or herbicide combination was able to completely control bellvine in any of these experiments, nor did any single system give consistently superior results.

These inconsistencies were partly a product of biological variation, but were also contributed to by the effectiveness of herbicide incorporation, which varied between fields and seasons, and the soil persistence of the herbicides, which was influenced by soil moisture content, water solubility, soil mobility and large rainfall events.

However, some general principles did emerge from the data sets. It is clear that an effective bellvine management system using the currently available inputs must include multiple management inputs over the cotton season. A treatment that is effective in controlling bellvine seedlings at one point in the season is unlikely to prevent new seedlings from emerging later in the season and may not control older plants that emerged earlier in the season. Consequently,

multiple management inputs are required to manage this weed.

Of the pre-planting residual herbicides, diuron and Zoliar gave the most consistent control of bellvine establishment up to the 4 leaf stage of crop development (Tables 2, 3, 12, and 14, Site 4). These herbicides were less effective on the remaining sites (Tables 13 and 14, Site 3). These poor results were associated with poor herbicide incorporation and heavy rainfall events that occurred after the herbicides were applied, probably washing much of the herbicide from the target area.

Table 12. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 02/03 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 1	Site 2
Zoliar 4 kg/ha	0	0.5
Diuron (800 g/kg) 2 kg/ha	0.3	0.6
Zoliar 2 kg/ha	1.0	0.7
Diuron (800 g/kg) 1.3 kg/ha	1.0	1.0
Prometryn 900 DF 2.5 kg/ha	2.6	0.3
Cotoran (500 g/L) 5.6 L/ha	2.8	2.4
Cotoran (500 g/L) 2.7 L/ha	3.3	0.4
Convoy DF (440+440 g/kg) 2.9 kg/ha	4.8	0.9
Prometryn 900 DF 1.7 kg/ha	6.5	0.5
Convoy DF (440+440 g/kg) 1.4 kg/ha	9.6	0.9
Untreated	4.4	5.2



Table 13. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 03/04 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 3	Site 4
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 kg/ha	24	12
Trifluralin (480 g/L) 2 L/ha + Diuron (800 g/kg) 2 kg/ha	24	14
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 + Convoy (440+440 g/kg) 2 kg/ha	26	16
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 kg/ha + Diuron (800 g/kg) 1 kg/ha	27	14
Zoliar 2 kg/ha	41	9
Untreated	56	17

Table 14. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 04/05 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 3	Site 4
Zoliar 1 kg/ha + Diuron (800 g/kg) 2 kg/ha	0.7	2.6
Diuron (800 g/kg) 2 kg/ha + Prometryn (800 g/kg) 2 kg/ha	1.0	4.2
Diuron (800 g/kg) 2 kg/ha	1.2	2.7
Zoliar 2 kg/ha	1.2	3.2
Prometryn (800 g/kg) 2 kg/ha	3.3	4.9
Untreated	4.4	4.5

Table 15. Bellvine control with herbicide combinations applied pre- and post-emergence to Roundup Ready cotton in the 03/04 season (Table 13, Site 4). The formulations used were: Convoy 440 + 440 g/kg, Diuron 900 g/kg, Roundup Ready Herbicide (RR), Prometryn 900 g/kg and Trifluralin 480g/L.

Pre-planting incorporated	Over-the-top 4 leaves	Directed Mid-Dec	Bellvine plants/m ²		
			4 leaves	Mid-Dec	Mid-Jan
Trifluralin 2 L/ha + Zoliar 1 kg+ Convoy 2 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	10.7	11.9	1.0
Zoliar 2 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	9.7	9.8	1.2
Zoliar 2 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	8.6	9.7	1.2
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	11.2	11.3	1.5
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	13.9	15.9	1.5
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	11.9	14.4	2.6
Zoliar 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	8.8	8.2	2.7
Trifluralin 2 L/ha + Zoliar 1 kg/ha + Diuron 1 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	14.6	16.7	3.1
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	10	11.5	3.4
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	16.6	15.8	3.5
Trifluralin 2 L/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	15.4	11.5	4.3
Trifluralin 2 L/ha + Zoliar 1 kg/ha + Diuron 1 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	11.8	14.5	5.3
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	23.8	23.5	8.3
Trifluralin 2 L/ha + Zoliar 1 kg + Convoy 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	20.4	20.8	8.6
Untreated	RR 1.5 kg/ha	RR 1.5 kg/ha	17	19.1	7.3

The over-the-top application of Roundup Ready Herbicide used during the emergence to 4 leaf growth window was very effective and controlled most bellvine seedlings that had emerged with the cotton crop. This good result occurred regardless of the presence or absence of pre-planting residual herbicides, removing nearly all emerged bellvine seedlings from all treatments. Consequently, the Roundup application substantially reduced the benefit gained from the pre-planting residual applications.

The effectiveness of Roundup applied at this stage was related to the generally favourable growing conditions at the time, the uniformly small size of the weeds and the ability to get 100% spray coverage on these weeds. Roundup applications later in the season tended to be less effective for bellvine control, as the bellvine plants were generally larger, full spray coverage was not always achieved, and weeds were often stressed.

Bellvine seedlings continued to emerge following irrigation and rainfall events. A second in-crop herbicide application was required in mid-December to control bellvine seedlings that emerged following the over-the-top Roundup application at the 4-leaf crop stage.

Good results were achieved with both diuron and prometryn applied as directed sprays at this stage, but poorer results were achieved with only a direct Roundup Ready Herbicide application (Table 15). There was no strong relationship between the bellvine density in mid-January and the pre-planting herbicide used, but a much stronger relationship between bellvine density and the use of a residual spray in the early-season application.

Bellvine seedlings continued to emerge following the first directed herbicide application and were again controlled by a directed lay-by spray (Table 16).

Bellvine density at canopy closure was lowest on treatments receiving an early-season residual herbicide, with a smaller influence from the lay-by directed herbicide application. This result occurred because the lay-by herbicide was not able to adequately control relatively large bellvine plants that had survived the early-season spray where no residual herbicide was used. Conversely, a non-residual herbicide application at lay-by was adequate on treatments where a residual herbicide had controlled all bellvine seedlings in the early-season directed spray.

The pre-planting residual herbicide had no influence on the bellvine density at canopy closure, given that nearly all bellvine seedlings were killed by the Roundup Ready Herbicide application at 4 leaves. In an earlier experiment (Table 2), treatments where the bellvine was not managed by the early-post-emergence spray had become unmanageable by lay-by.

The highest bellvine densities were on plots that had received only Roundup Ready Herbicide or Roundup Ready Herbicide + Envoke as both the early season and lay-by directed spray applications.

Table 16. Bellvine control with herbicide combinations applied pre- and post-emergence to Roundup Ready cotton in the 04/05 season (Table 14, Site 4). The formulations used were: Convoy 440 + 440 g/kg, Diuron 900 g/kg, Roundup Ready Herbicide (RR), Prometryn 900 g/kg and Trifluralin 480g/L.

Pre-planting Incorporated	Over- the-top (kg/ha) 2 leaves	Directed		Bellvine plants/m ²	
		Mid-Dec	Layby	Lay-by	Late-Jan
	RR 1.5	RR 1.5 + Zoliar 1 + Diuron 2	RR 1.5 kg/ha	0.2	0.0
Zoliar 2 kg/ha	RR 1.5	Diuron 2 kg + Envoke 5 g/ha	Diuron 2 kg + Envoke 5 g/ha	0.0	0.1
	RR 1.5	RR 1.5 + Diuron 2 + Prometryn 2	RR 1.5 kg/ha	0.1	0.1
Diuron 2 kg/ha	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.5	0.1
	RR 1.5	RR 1.5 kg + Diuron 2 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	0.5	0.1
	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.2	0.1
Zoliar 2 kg/ha	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.5	0.1
	RR 1.5	RR 1.5 kg + Zoliar 2 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	0.7	0.1
Zoliar 1 + Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	1.1	0.2
Prometryn 2 kg/ha	RR 1.5	RR 1.5 kg + Diuron 2 kg/ha	RR 1.5 kg/ha	0.3	0.2
Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	1.2	0.3
	RR 1.5	RR 1.5 kg + Envoke 20 g/ha	RR 1.5 + Envoke 20 g/ha	0.2	0.5
Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	0.9	0.7
Zoliar 1 kg + Diuron 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	2.0	0.8
Diuron 2 + Prometryn 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	2.4	0.9
Zoliar 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	2.6	1.0
	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	1.8	1.1
Zoliar 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	1.6	1.4
	RR 1.5	RR 1.5 kg + Envoke 5 g/ha	RR 1.5 + Envoke 5 g/ha	1.6	1.7
Diuron 2 + Prometryn 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	2.7	1.8

Herbicides systems for managing bellvine in cotton

A herbicide program for managing bellvine in cotton will include multiple inputs throughout the season. These inputs must be targeted against bellvine seedlings, as the weed is most easily controlled at the seedling stage, and must ensure that bellvine seedlings are not able to establish and develop into large plants in the cotton crop. The timing of these inputs will be determined by the number of bellvine seedlings present at any one time.

The 4-leaf over-the-top Roundup Ready Herbicide application is an important component of a bellvine

management program in Roundup Ready cotton. Pre-planting residual herbicides may also be used with Roundup Ready cotton, but may not be essential as long as the 4-leaf spray is able to be applied, depending on the spectrum of other weeds that may be present.

Acceptable bellvine control may be achieved later in the season with inter-row cultivation, chipping and directed Roundup applications in Roundup Ready cotton where only a light population of bellvine emerges. However, if a heavy infestation of bellvine is present, early season and lay-by applications of residual herbicide will be required.

Bellvine is more difficult to manage in non-Roundup Ready cotton. An application of pre-planting residuals herbicides is essential in this situation, and early-season and lay-by directed applications of residual herbicides will also probably be required along with inter-row cultivation and chipping passes to control this weed.

Bellvine plants that emerge late in the season should have little impact on the crop and can be controlled at defoliation or after picking.

Pre-harvest glyphosate

A pre-harvest application of glyphosate can be effective in controlling a low to moderate density of bellvine plants which has survived through to harvest, provided the bellvine is actively growing at the time of application. When a pre-harvest glyphosate is applied to an early crop, it should be possible to prevent bellvine from setting seed; any immature seeds already produced will be rendered sterile by the glyphosate.

This strategy will greatly reduce the return of bellvine seed to the seed bank, allowing the bellvine population to be reduced to a more manageable level over 2 or 3 seasons.

It is equally important that any bellvine plants that are not killed by this treatment are controlled soon after picking before they are able to set viable seed.

Alternative residual herbicides for managing bellvine in fallows and rotation crops

Tordon 242 was the only alternative residual herbicide tested which resulted in a long-term reduction in the germination of bellvine seeds (Table 17). Tordon 242 can be applied to cereal and linseed crops, but picloram, one of the constituents of Tordon 242, is toxic to cotton and has a long residual life in the soil (can be up to 300 days half-life). Consequently, there is a minimum 12 month plant-back period to cotton for Tordon 242.

Bellvine germination was also slightly delayed by Atrazine, but the remaining herbicides had no residual effect on this weed.



Pre-planting residual herbicides give little benefit for bellvine control in Roundup Ready cotton where Roundup Ready Herbicide is applied at the 4-leaf crop stage, but may be required to control other weeds, such as the grass weeds in this Roundup Ready crop.



An effective in-crop bellvine management program over 3 season using Roundup Ready cotton and including a pre-harvest glyphosate greatly reduced the bellvine density in this field resulting in a 4-bale crop almost free of bellvine.

Table 17. Bellvine seedling emergence following applications of residual herbicides.

Herbicide	% Cumulative bellvine germination			
	1 week	2 weeks	4 weeks	1 year
Ally 7 g/ha	69	87	89	89
Atrazine (900 g/ka) 3.3 kg/ha	57	77	80	81
Harmony M 45 g/ha	71	87	87	87
Lontrel (300 g/L) 500 ml/ha	90	91	92	93
Sencor (750 g/kg) 470 g/ha	78	83	83	83
Simazine (900 g/kg) 2.2 kg/ha	75	88	88	89
Spinnaker 400 ml/ha	88	88	89	89
Tordon 242 1 L/ha	11	20	21	22
Untreated	82	88	89	90

Summary

Bellvine is an annual weed that is a major problem in cotton. It is an aggressive, highly competitive weed that can grow through and over a cotton crop and can tangle inter-row and harvesting equipment.

Very high densities of bellvine seedlings can emerge with the cotton crop, and successive germinations may occur throughout the season. Bellvine plants do not flower and set seed until late summer and autumn, but are capable of producing very large numbers of seeds per plant.

Bellvine has few hard seeds, and seeds readily germinate in favourable conditions. Consequently, bellvine is not a plant that has a large, long-term seedbank, and should not necessarily be a long-term weed problem. The bellvine population in a given season will largely reflect the amount of seed produced over the past 1 or 2 seasons. A bellvine problem should be able to be greatly reduced by good management over a couple of seasons, provided that no plants are allowed to set seed. Summer fallows and rotation crops such as sorghum may give the best opportunity to manage bellvine.

Bellvine is readily controlled by cultivation and herbicides in fallows, but is very difficult to control in cotton.

None of the pre-emergence residual herbicides were effective in controlling bellvine. Best results were achieved with trifluralin, diuron and Zoliar. Roundup Ready Herbicide applied over-the-top of Roundup Ready cotton at the 4-leaf stage was very effective in controlling bellvine seedlings. Moderate infestations of bellvine can be managed with the combination of pre-planting residuals and in-crop applications of Roundup.

Directed applications of diuron and prometryn are relatively effective in controlling bellvine later in the season in-crop. Both mid-season and lay-by applications of residuals may be required to control bellvine in a heavy infestation. Directed applications of Roundup are not as effective in controlling bellvine at this stage.

An effective bellvine management system will use all the available control options (cultivation, chipping, herbicides, rotations and fallows) in combination.

MANAGING CAUSTIC WEED IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
Background	H6.1
Herbicides for pre-emergent control of caustic weed in cotton	H6.1
Herbicides for post-emergence control of caustic weed in cotton	H6.2
Summary	H6.2



Caustic weed, also known as doily weed, is an annual weed that most cotton growers have, but ignore.

Background

Caustic weed (*Chamaesyce drummondii*), also known as doily weed, is an annual weed that most cotton growers have, but ignore. Seedlings emerge throughout the season and can establish at high densities, sometimes resulting in a 'green carpet' in fields, with plants covering much of the furrow and hill. It has a tap root and prostrate growth habit, and individual plants may exceed 50 cm in diameter. Due to its habit and density, it is expensive to chip, and is not normally controlled in cotton; chippers generally 'fail' to see it. However, some growers have found that if caustic weed

germinates at sufficient densities early in the season, it can reduce cotton yields. Caustic weed can also be problematic in dryland cotton, competing for moisture and nutrients.



Caustic weed can occur at high densities, sometimes resulting in a 'green carpet' in fields. Individual plants may exceed 50 cm in diameter. Due to its growth habit and density, it is expensive and impractical to hand chip.

Herbicides for pre-emergent control of caustic weed in cotton

Dual and Stomp both gave some level of control of caustic weed when applied and incorporated prior to cotton planting (Table 1). A high rate of Stomp was very effective in controlling caustic weed when surface applied and not incorporated.

Table 1. Control of caustic weed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Narrabri. Control was assessed 5 weeks after application.

Herbicide	% Control
Incorporated	
Dual (720 g/L) 2 L/ha	64
Stomp (330 g/L) 3 L/ha	46
Treflan (400 g/L) 2.8 L/ha	0
Surface applied	
Dual (720 g/L) 2 L/ha	50
Stomp (330 g/L) 4.5 L/ha	90
Cotoran (500 g/L) 4.5 L/ha	23
Untreated	0

Of the other residual herbicides that might be applied pre- or post- cotton planting, Diuron gave the best control 35 days after application (Table 2). These herbicides were applied at layby and were not incorporated.

Table 2. Pre-emergence control of caustic weed with residual herbicides applied at lay-by in an irrigated cotton crop at Warren. Control was assessed after 35 days.

Herbicide	% Control 35 days
Diuron (500 g/L) 2 L/ha	43
Diuron (500 g/L) 3 L/ha	67
Cotogard (250 + 250 g/L) 2 L/ha	20
Gesagard (500 g/L) 2.2 L/ha	7
Cotoran (500 g/L) 2.8 L/ha	0
Untreated	0

Herbicides for post-emergence control of caustic weed in cotton

A range of herbicides were applied post-emergence in January to a heavy infestation of caustic weed growing in cotton (Table 3). Roundup CT, higher rates of Diuron, and Daconate all gave good control of caustic weed 35 days after spraying. The control with Diuron was improved by the addition of DCTron oil at 1%.

Table 3. Caustic weed control with post-emergence herbicides applied over-the-top of an irrigated cotton crop at Warren in January. Control was assessed 18 and 35 days after application.

Herbicide	% Weed kill	
	18 days	35 days
Roundup CT 1.2 L/ha	93	100
Roundup CT 1.2 L/ha + Goal 75 ml/ha	100	100
Diuron (500 g/L) 2 L/ha	23	44
Diuron (500 g/L) 2 L/ha + 1% DCTron	65	70
Diuron (500 g/L) 3 L/ha	73	100
Daconate 2.8 L/ha	27	90
Diuron (500 g/L) 1.4 L/ha + Daconate 1.4 L/ha	53	83
Cotoran (500 g/L) 2.8 L/ha	0	3
Cotogard DF (250 + 250 g/L) 2 L/ha	10	29
Gesagard (500 g/L) 2.2 L/ha	42	30
Untreated	0	0

The results of a second experiment on a dryland site were similar (Table 4), although the caustic weed was moisture stressed following application and the herbicides were less effective than in the previous experiment. Higher rates proved more effective than lower chemical rates in all cases. Diuron again gave the best level of control, with the addition of DCTron oil improving the efficacy of the Diuron treatments. Roundup CT was less effective on stressed caustic weed, but higher rates could be expected to give a better result. The addition of Goal reduced efficacy rather than improving it in this instance. It is likely that the

Goal killed the foliage of the stressed caustic weed before the glyphosate was able to translocate throughout the plant, resulting in the observed reduction in control with the addition of Goal. Daconate was also ineffective in stressed conditions.

Table 4. Caustic weed control with post-emergence herbicides applied on a dryland site at Narrabri in January. Control was assessed 34 days after application.

Herbicide	% Weed kill 34 days
Roundup CT 1.2 L/ha	57
Roundup CT 1 L/ha	53
Roundup CT 0.6 L/ha	42
Roundup CT 1.2 L/ha + Goal 75 ml/ha	24
Diuron (500 g/L) 3 L/ha	92
Diuron (500 g/L) 2.5 L/ha	57
Diuron (500 g/L) 1.5 L/ha	32
Diuron (500 g/L) 3 L/ha + 2% DCTron	100
Diuron (500 g/L) 2.5 L/ha + 2% DCTron	79
Diuron (500 g/L) 1.5 L/ha + 2% DCTron	63
Daconate 3 L/ha	0
Gesagard (500 g/L) 3 L/ha	10
Untreated	0

Summary

Caustic weed is a minor weed of cotton that competes for nutrients and water, and at high densities can reduce cotton yields. It is relatively easily controlled and is often ignored, but it is a persistent weed that may become more problematic in reduced input systems.

Stomp and diuron gave the best control of the residual herbicides, with diuron giving good post-emergence control as well as some pre-emergence control of caustic weed. Glyphosate (Roundup CT) also gave good post-emergence control of caustic weed in an irrigated field.

An integrated weed management system including inter-row cultivation, residual herbicides and glyphosate should effectively control this weed. A mid-season directed application of diuron may be a useful tool in fields where no pre-planting residual herbicides are used.

MANAGING MINTWEED IN COTTON

Graham Charles and Grant Roberts
(NSW Dept of Primary Industries)

Contents	Page
Background	H7.1
Herbicides for pre-emergent control of mintweed in cotton	H7.2
Contact herbicides for post-emergence control of mintweed in cotton	H7.2
Alternative herbicides for pre-emergence control of mintweed	H7.2
Fallow herbicides for control post-emergence control of mintweed	H7.3
Summary	H7.3



Mintweed is a minor annual weed of cotton. It develops a compact bush and is a prolific seed producer. A single plant can produce up to 180 000 seeds in a season.

Background

Mintweed (*Salvia reflexa*), is generally a minor annual weed of cotton, but has the potential to become a serious pest in some situations. Mint weed has in the past been a major problem weed on some fields in the Macquarie and Upper Namoi valleys, requiring additional inputs of residual herbicides and hand-chipping for control.



Mintweed has a distinctive cotyledon shape and texture and the leaves have a strong mint smell when crushed.

Mintweed is easily identified. It has a distinctive cotyledon shape and texture and the leaves of seedlings and plants have a strong mint smell when crushed.

A large flush of mintweed seedlings can emerge with or soon after the cotton crop and lesser numbers of seedlings may continue to emerge throughout the season. Seedlings grow rapidly in warm spring conditions (more rapidly than the cotton crop) and can quickly smother establishing cotton seedlings, competing strongly for light, water and nutrients. Mintweed seedlings may begin to flower and set seed within 50 - 60 days of emergence and will continue to set seed throughout the season. Later emerging seedlings grow even more rapidly and may begin flowering as soon as 32 days after emergence.

A mature plant can produce up to around 180 000 seeds during the season, but these seeds initially have strong dormancy and will not germinate before the following season. This dormancy is broken over winter, often resulting in a flush of mintweed seedlings in spring.

Mintweed has been problematic in some of the cooler cotton growing areas and may also be problematic in dryland cotton, competing for moisture and nutrients. The first flush of seedlings

has often been controlled with inter-row cultivation and chipping, but this option is labour-intensive and expensive.



A flush of mintweed seedlings may emerge with the cotton crop and grow rapidly in the warm conditions, quickly smothering establishing cotton seedlings.

Herbicides for pre-emergent control of mintweed in cotton

Dual and diuron both gave some level of control of mintweed when applied and incorporated prior to cotton planting, with the best control coming from a combination of the two herbicides (Tables 1 & 2).

Good soil incorporation and good soil moisture are essential to the success of these pre-planting treatments. Poor incorporation, a cloddy seedbed or rapidly falling soil moisture are all likely to result in poor control of mintweed with pre-planting incorporated residual herbicides.

Stomp, Gesagard, Cotogard and Cotoran were all relatively ineffective in controlling mintweed, but are valuable for controlling a range of other weeds. Trifluralin was not included in the experiments.

Table 1. Control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll. Control was assessed 8 weeks after application.

Herbicide	% Control
Dual (720 g/L) 4 L/ha	60
Zoliar 4 kg/ha	40
Dual (720 g/L) 2 L/ha	38
Gesagard (500 g/L) 6 L/ha	30
Stomp (330 g/L) 3 L/ha	10
Cotoran (500 g/L) 6 L/ha	7
Diuron (500 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 4 L/ha	40
Dual (720 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 4 L/ha	20
Diuron (500 g/L) 4.7 L/ha *	0
Untreated	0

Note* - this diuron treatment was not incorporated.

Table 2. Pre-emergence control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll (2nd season). Control was assessed 8 weeks after application.

Herbicide	% Control
Dual (720 g/L) 4 L/ha	73
Dual (720 g/L) 2 L/ha	75
Diuron (900 g/kg) 2.5 kg/ha	65
Cotogard (250 + 250 g/L) 3.5 L/ha	12
Dual (720 g/L) 2 L/ha + Diuron (900 g/kg) 2.5 kg/ha	90
Dual (720 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 3.5 L/ha	46
Diuron (900 g/kg) 2.5 kg/ha + Cotogard (250 + 250 g/L) 3.5 L/ha	41
Untreated	0

Contact herbicides for post-emergence control of mintweed in cotton

Glyphosate and heavy rates of Daconate gave the best post-emergence control of mintweed with contact herbicides (Table 3), although Daconate was less effective in a second experiment (Table 5). Shielded applications of glyphosate should be effective in controlling mintweed in conventional cotton, but may leave an unacceptably large population of mintweed in the cotton plant-line. Roundup Ready Herbicide should be effective in removing the early flush of mintweed in Roundup Ready cotton and Roundup Ready Flex cotton crops. However, later germinations will require additional treatments.

Table 3. Post-emergence control of mintweed with broadcast herbicides applied to 1 – 5 leaf mintweed seedlings in an irrigated cotton crop at Carroll. There was a population of around 10 mintweed seedlings per m² when the herbicides were applied.

Herbicide	% Weed Kill
Glyphosate 450 2 L/ha	100
Daconate 1 L/ha	10
Daconate 2 L/ha	85
Daconate 3 L/ha	100
Basta 5 L/ha	88
Staple 60 g/ha	60
Staple 90 g/ha	75
Staple 120 g/ha	65
Daconate 1 L/ha + Staple 90 g/ha	83
Daconate 2 L/ha + Staple 60 g/ha	80
Dual (720 g/L) 4 L/ha	10
Dual (720 g/L) 2 L/ha	5
Untreated	0

Dual, which gave good pre-emergence control of mintweed, was ineffective for post-emergence control. Staple appears to have some activity on mintweed, but even at 120 g/ha (the maximum use rate) did not give effective control of this weed. Combinations of Staple and Daconate were

WEEDpak

section H7

included in order to explore a more cost effective way of using Staple, but gave no better control than either herbicide alone.

Alternative herbicides for pre-emergence control of mintweed

Excellent mintweed control was achieved with Atrazine, Simazine and Primextra (a mixture of atrazine and metolachlor). These herbicides are not safe to apply to cotton, but can be used with rotation crops such as maize and sorghum (Atrazine and Primextra (plus Concept for sorghum)), chick peas and faba beans (Simazine).

An option for cotton growers with a heavy infestation of mintweed is to rotate to one of these alternative crops for one or two seasons until the mintweed seedbank is reduced. However, there is an extended plant-back period before it is safe to grow cotton following the use of these residual herbicides, depending on the application rate, soil type and pH and soil moisture (rainfall and irrigation pattern).

Table 4. Control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll. Control was assessed 8 weeks after application.

Herbicide	% Control
Atrazine (500 g/L) 5.4 L/ha	100
Simazine (900 g/kg) 3 kg/ha	100
Primextra (227 + 223 g/L) 4 L/ha	90
Untreated	0

Fallow herbicides for post-emergence control of mintweed

Although a wide range of herbicides and herbicide combinations are available for controlling weeds in fallows, spray drift can be a major issue with many of these options as most are not safe on other crops, including cotton, and can cause unacceptable levels of damage to crops or pastures if spray drift does occur.

Glyphosate, bromoxynil and atrazine were all effective in controlling mintweed when applied over-the-top of 1 - 4 leaf seedlings (Table 5). However, plant-back issues may occur with atrazine, as previously discussed. Plant-back problems can also occur with some of the other options, although the plant-back periods are much shorter than with atrazine.

Spray.Seed and Basta also gave reasonable control of mintweed, but some seedlings survived these treatments and would have needed to be controlled with a follow up treatment.

Table 5. Mintweed control with post-emergence herbicides applied over-the-top to 1 – 4 leaf mintweed seedlings in an irrigated cotton crop at Carroll in January.

Herbicide	% Weed kill
Glyphosate 450 2 L/ha	100
Bromicide 3 L/ha	100
Atrazine (500 g/L) 5.4 L/ha	100
Spray.Seed 4 L/ha	88
Basta 5 L/ha	88
Daconate 3 L/ha	60
Banvel 200 2 L/ha	53
Express 30 g/ha	0
Glyphosate 450 0.6 L/ha + Express 15 g/ha	48
Untreated	0

Summary

Mintweed is a minor annual weed of cotton that can emerge in large numbers at or soon after crop emergence. Mintweed seedlings grow more rapidly than cotton seedlings in spring conditions and can compete for sunlight, nutrients and water.

A pre-planting combination of Dual and Diuron gave the best residual control of mintweed. Atrazine and simazine also gave excellent residual control of mintweed, although these herbicides can not be safely used in cotton.

Glyphosate gave good post-emergence control of mintweed in cotton, and should be an effective management option for this weed in Roundup Ready Flex crops.

MANAGING LIPPIA IN THE COTTON FARMING SYSTEM

Graham Charles
(NSW Dept of Primary Industries)

Contents	Page
Background	H8.1
Lippia and irrigation structures	H8.1
Lippia and water movement	H8.2
Lippia and farming	H8.2
Lippia and grazing	H8.2
Lippia and the riparian zone	H8.2
Herbicides for controlling lippia	H8.2
Summary	H8.4



Lippia is an aggressive perennial weed that is rapidly spreading through the inland river system.

Background

Lippia (*Phyla nodiflora*), is a highly invasive weed which is rapidly spreading in the Murray Darling Basin, and currently infests over 5 million ha. It is seriously degrading the riparian and floodplain environments in this region, reducing biodiversity and threatening valuable ecosystems.

As well as its major environmental impact, lippia has serious negative implications for the grazing

industry. Lippia competes very strongly with all native and introduced pasture species, establishing on what is often the most valuable grazing areas. Once established, lippia out-competes other pasture species, resulting in almost pure lippia stands with little grazing value.



Lippia spreads until it forms an almost continuous mat, out competing other species. Note the lack of any vegetation bulk in this infestation in the Gwydir valley.

Lippia flowers prolifically, establishes readily from seed, and also spreads from vegetative parts that are carried in mud and flood waters. It is a perennial plant that grows rapidly in wet conditions, but can survive prolonged dry periods.

Lippia is extremely tolerant of grazing, but has little grazing value. Neither heavy grazing nor the exclusion of grazing appear to restrict the spread of this weed.

However, lippia doesn't tolerate cultivation, and so isn't normally a problem in conventional farming systems. Yet, lippia has the potential to directly impact the cotton industry in a number of ways.

Lippia and irrigation structures

Lippia has an extensive and well developed root system that enables it to dry the soil to depth. This drying can result in severe cracking in heavy clay soils, opening the soil to erosion. Lippia infested creek and river banks are often unstable and heavily eroded. The same effect could occur on irrigation structures, reducing bank stability, leading to erosion and bank failures.

Lippia could easily establish above the water level in a turkey's nest dam and grow over the banks. If this happens, lippia will eventually cause extensive cracking of the banks, and will inevitably lead to bank failure.

Turkey's nest dams with lippia established on the walls are predisposed to fail.

It is critical that lippia not be allowed to establish on irrigation structures.



Lippia can cause severe cracking, destabilizing banks and causing slumping. (Photo: Mike Lucy)

Lippia and water movement

Heavy infestations of lippia result in a great reduction in the bulk of vegetation on the ground, potentially increasing the rate of water movement and the potential for erosion and soil movement.

Continuing expansion of the lippia infested areas in the river valleys is likely to result in an increase in the rate of water flow in these valleys during flood times, increasing erosion and soil movement problems.

Lippia and farming

Lippia is not a problem in conventional farming systems, as it doesn't tolerate cultivation. However, lippia is likely to become problematic in zero-tillage systems, where it does tolerate the herbicides commonly used.

Inclusion of strategic cultivation into a zero-tillage system may become a necessary management input where lippia becomes a problem.

Lippia and grazing

The spread of lippia in pastures can be reduced by good grazing management, encouraging other pasture species. Competitive pasture species may need to be introduced to degraded areas, and over-grazing and set-stocking should be avoided.

Nonetheless, research from Queensland indicates that lippia is likely to out compete any and all pasture species in the long-term. Careful grazing

management is essential to ensure the longevity of pastures in susceptible areas.

Lippia and the riparian zone

Moves by the cotton industry towards better management of the riparian zone are being hampered by heavy lippia infestations where these occur. Re-establishment of native species into areas degraded by lippia will be very difficult and will probably necessitate short-term control of lippia with cultivation and/or herbicides.

Herbicides for controlling lippia

Lippia doesn't tolerate cultivation, but cultivation isn't a desirable option in easily erodible areas, in pastures or treed areas, or in close proximity to water, the areas where lippia is most frequently found.

A range of herbicides that control lippia is available, although repeated applications are always necessary, as lippia rapidly re-establishes from seed and surviving plants and plant pieces.

Lippia is also likely to reinvade clean areas after flood inundation. Management must make allowances for the movement of this weed in flood water, and in high-flow water pumped from rivers during flood events.



A table-drain uniformly infested with lippia was used for a herbicide screening experiment.

Lantana 600[®], an Agricrop product, is registered at 5 L/ha for use on lippia on non-crop areas.

The Australian Pesticides & Veterinary Medicines Authority (APVMA) has also approved the use of 2 and 3 way mixtures of glyphosate (450 g/L) at 2.6 - 5.4 L/ha plus 2,4-D amine (225 g/L) at 2.4 L/ha and/or metsulfuron (600 g/kg) at 15 - 30 g/ha for lippia control on fallows in NSW and Qld. Effective control of this weed requires 2 applications over summer when possible. For more information on the permits and herbicide use, refer to the APVMA Permit web site at: www.apvma.gov.au. The current permits also allow for the use of 2,4-D amine (500 g/L) at 2 - 4 L/ha for controlling lippia in pastures.

WEEDpak

section H8

However, 2,4-D can not be safely used around cotton, and metsulfuron has a long plant-back to cotton and some other species, especially when applied to alkaline soils.

So how effective are glyphosate and Lantana 600 alone?

The best control over a 2 year period from a field experiment in the Namoi valley was observed with Roundup CT® at 20 L/ha and Arsenal® at 6 L/ha (Table 1). Roundup CT at 5 L/ha was also still giving a reasonable level of control after 1 year. This result suggests that repeated applications of Roundup CT at around 5 L/ha are necessary to give effective long-term control of lippia, and are allowed under the current APVMA permit.

Table 1. The long-term control of lippia following a single herbicide application in autumn 2000 in the lower Namoi Valley. Weed kill was assessed 60 days, 1 and 2 years after application.

Herbicide	% Weed kill		
	60 days	1 year	2 years
Arsenal 6 L/ha	67	77	40
Arsenal 2 L/ha	30	10	10
Roundup CT 20 L/ha	100	80	37
Roundup CT 5 L/ha	70	60	27
Lantana 600 6 L/ha	63	43	27
Lantana 600 3 L/ha	53	33	23
Tordon 75D 5 L/ha	97	13	10
Starane 6 L/ha	57	3	10
Starane 2 L/ha	80	3	7
Tordon 242 5 L/ha	30	7	10
Garlon 2 L/ha	77	7	10
Grazon 2 L/ha	47	7	10
Untreated	0	0	3

Note* Lantana 600® is the only herbicide registered for the control of lippia. Glyphosate may be used under an APVMA permit.

Given the high cost of a 6 L/ha rate of Arsenal, the lack of registration of this product for this use and the problems sometimes associated with the use of this herbicide, the results from this experiment don't justify the use of Arsenal to control lippia.

None of the other herbicides that might be used in a fallow over summer, Tordon®, Starane®, or Grazon® were effective in controlling lippia. These results are supported by the findings of Mike Lucy (QDPI&F) and others who recorded similarly poor results from a range of fallow herbicides.

Lippia control was improved by repeated applications of Lantana 600 and Roundup CT (Table 2). Both herbicides gave good results, and better control from a repeated application of a lower rate than was achieved with a single application at a higher rate. Lantana 600 at 5 L/ha (twice) gave very good control after 1 year (90%). Two applications of Roundup CT at 5 L/ha also gave good results on a difficult-to-control weed.

Clearly, both these herbicides gave good levels of control with repeated applications at their label/permit rates and would be suitable for controlling lippia in fallows.

Lantana 600 has an advantage over Roundup CT for spot applications in that it acts extremely quickly when applied to flowering lippia, rapidly dulling the flowers. This readily distinguishes sprayed and unsprayed patches, simplifying spot applications.

Lower rates of Arsenal didn't give control comparable with the results of Lantana 600 or Roundup CT and should not be used for the reasons previously stated.

Table 2. The long-term control of lippia following herbicide applications in summer and autumn 2000/2001. Weed kill was assessed 60 days and 1 year after the initial herbicide application. The % ground cover of other species 1 year after the initial herbicide application is also shown.

Herbicide		% Weed control		% Other species
		60 days	1 year	1 year
Lantana 600 5 L/ha	Lantana 600 5 L/ha	95	90	83
Roundup CT 10 L/ha	Roundup CT 10 L/ha	95	70	57
Roundup CT 5 L/ha	Roundup CT 5 L/ha	95	70	63
Roundup CT 15 L/ha		80	47	60
Roundup CT 10 L/ha		70	55	50
Roundup CT 5 L/ha		57	40	57
Lantana 600 10 L/ha		53	33	73
Lantana 600 5 L/ha		80	47	60
Arsenal 2 L/ha	Arsenal 2 L/ha	100	37	23
Arsenal 1 L/ha	Arsenal 1 L/ha	93	20	37
Arsenal 2 L/ha	Roundup CT 5 L/ha	79	7	27
Arsenal 4 L/ha		93	33	43
Arsenal 2 L/ha		67	10	27
Arsenal 1 L/ha		72	57	60
Untreated		3	7	23

Note* Lantana 600® is the only herbicide registered for the control of lippia. Glyphosate may be used under an APVMA permit.

Combinations of glyphosate + 2,4-D amine and glyphosate + Ally appeared to give some improvement in lippia control compared to these herbicides alone but the onset of drought conditions made it impossible to determine the long-term effect of these treatments (Table 3). None of the combinations gave improved control compared to Lantana 600 but some did give better control than Roundup CT alone.

2,4-D and 2,4-D or metsulfuron combinations with glyphosate could be useful in fallow applications where there is no risk of herbicide drift to sensitive crops such as cotton, and where there is sufficient time between the herbicide application and the following cotton crop.

Table 3. The control of lippia following a single herbicide application in November 2001 in the lower Namoi Valley. Weed kill was assessed 60 days after application.

Herbicide	% Weed kill 60 days
Lantana 600 10 L/ha	82
Lantana 600 5 L/ha	67
Tordon granules 20 kg/ha	52
Roundup CT 5 L/ha	41
2,4-D amine 4 L/ha	28
2,4-D amine 2 L/ha	15
Ally 30 g/ha	15
Roundup CT 2.5 L/ha	7
Ally 15 g/ha	7
Tordon granules 20 kg/ha	4
Roundup CT 5 L/ha + Ally 30 g/ha	67
Roundup CT 5 L/ha + Tordon 20 kg/ha	63
Roundup CT 5 L/ha + 2,4-D amine 4 L/ha	56
Roundup CT 5 L/ha + 2,4-D amine 4 L/ha + Ally 30 g/ha	44
Roundup CT 2.5 L/ha + 2,4-D amine 2 L/ha + Ally 15 g/ha	33
Roundup CT 2.5 L/ha + 2,4-D amine 2 L/ha	30
Roundup CT 2.5 L/ha + Tordon 10 kg/ha	26
Roundup CT 2.5 L/ha + Ally 15 g/ha	15
Untreated	0

Note* Lantana 600® is the only herbicide registered for the control of lippia. Glyphosate, 2,4-D amine and metsulfuron may be used under an APVMA permit.



Roundup CT® at 5 L/ha gave good short and medium-term control of lippia in a table-drain, but also removed all other species..

Management of lippia not only involves the control of the lippia, but also the re-establishment of other competitive species. Lantana 600 is the herbicide of choice where other species are present as it is relatively soft on most other species, leaving more of these species to compete with any re-establishing lippia. This feature is important to the success of a lippia management program, as lippia is likely to reinvade clean areas. Areas treated twice with Lantana 600 at 5 L/ha (Table 2) had the best recovery of other species with 83% ground cover of other species 1 year after the first herbicide application. Lantana 600 will control some other species including galvanised burr, spear thistle and harrisia cactus.

For the same reasons, lower rates of glyphosate should be used where possible to allow for the retention of other species.

Summary

Lippia is a highly undesirable weed and should not be allowed to establish in the cotton industry. Particular care must be taken to ensure that lippia doesn't establish on irrigation structures as its presence is likely to lead to the failure of these structures.

Lippia should be controlled with cultivation where appropriate, or repeated applications of Lantana 600 on non-crop areas, or glyphosate on fallows. Glyphosate plus metsulfuron is the preferred option on fallows on non-alkaline soils, where cotton will not be a following crop.

2,4-D amine may be used to control lippia in pastures provided that there is no risk of spray drift to sensitive crops such as cotton.

MANAGING FLAXLEAF FLEABANE IN COTTON

Jeff Werth, Todd Green, Michael Widderick & HanWen Wu

(Qld. Department of Employment Economic Development and Innovation,
University of New England, & NSW Dept. Primary Industries)

Contents	Page
The fleabane family	H9.1
The flaxleaf fleabane plant	H9.2
Strategies for managing flaxleaf fleabane	H9.3
Field history	H9.3
Monitoring seedling emergence	H9.4
Using a variety of IWM tools	H9.4
Preventing survivors from setting seed	H9.4
Controlling flaxleaf fleabane in fallows	H9.4
Residual herbicides for controlling flaxleaf fleabane	H9.5
Controlling flaxleaf fleabane in cotton	H9.6
Managing flaxleaf fleabane in the farming system	H9.7
Glyphosate resistance	H9.8
Farm hygiene	H9.11
Summary	H9.12

Tall fleabane tends to be the more problematic species elsewhere in the world, but is of minor importance in Australia, where it is most commonly found on roadsides and in pastures.



The fleabane family

Flaxleaf or hairy fleabane (*Conyza bonariensis*) is a member of the Asteraceae, or daisy family of plants. The Asteraceae is the largest of the plant families and includes many weedy species, most notably the thistle family.

The *Conyza* genus (the part of the Asteraceae family including the fleabanes) contains 60 species, found throughout the temperate zones of the world. There are seven *Conyza* or fleabane species in Australia, the three most important species being flaxleaf fleabane, Canadian fleabane (*C. canadensis*) and tall fleabane (*C. sumatrensis*). Flaxleaf fleabane is native to South America and is the most weedy and the most common of the fleabane species in cropping systems in New South Wales and Queensland.

Flaxleaf fleabane is a member of the daisy family. It has become a major problem in the conservation farming systems of northern NSW, and southern and central Queensland. It is easily confused with tall fleabane and Canadian fleabane.

The flaxleaf fleabane plant

Flaxleaf fleabane is an annual or short-lived perennial weed that is now common right across the cotton industry.

Flaxleaf fleabane germinates between temperatures of 10°C and 30°C, with optimal emergence occurring from 20 - 25°C (Figure 1).

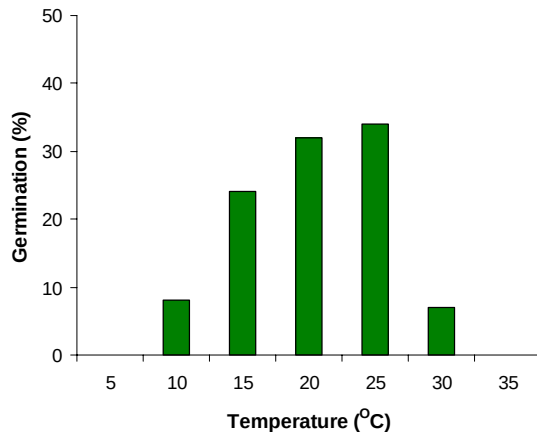


Figure 1. Temperature range for flaxleaf fleabane germination.

In the field, this correlates to mild conditions, generally in autumn, early winter and spring. However, there can be some emergence during mid-winter and summer when conditions are right. The likely times for emergence are illustrated in the lifecycle and management tables (Tables 8 and 9).



Flaxleaf fleabane rosettes in mature cotton. These plants are likely to have emerged during mild/wet conditions in mid-summer.

The growth rate of flaxleaf fleabane is affected by the time of its emergence. Plants that emerge in autumn and early winter grow slowly above ground, however below ground the roots continue to grow. This provides the plant with the ability to grow to flowering quickly in warmer spring temperatures. Plants that emerge in spring grow relatively more quickly, putting more resources into above-ground growth, but mature later in summer compared to the plants that established in autumn.

Due to the larger root system, the over-wintered plants are harder to control than plants of the same size that have emerged in spring.

A single fleabane plant is capable of producing over 100 000 seeds. Therefore, even at a low germination percentage (say, 5%), there is potential for 5000 seedlings to emerge at 30°C from just a single, uncontrolled plant.

Each seed has a pappus, or light hairs attached, which enable the seed to be easily dispersed by wind.



Flaxleaf fleabane plants have multiple flowers and can produce a large number of small seeds. The pappus (hairs attached to the end of the seed) assist in wind dispersal.

Most fleabane seeds lose their viability within 12-18 months on the soil surface. However, when buried, fleabane seeds can persist for several years (Figure 2).

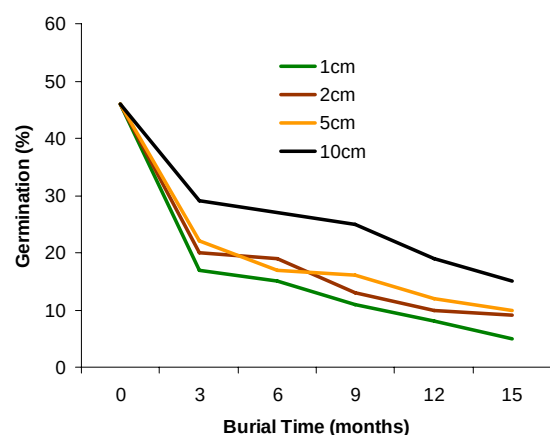


Figure 2. The persistence of flaxleaf fleabane increases as the depth of seed burial increases.

Flaxleaf fleabane requires light to germinate. Experiments have shown the even when temperature and moisture conditions are right, fleabane seeds will not germinate in the absence of light. This is illustrated in Figure 3, where no germination occurred under 100% shade, even though conditions were otherwise suitable for germination. However, some germination did occur on 90% shade, indicating that although flaxleaf fleabane requires light, it may not need much light to germinate.

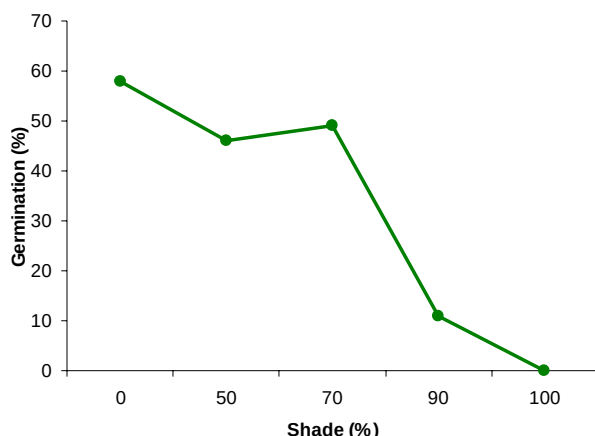


Figure 3. Effect of partial and complete shading under shade cloth on flaxleaf fleabane germination.

This is further illustrated in Figure 4, which shows the effect of stubble load and soil type on flaxleaf fleabane germination. Germination was highest on grey soil, followed by red soil with no stubble. In general, as the stubble load increased, flaxleaf fleabane germination decreased. However, even under the highest stubble load of 3.6 t/ha (which equated to approximately 86% shade), approximately 10 - 20% of seeds were still able to germinate, dependant on soil type.

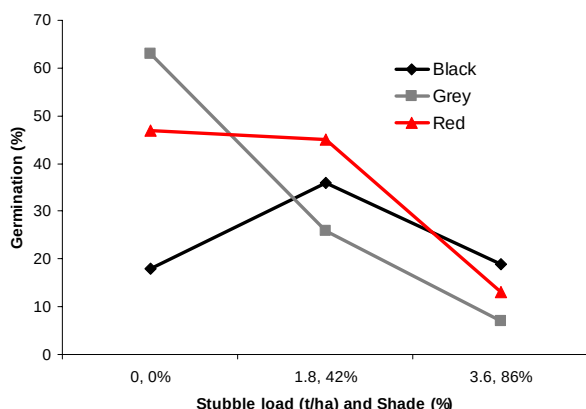


Figure 4. Effect of shading on flaxleaf fleabane germination, using stubble and three soil types.



Flaxleaf fleabane seedlings can establish at any time of the year, potentially adding to the seed bank and future problems. (Photo G. Charles).

Strategies for managing flaxleaf fleabane

Successful management of flaxleaf fleabane requires an IWM program centred on reducing the seed bank replenishment. That is, the easiest way of controlling flaxleaf fleabane is to not have it in the first place, or to exhaust the seed bank.

A number of components will be central to any fleabane management program. These include:

- knowing the field history,
- monitoring seedling emergence,
- using a variety of IWM tools, and
- preventing survivors from setting seed.

Field history

It is important to know previous herbicide history, as fleabane populations that have been exposed to glyphosate over a number of years are likely to be more difficult to control with glyphosate compared to populations that have no previous history of glyphosate. In fact, some flaxleaf fleabane populations have had an extensive history of glyphosate exposure have been found to be resistant to glyphosate. Larger fleabane plants from these populations will be almost impossible to kill using glyphosate.

Monitoring seedling emergence

Be aware of when flaxleaf fleabane is likely to emerge. Generally, it is more likely to emerge following rain in late autumn, early winter and early spring. However, flaxleaf fleabane will emerge whenever there are moist and mild conditions, and this could be at any time of year, even mid-summer. Plants are much easier to control when they are young, so it is important to closely monitor potential fleabane emergence throughout the cropping system, including the fallow period.

Using a variety of IWM tools

It is important to use a variety of chemical and non-chemical tactics to manage flaxleaf fleabane. When herbicides are used as the primary management tools, it is important to rotate herbicide groups. Robust herbicide rates must be used in order to get maximum effectiveness to keep weed numbers low. Keeping weed numbers low is important for resistance management, as resistance is less likely to develop in fields with fewer weeds than in heavily infested fields.

Preventing survivors from setting seed

Control of survivors is vitally important; flaxleaf fleabane's prolific seed production means that even if very few plants are left, they will produce very large numbers of seeds, with the potential for a large, future weed problem. This will considerably reduce the effectiveness of previous control measures and perpetuate the problem.

Controlling flaxleaf fleabane in fallows

Flaxleaf fleabane has emerged as a problem weed largely due to the prevalence of no-till, glyphosate based farming systems. It is obvious in the trial results of Table 1 that glyphosate is much less effective on larger plants. A number of tank-mix partners were trialled for their effectiveness to improve control in fallow. A number of tank-mixes were relatively successful. The most successful in this case was glyphosate mixed with Tordon 75-D, which is now registered for control of flaxleaf fleabane seedlings and young rosette plants.

Table 1. Effects of post-emergent treatments on flaxleaf fleabane in winter fallow in 2003. Weed kill was assessed nine weeks after application.

Treatment	Rate (L or g/ha)	% Weed kill
Spray.Seed	2.4	57
Paraquat (rosette < 8 cm)	1.5	53
Roundup CT (rosette < 8 cm)	1.5	88
Roundup CT (rosette > 10 cm)	1.5	13
Roundup CT fb Spray.Seed*	1.5 fb 2.4*	96
Roundup CT + Amitrole T	1.5 + 2.5	93
Roundup CT + Ally	1.5 + 7	90
Roundup CT + Amicide 500	1.5 + 2	97
Roundup CT + Ally + Amicide 500	2.5 + 7 + 1	93
Roundup CT + Tordon 75-D	2.5 + 1	99
Roundup CT + Grazon DS	2.5 + 0.75	98
Roundup CT + Cadence	2.5 + 0.7	96
Roundup CT + Garlon + Ally	2.5 + 0.12 + 7	96
Amicide 500 + Amitrole T	2 + 2.5	94
Amicide 500 + Ally	2 + 7	95

Note. Fb – indicates the first herbicide application was followed by the 2nd herbicide. Other herbicide combinations in this table were tank-mixed.*

Herbicide performance depends largely on weed size and growing conditions at spraying. In general, responses from herbicide applications can be quite slow, with some visual symptoms not becoming apparent till nearly a month after application.

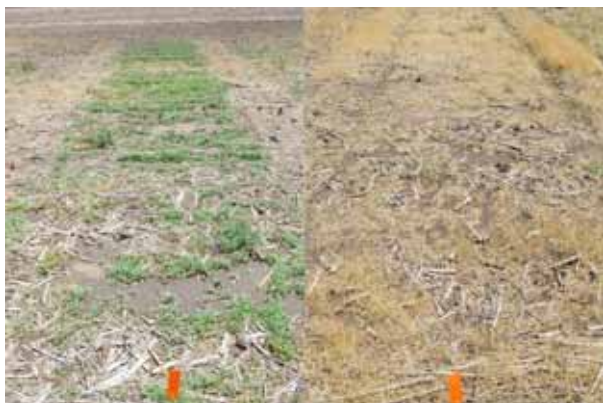
It is interesting to note that none of the treatments in Table 1 provided 100% control of flaxleaf fleabane, although the Tordon 75D and Grazon DS treatments came close. It was also noted that in practice, the results that growers have been experiencing have been quite variable. Due to its very high seed production, even very small numbers of escapes of flaxleaf fleabane can have considerable consequences.

As a result, it was decided to trial the “double-knock” herbicide tactic on fleabane. “Double-knock” is the sequential application of knock down herbicides from different herbicide mode of action groups. This technique, developed to control glyphosate resistant ryegrass, involves applications up to 2 weeks apart, where it is assumed that the 2nd herbicide application will control potential survivors of the 1st application. Therefore, it is assumed that the 1st application will also be relatively effective on the weeds sprayed, and it is important the both applications contain robust herbicide rates of herbicides which are effective against the target weed.

Table 2. Percentage kill of flaxleaf fleabane plants using the “double-knock” tactic at Dalby in 2006. The second knock was applied 7 days after the initial knock.

Initial knock	Second knock	% Weed kill
No herbicide (Control)		0
Roundup CT 2 L/ha	na	55
Roundup CT 2 L/ha	Spray.Seed 1.6 L/ha	95
Roundup CT 2 L/ha	Spray.Seed 2.4 L/ha	97
Roundup CT 2 L/ha + Surpass 1.5 L/ha	Spray.Seed 1.6 L/ha	99
Roundup CT 2 L/ha + Surpass 1.5 L/ha	Spray.Seed 2.4 L/ha	99
Roundup CT 2 L/ha + Surpass 3 L/ha	Spray.Seed 2.4 L/ha	100
Roundup CT 2 L/ha	Amicide 625 1.5 L/ha	94
Roundup CT 2 L/ha	Amicide 625 3 L/ha	91

The effect of the double-knock is shown in Table 2. Note that this fleabane population was not well controlled by the single application of glyphosate, with 2 L/ha of Roundup CT only controlled 55% of weeds sprayed. The double-knock significantly improved fleabane control, but a combination of glyphosate+ 2,4-D followed by Sprayseed, all at robust rates was required to achieve 99 - 100% control.



Using the double-knock tactic of glyphosate followed by paraquat (right side) greatly improved the control of flaxleaf fleabane compared to the result from glyphosate alone (left side).

Further experiments were conducted to determine the best time between applications using the double-knock tactic. The effectiveness of paraquat was also examined compared to Spray.Seed®, which contains both paraquat and diquat. The time between treatments ranged from separate applications on the same day, to 14 days for

paraquat and Spray.Seed, and 5 days for 2,4-D (Figure 5).

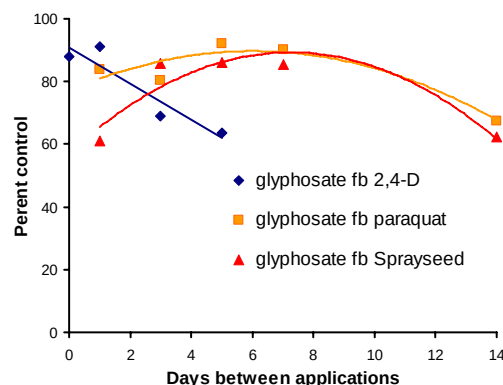


Figure 5. Effect of timing between glyphosate and follow-up applications of 2,4-D, paraquat and Spray.Seed on flaxleaf fleabane control.

The control of flaxleaf fleabane with applications of glyphosate followed by either Spray.Seed or paraquat were similar, with the optimum timing between applications being between 5 - 10 days. However, as the time increased between applications of glyphosate and 2,4-D, control decreased, with the best results achieved by applying the 2,4-D within one day of the glyphosate.

Residual herbicides for controlling flaxleaf fleabane

Flaxleaf fleabane seedlings often emerge in the field in dense populations, such that the rosettes are often overlapping, with larger plants shading the smaller plants, making it very difficult to achieve good herbicide coverage on all plants. The high density of seedlings places pressure on post-emergent herbicides to provide effective control, particularly where poor coverage occurs due to the shading of smaller plants. Residual herbicides, therefore, have an important role in minimising the number of seedlings that emerge and subsequently need to be controlled using a post-emergence herbicide.

A number of residual herbicides have been trialled for their effectiveness at minimising flaxleaf fleabane emergences. An experiment combining residual herbicides with the 2nd herbicide application in a double-knock tactic was conducted at Dalby in 2009. The aim of this experiment was to simulate controlling existing fleabane rosettes, while minimising future emergences.

All herbicides had a significant effect on fleabane emergences, with atrazine, Balance, and Sharpen performing the best (Table 3).

Table 3. Residual control of flaxleaf fleabane when combined with a double-knock treatment. Trial was conducted at Dalby in 2009.*

Herbicide	Emergences per 100m ² (126 DAT)
<i>Glyphosate CT 1.5 L/ha + Surpass 475 1.0 L/ha fb Spray.Seed 1.6L/ha combined with...</i>	
No residual	1543
Atrazine 4 L/ha	0
Diuron 1.5 kg/ha	58
Sharpen 200 ml/ha	5
Glean 20 g/ha	13
Balance 100 g/ha	2

Note* Refer to herbicide labels for plant-back periods to cotton.

The residual control significantly improved when Surpass 475 was replaced by Tordon 75D as the mix partner with glyphosate in the first application (Table 4). The addition of picloram in the Tordon 75D considerably reduced fleabane emergence even when no further residual herbicides were applied.

Table 4. Residual control of flaxleaf fleabane when combined with a double-knock treatment. Trial was conducted at Dalby in 2009.*

Herbicide	Emergences per 100m ² (126 DAT)
<i>Glyphosate CT 1.5 L/ha + Tordon 75D 0.7 L/ha fb Spray.Seed 1.6L/ha combined with...</i>	
No residual	178
Atrazine 4 L/ha	0
Diuron 1.5 kg/ha	0
Sharpen 200 ml/ha	0
Glean 20 g/ha	12
Balance 100 g/ha	8

Note* Refer to herbicide labels for plant-back periods to cotton.

All the herbicides trialled in Tables 3 & 4 have significant plant-back periods to cotton, although diuron can be used as a pre-emergent and post-emergent (lay-by). Therefore, another experiment was conducted to determine the effectiveness of the residual herbicides more commonly used in cotton.

The results in Table 5 are from one field experiment. These preliminary results have been backed up by two glasshouse experiments. The group C herbicides, prometryn and Convoy (prometryn + Fluometuron) were both effective at reducing fleabane emergence. Norflurazon, actually registered for nutgrass at a rate of 5 kg/ha, also reduced fleabane emergence when used at 1 kg/ha in this trial.

Table 5. Residual control of flaxleaf fleabane with residual herbicides used in cotton. Trial was conducted in 2010 at Millmerran.

Herbicide	Plants/m ²	
	36 DAT	51 DAT
Nil	4.2	7.0
Pendimethalin 3.3 L/ha	3.5	7.5
Convoy 2.9 kg/ha	0.0	0.3
Prometryn 2 kg/ha	0.0	0.2
Metolachlor 2 L/ha	0.5	1.2
Norflurazon 1 kg/ha	0.5	1.2

Control of flaxleaf fleabane in cotton

The herbicide options for controlling flaxleaf fleabane in cotton are limited. The use of pre-emergent herbicides such as diuron (not specifically registered for fleabane control, but registered for broadleaf control) or Convoy will aid to reduce fleabane emergence in crop. The application of a lay-by, such as diuron or prometryn, will reduce possible emergences that may occur later in the season. However, there are likely to be some escapes and plants which establish will continue to grow throughout the season and by the time of picking, will be large, mature and setting seed. Any control measures applied at this time will prevent further seed set, but are generally too late and are ineffective in managing the weed population.



Heavy flaxleaf fleabane infestations have become all too common on many fallow fields. These fleabane plants emerged in the previous wheat crop and are now very difficult to control with herbicides. (Photo G. Charles).

Knowing that glyphosate is not likely to be effective in controlling flaxleaf fleabane in Roundup Ready Flex cotton crops, a useful strategy may be to apply a band of residual herbicide to the plant-line to reduce emergences in the plant-line of these crops. This could then be followed by a partial double-knock, consisting of a robust rate of Roundup Ready herbicide over-the-top of the crop, with a shielded paraquat or Spray.Seed application in the inter-row area, or inter-row cultivation between the rows 5-10 days after the glyphosate.

The use of non-chemical methods, such as inter-row cultivation and hand hoeing, can be very valuable to control plants between rows and escapes from previous control measures.

Managing flaxleaf fleabane in the farming system

Flaxleaf fleabane populations need to be monitored and managed in the whole farming

system, all year round, in order for effective control to be maintained. How fleabane is managed in one crop or fallow, is likely to have a large impact on the following crop or fallow.

Flaxleaf fleabane plants can produce large quantities of seed, potentially creating a heavy penalty when escapes mature. However, seed persistence is relatively short and a few years of consistent and effective management will significantly reduce numbers.

Control in winter cereals can be quite variable, as is shown in Table 6. However, winter cereals can also be effective in competing with fleabane for light and nutrients. Wheat and barley crops that have been grown with high plant populations and relatively narrow rows (25 cm) have been shown to be very competitive with sowthistle. The same principles apply to flaxleaf fleabane. Crop competition can be an effective tool that reduces reliance on herbicides, as any fleabane plants that do establish in a competitive cereal crop will be small and produce relatively little seed.

Table 6. Control of emerged flaxleaf fleabane in wheat. Trial was conducted at Warwick in 2010.*

Herbicide	% Weed kill	
	4 week old fleabane	8 week old fleabane
No herbicide	0	0
Ally 5 g/ha	40	12
Amicide 625 1.2 L/ha	69	57
Hotshot 750 mL/ha	83	62
Starane Advance 600 mL/ha	64	11
Tordon 242 1 L/ha	77	69
Tordon 75D 300 mL/ha	54	77
Ally 5 g/ha + MCPA LVE 750 mL/ha	48	40
Hotshot 750 mL/ha + MCPA LVE 750 mL/ha	79	19
Starane Advance 600 mL/ha + MCPA LVE 750 mL/ha	63	49
Tordon 242 1 L/ha + Ally 5 g/ha	58	76
Tordon 75D 300 mL/ha + Amicide 625 375 mL/ha	69	70

*Refer to herbicide labels for plant-backs periods to cotton.

Summer crops, such as sorghum, are generally less competitive than winter crops (due to the wide row spacing normally used), but allow the use of atrazine, which is effective for reducing flaxleaf fleabane emergence (Tables 3 and 7). Atrazine applications made early in a fallow before planting sorghum can provide season-long control.

However, cotton can not follow close-on to an atrazine application. Atrazine plant-back periods to cotton range from 6 months for applications up to 1.26 kg active/ha, to 18 months for applications between 1.26 - 2.97 kg active/ha (the plant-back periods will be longer in dry conditions). In the experiments presented in Table 7, 4 L atrazine/ha (2 kg active/ha) was the more effective rate and this rate has a plant-back period to cotton of 18

months. It is therefore, very important to consider cropping rotations and the whole farming system when planning control of flaxleaf fleabane with herbicides such as atrazine, that have prolonged plant-back periods to cotton.

An understanding of the lifecycle of flaxleaf fleabane and how it fits into the farming system is illustrated in Tables 8 and 9. As control is more effective when plants are young, it is important to be aware of when flaxleaf fleabane is likely to emerge. Tactics can then be adapted to either reduce the numbers emerging, or control emerged plants. Stopping plants from maturing and setting seed is vital to preventing additions to the seed bank.

Table 7. Control of flaxleaf fleabane in 3 sorghum experiments*.

Herbicide treatment (product/ha)			% Weed kill		
Fallow	Pre-plant	Pre-emergent	2004	2005(1)	2005(2)
Atrazine 4L/ha			89	84	99
Atrazine 2L/ha			60	64	85
	Glyphosate CT 2L/ha + Surpass 3L/ha	Atrazine 4L/ha	99	95	100
	Glyphosate CT 2L/ha ⇒ Sprayseed 1.5L/ha	Atrazine 4L/ha	99	88	99
	Glyphosate CT 2L/ha + Surpass 3L/ha	Atrazine 2L/ha	98	100	97
	Glyphosate CT 2L/ha + Dicamba 1.0L/ha	Atrazine 2L/ha	99	95	100

*Refer to herbicide labels for plant-back periods to cotton.

Glyphosate resistance

In a recent assessment of species that have a high risk of developing resistance to glyphosate, flaxleaf fleabane was found to be one of the highest risk species. Its capacity to produce large quantities of seed, often resulting in very dense populations, makes it an ideal candidate for glyphosate resistance, particularly if glyphosate is the predominate herbicide used to manage those dense populations.

Flaxleaf fleabane has always been perceived as being relatively tolerant of glyphosate and its prevalence has been attributed to reliance on glyphosate in no-till farming systems. Recent research, however, has shown that this is not the full story and that the level of control with glyphosate is linked with the weed control history.

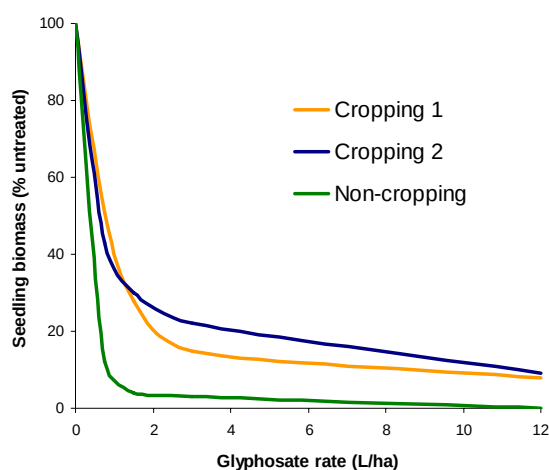


Figure 6. Decreased response to glyphosate of flaxleaf fleabane populations from cropping backgrounds.

A large number of samples of flaxleaf fleabane populations from Queensland and New South Wales were gathered in 2003 to test their sensitivity to glyphosate. These populations came from cultivated fields, roadsides and town water reservoirs, all with varied histories of exposure to herbicides. There was a clear difference in the sensitivity of flaxleaf fleabane population that had previous exposure to herbicides, compared to those that didn't (Figure 6). Some of these populations have since been confirmed as being resistant. A further experiment compared the effectiveness of the double-knock tactic on two populations with different herbicide histories. The population from the cropping background was found to be less sensitive to a mix of glyphosate + 2,4-D in addition to being less sensitive to glyphosate (Figure 7). However, using the double-knock tactic still proved to be effective on both populations. When the first application contained glyphosate and 2,4-D, total control was achieved. This further highlights the importance of employing the double-knock tactic in managing flaxleaf fleabane.

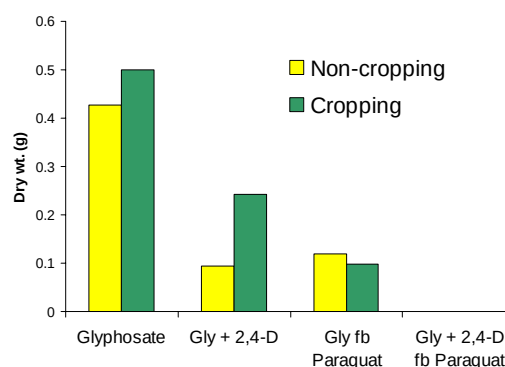


Figure 7. Response of flaxleaf fleabane populations from non-cropping and cropping areas to glyphosate, 2,4-D and "double-knock".

Table 7. *Fleabane lifecycle and integrated weed management options in back-to-back Roundup Ready Flex® cotton cropping systems*

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr				
Fleabane Emergence	Likely	Less likely					Likely			Less likely		Likely			Less likely				Likely					
Fleabane Flowering / seeding																								
Crop	Roundup Ready Flex® cotton									Fallow			Roundup Ready Flex® cotton											
Double-knock for a clean start and to control survivors																								
Pre-emergent herbicides																								
At-planting residual																								
In-crop directed residual																								
Robust Roundup Ready® fb shielded paraquat / Spray.Seed																								
Inter-row cultivation																								
Hand chipping																								
Spot spraying – non-selective herbicides																								
Scouting (key times)																								
Farm hygiene (key times for equipment)	Planting equipment Cultivation equipment								Transport equipment	Planting equipment				Planting equipment Cultivation equipment										

Table 8. *Fleabane lifecycle and integrated weed management options in Roundup Ready Flex® cotton/rotation crop farming systems*

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug					
Fleabane Emergence	Likely	Less likely			Likely			Less likely		Likely			Less likely			Likely			Less likely										
Fleabane Flowering / seeding																													
Crop	Roundup Ready Flex® cotton									Winter cereal						Fallow prior to cotton													
Double-knock for a clean start and to control survivors																													
Pre-emergent herbicides																													
At-planting residual																													
Post-emergent herbicides																													
In-crop directed residual																													
Robust Roundup Ready® fb shielded paraquat / Spray.Seed																													
Inter-row cultivation																													
Hand chipping																													
Spot spraying – non-selective herbicides																													
Scouting (key times)																													
Farm hygiene (key times for equipment)	Planting equipment				Cultivation equipment						Transport equipment			Planting equipment										Cultivation equipment					



Farm hygiene

Controlling flaxleaf fleabane on non-crop areas, such as beside fields, roadsides, irrigation channels and fence lines, is very important as fleabane is easily spread by wind and water. The double-knock tactic can be used effectively in these areas, although it is still important to target small weeds as larger plants are difficult to control and even the double-knock struggles to control these plants.

A number of residual herbicides have also been trialled for controlling fleabane in non-crop areas, however, diuron was the most consistent of these.



Roadsides, irrigation channels and fence lines can be potential sources of fleabane infestation and must be included in a property-wide management program.

Summary

The success of fleabane in the cotton system can be attributed to its ability to emerge in different seasons, relative tolerance to glyphosate and its prolific fecundity. A long term, whole farm, integrated approach is needed for its effective control. Key management tactics include:

- close monitoring of seedling emergence flushes,
- controlling weeds when young to maximise herbicide performance,
- controlling survivors to prevent seed production and reduce the soil seed bank
- using a combination of pre- and post-emergent herbicides, cultivation and hand hoeing
- using a double-knock tactic to gain effective control and prevent seed set,
- using crop competition to reduce the weed's competitive ability and improve its management in winter cereals,
- implementing an intense control program for 2-3 years to reduce the seed bank, and
- controlling fleabane on non-crop areas, such as roads, irrigation channels and fence lines, to prevent re-infestation into the crop.

An IWM plan needs to be implemented for the whole farm and crop rotation for effective management and prevention of resistance to herbicides.

ROTATION CROPS

Introduction

The use of rotation crops and fallows is an important part of the Integrated Weed Management strategy, as well as being beneficial for managing diseases, insects, and soil problems. Rotation crops and fallows give cotton growers the opportunity to use a different range of herbicides, and to use strategic cultivation to manage specific problems.

One of the difficulties with the use of alternative herbicides, however, is that most herbicides are not inactivated on contact with the soil. Consequently, they have residual properties and can be toxic to the following crops. This is equally true of many of the herbicides used in cotton, in fallows and in rotation crops.

One result of this problem in the cotton cropping system is that many of the herbicides that are effective in fallows and rotation crops can not be used in the cotton system because they are likely to be toxic to the following cotton crop. Weed control has been an issue in many of the rotation crops, and particularly in the broad-leaf rotation crops.

Contents:

12. Herbicides for use with Pigeon Pea Trap Crops

13. Managing Weeds in Vetch Rotation Crops

14. Managing Lucerne Strips in Cotton

12. Herbicides for use with Pigeon Pea Trap Crops

Pigeon peas are useful as a trap crop and refuge for beneficial insects.

A range of herbicides is now available for use with pigeon peas, covered by product registration (refer to the product label) and a minor use permit from the Australian Pesticides & Veterinary Medicines Authority (refer to the APVMA web site at www.apvma.gov.au for details). The products covered by the permit may only be used on pigeon peas that are not used for human or livestock consumption. These crops can only be harvested for planting seed for future trap crops.

Weeds in pigeon peas can be best managed using a pre-planting application of prometryn or Sencor and either trifluralin or pendimethalin, and post-emergence applications of prometryn as a directed spray, or Sencor, or one of the selective grass herbicides listed.

13. Managing Weeds in Vetch Rotation Crops

Vetch is being increasingly grown as an alternative rotation crop for cotton, capable of adding large amounts of nitrogen to the soil.

Weed management in vetch is problematic, with few registered herbicides for pre-planting applications, and no herbicides registered for controlling broad-leaf weeds in vetch, or for controlling vetch prior to planting cotton.

Many of the herbicide options discussed in this article are off-label. Growers wishing to make an off-label pesticide application must first obtain a minor-use permit from the APVMA for the proposed use.

14. Managing Lucerne Strips in Cotton

Lucerne strips are valuable for promoting beneficial insects in cotton and as trap crops.

Weeds can be controlled in established lucerne with diuron and prometryn and some of the grass herbicides. Bromoxynil and 2,4-DB can also be used to control small broad-leaf weeds in lucerne after cotton picking and before cotton planting.

Established lucerne can be killed with heavy cultivation or herbicides when the lucerne is actively growing. A tank mix of Grazon DS[®] + Roundup CT[®] is registered for controlling established lucerne. However, picloram, one of the components of Grazon DS, has a long plant-back period to cotton and some other rotation crops. There is also an APVMA permit to control lucerne with 2,4-D amine. Check the APVMA web site for the current permit status at: www.apvma.gov.au. None of the 2,4-D formulations can be safely used near cotton, so this herbicide option is limited to the period when no cotton is present.

HERBICIDES FOR PIGEON PEA TRAP CROPS

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
Registration and permit information	12.1
Background	12.1
Pre-emergent herbicides	12.2
Crop safety	12.3
Post-emergence options	12.4
Summary	12.4



Weeds can be a major problem in pigeon pea trap crops. This crop at Emerald was over-run by amaranthus and black pigweed.

Herbicides for use with pigeon pea trap crops grown in conjunction with Bollgard II cotton. Products are covered by registration or minor use permit.

Pre-planting	Broadcast	Post-emergence
		Directed spray
pendimethalin (330 g/L) @ 2.5 to 3 L/ha	Falcon WG (250 g/kg) @ 180 g/ha	prometryn (500 g/L) @ up to 4.5 L/ha
pendimethalin (455 g/L) @ 1.8 to 2.2 L/ha	Fusilade WG (212 g/L) @ 1 L/ha	prometryn (900 g/kg) @ up to 2.5 kg/ha
trifluralin (400 g/L) @ up to 2.8 L/ha	quizalofop (99.5 g/L) @ 250-1000 mL/ha	
trifluralin (480 g/L) @ up to 2.3 L/ha	Select (240 g/L) @ 250-375 mL/ha	
prometryn (500 g/L) @ up to 4.5 L/ha	Sencor 480 (480 g/L) @ 750 mL/ha	
prometryn (900 g/kg) @ up to 2.5 kg/ha	Sertin Plus (120 g/L) @ 1.6 L/ha	
Sencor 480 (480 g/L) @ 750 mL/ha	Verdict (130 g/L) @ 0.6 L/ha	
	Verdict (520 g/L) @ 0.6 L/ha	

Background

Pigeon peas are being grown throughout the cotton industry as a trap crop and refuge for beneficial insects. These crops are grown as part of the insect management strategy, in association with Bollgard II® cotton and area wide management. However, poor weed management

has been a major problem in many pigeon pea crops.

Basic agronomy work to develop pigeon peas as a commercial cash crop was undertaken in the 1980s. As part of this work, a range of herbicides was screened for use with pigeon peas (Tables 1 & 2). Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).

Table 1. Herbicides applied to pigeon pea pre-planting.

Herbicide	Rate (kg or L)	Phytotoxicity*
Gesagard	3	0
Stomp	3	0
Teflan	1.4	0
Gesagard	4	0.5
Sencor 700	0.5	0.5
Scepter	1	0.5
Scepter	1.5	1
Dual	3	1
Simazine	2	1
Diuron 500	2	2
Atrazine	3	3
Simazine	3	3

*Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).

Of the herbicides applied pre-planting, Gesagard, Stomp and Treflan all appeared to be relatively safe to use with pigeon peas. Varying degrees of phytotoxicity were observed with the remaining herbicides applied pre-planting and with all the herbicides applied post-emergence.

Table 2. Herbicides applied broadcast, post-planting to pigeon peas.

Herbicide	Rate (kg or L)	Phytotoxicity
Basagran	2	1
Sencor 700	0.35	1
Scepter	1	1
Gesagard	2	2
Scepter	1.5	3
Gesagard	4	3
Blazer	2	3
Diuron	2	3

Sencor 480 and pendimethalin are registered for use on pigeon peas and registration is included on some trifluralin labels but not on others.

With the introduction of Bollgard II cotton, trap crops and area wide management, pigeon peas have been widely planted throughout the cotton industry. With limited herbicide options available, these trap crops are often the weediest crops on a farm. Problem weeds range from bellvine and wild sunflower, to amaranthus and black pigweed. Broad-leaf weed control is a major issue for pigeon peas.



Another weedy pigeon pea crop infested with broad-leaf weeds including wild sunflower and sesbania.

Pre-emergent herbicides

A range of pre-emergent herbicides was tested in the 1999/2000 season in trials at Narrabri, Theodore and Emerald. The experiments focused on the herbicides and herbicide combinations that are currently used in cotton. These herbicides have the advantage that they are readily available on cotton farms and have no plant-back problems to cotton. Crop safety (phytotoxicity) and the weed control (weed pressure index) attained with each treatment was recorded.

The weed pressure index was estimated by recording the presence of weeds in each plot and adding the numbers, after weighting the data for the bigger (more competitive) weeds. This index is expressed as small weed equivalents per m². The data were averaged over the 3 sites (Table 3).

Table 3. Early- and mid-season weed control from the herbicides applied pre-planting and incorporated, or post-planting broadcast.

Treatment	Weed index	
	Early-	Mid-
Untreated	76.6	28.0
Treflan 1.4 L/ha	13.2	5.1
Treflan 2.8 L/ha	11.0	5.5
Stomp 3 L/ha	51.2	18.1
Gesagard 2.25 L/ha	8.5	9.1
Gesagard 4.5 L/ha	3.8	6.2
Cotoran 2 L/ha	25.0	9.0
Cotoran 4 L/ha	5.1	3.3
Spinnaker 0.2 L/ha	21.9	11.2
Spinnaker 0.4 L/ha	15.6	3.8
Treflan 2.8 + Gesagard 4.5 L/ha	1.5	2.6
Treflan 2.8 + Cotoran 4 L/ha	0.9	1.4
Stomp 3 + Gesagard 4.5 L/ha	2.6	6.5
Stomp 3 + Cotoran 4 L/ha	5	2.4

Post-emergence treatments

Basagran 1 L/ha	11.7
Basagran 2 L/ha	24.8
Sencor 0.7 L/ha	13.9
Sencor 1.4 L/ha	21.6
Spinnaker 0.2 L/ha	14.5
Spinnaker 0.4 L/ha	9.1

Three additional herbicides were applied broadcast, post-emergence at each site. Results from a second set of observations include the additional herbicides. None of the herbicides applied post-emergence gave as good weed control as the pre-planting combinations.

All treatments gave some weed control compared to the untreated plots, with the best control on the herbicide combinations that included Treflan. The poor result from Stomp was due to very poor weed control on only one of the three sites. Large numbers of common sowthistle and blackberry nightshade were present on this site, but were not controlled by Stomp. Good control was observed with Stomp on the other two sites where these two weeds were not so abundant.

Crop safety

Not all the herbicides used were safe on pigeon peas.

Phytotoxicity was observed on the diuron treatment on the first trial at Narrabri, as expected from the earlier data. No problems were apparent with the other herbicides.

However, 50 to 75 mm of rain occurred during crop emergence at Theodore and Emerald and a large proportion of the seedlings on the Cotoran treatments and combinations including Cotoran were killed (Table 4).

Table 4. Phytotoxicity from the herbicides and combinations applied pre-emergence.

Herbicide	Phytotoxicity rating
Untreated	0
Treflan 1.4 L/ha	0
Treflan 2.8 L/ha	0.13
Stomp 3 L/ha	0
Gesagard 2.25 L/ha	0
Gesagard 4.5 L/ha	0
Cotoran 2 L/ha	0.54
Cotoran 4 L/ha	1.21
Diuron 2 L/ha	1.11
Spinnaker 0.2 L/ha	0.28
Spinnaker 0.4 L/ha	0
Treflan 2.8 + Gesagard 4.5 L/ha	0.38
Treflan 2.8 + Cotoran 4 L/ha	2.63
Stomp 3 + Gesagard 4.5 L/ha	0.17
Stomp 3 + Cotoran 4 L/ha	1.33

Given the similar levels of weed control observed with both Gesagard and Cotoran and their combinations, Cotoran was dropped due to its risk of phytotoxicity, in favour of Gesagard which showed no phytotoxicity, even with rain during emergence.



Pigeon pea seedlings killed by Cotoran following rain during emergence at Theodore (above) and Emerald (below).



A small amount of stunting was observed with the high rate of Treflan, but the damage was minor and the plants soon grew out of this damage.

Post-emergence options

A further experiment examined the best options for post-emergence weed control, using some of the selective grass herbicides, and standard broad-leaf herbicides as directed sprays.

All herbicides were applied over-the-top of 70-cm high pigeon peas to test the level of phytotoxicity of these herbicides. This was done on the assumption that the herbicide that caused the least damage when applied over-the-top, would have the least potential to cause damage when applied as a directed spray.

Phytotoxicity was assessed 8, 28 and 48 days after treatment, by assessing the extent of damage to old growth (growth present at the time of spraying), the damage to new growth, and the effect on flowering.

Pigeon peas were completely tolerant of the selective grass herbicides used, which had no effect on growth or flowering.

All the broad-leaf herbicides damaged the pigeon peas, with diuron causing the most damage and Gesagard the least damage (Table 5).

Table 5. Percentage leaf damage 48 days after herbicide application over-the-top of 70-cm high pigeon peas.

Treatment	Bottom leaves	Top leaves
	(old growth)	(new growth)
Untreated	0	0
Diuron 0.9 L/ha	55	5.5
Diuron 1.8 L/ha	82.8	7.4
Diuron 3.5 L/ha	87.5	20.1
Cotoran 1.4 L/ha	17.5	0
Cotoran 2.8 L/ha	29.9	2.8
Cotoran 5.6 L/ha	52.4	6.6
Cotogard 0.9 L/ha	7.3	0.2
Cotogard 1.8 L/ha	20.3	0.5
Cotogard 3.5 L/ha	42.5	2.3
Gesagard 1.12 L/ha	14.6	0
Gesagard 2.25 L/ha	20.3	1.5
Gesagard 4.5 L/ha	32.6	0.4

The herbicides had surprisingly little effect on flowering (Table 6), even though the over-the-top treatments caused a large amount of leaf damage to the pigeon peas. Even the highest rate of diuron, which caused an 88% loss of the sprayed leaves, resulted in only a 32% reduction in flowering. There was an 7% reduction in flowering from applying the heaviest rate of Gesagard over-the-top.

Figure 6. Percentage flowers relative to untreated plots 48 days after spraying.

Treatment	% Flowering
Diuron 0.9 L/ha	85
Diuron 1.8 L/ha	75
Diuron 3.5 L/ha	68
Cotoran 1.4 L/ha	100
Cotoran 2.8 L/ha	90
Cotoran 5.6 L/ha	83
Cotogard 0.9 L/ha	98
Cotogard 1.8 L/ha	98
Cotogard 3.5 L/ha	88
Gesagard 1.12 L/ha	100
Gesagard 2.25 L/ha	90
Gesagard 4.5 L/ha	93

Summary

Pigeon peas are useful as a trap crop and refuge for beneficial insects.

A range of herbicides are now available for use with pigeon peas, covered by product registration (refer to the product label) and a minor use permit from the Australian Pesticides & Veterinary Medicines Authority (refer to the APVMA web site for details). The products covered by the permit may only be used on pigeon peas that are not used for human or livestock consumption. These crops can only be harvested for planting seed for future trap crops.

Weeds in pigeon peas can be best managed using a pre-planting application of prometryn or Sencor and either trifluralin or pendimethalin, and post-emergence applications of prometryn as a directed spray, or Sencor, or one of the selective grass herbicides listed.

MANAGING WEEDS IN VETCH ROTATION CROPS

Graham Charles
(NSW Dept of Primary Industries)

Contents	Page
Background	13.1
Pre-planting herbicides	13.2
Post-emergence weed control in vetch crops	13.3
Removing vetch crops with herbicides	13.3
Summary	13.5

Background

Vetch is being increasingly grown as an alternative rotation crop for cotton. It is a useful green manure crop, and is capable of adding large amounts of nitrogen to the soil.

Vetch crops can be sown in autumn into a fallow or crop stubble. They are commonly sown into cotton stubble soon after picking. Vetch grows over winter, and is normally removed in early spring, prior to cotton planting and before the vetch has started to set seed. Removing the crop prior to seed-set is important as vetch is hard-seeded and can produce large quantities of viable seed. If it is allowed to seed, vetch will be a nuisance weed in later cotton crops.

Weed management in vetch is problematic, with few herbicides registered for in-crop weed control. Management of broadleaf weeds is especially difficult in vetch. Broadleaf weeds can compete strongly with the vetch, reducing the value of the crop and potentially leading to increased weed problems in later years. Also, no herbicides are registered for controlling the vetch to allow replanting back to cotton where this option is desired.

It is a legal requirement that pesticide users follow the directions on the product label. Growers who wish to make an off-label pesticide application must first obtain a minor-use permit from the APVMA for the proposed use.

Many of the herbicide options discussed in this article are off-label and must be covered by a minor-use permit.



Vetch crops may be sown into cotton trash after picking. They can fix large amounts of nitrogen and may be plowed in as green manure, or killed by herbicides and left as a surface mulch.

Pre-planting herbicides

Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. A wide range of products are registered for controlling weeds in fallows. Spray.Seed (various trade names) and Surpass + glyphosate (various trade names for both products) are registered for controlling weeds prior to planting vetch. There is a 7 - 10 day plant-back period constraint before planting vetch following a Surpass application.

Growers should be aware that vetch emergence and establishment may be adversely affected by residual herbicides previously applied to cotton when vetch is planted immediately following a cotton crop.

There are no pre-planting residual herbicides registered for use with vetch crops in NSW or Qld. Some formulations of trifluralin (sold under a range of trade names) are registered for pre-planting use in vetch crops in SA and WA, but not in NSW or Qld.

A range of residual pre-planting herbicides and herbicide combinations were screened in an experiment at the ACRI in 2005. Herbicides were applied and incorporated prior to planting the vetch and the crop was watered up.

No establishment problems were observed with any of the herbicides used, with satisfactory establishment levels on all treatments (Table 1). Some variability was apparent in the data related to background residual herbicides used on the preceeding cotton crop.

Table 1. Establishment of vetch following applications of pre-planting residual herbicides.

Herbicide	% establishment
Diuron 2kg/ha	95
Simazine 2 kg/ha	93
Crew* 2.4 L/ha + Diuron 2 kg/ha	90
Fluometuron 4 L/ha	88
Stomp 3 L/ha + Prometryn 2 kg/ha	85
Prometryn 2 kg/ha	85
Stomp 3 L/ha + Simazine 2 kg/ha	83
Stomp 3 L/ha + Fluometuron 4 L/ha	80
Crew 2.4 L/ha + Prometryn 2 kg/ha	80
Crew 2.4 L/ha + Simazine 2 kg/ha	80
Crew 2.4 L/ha	78
Crew 2.4 L/ha + Fluometuron 4 L/ha	78
Stomp 3 L/ha + Diuron 2kg/ha	78
Stomp 3 L/ha	73
Nil	90

*The active ingredient in Crew is trifluralin (330 g/L).

Vetch growth was monitored following establishment. All treatments grew satisfactorily, but some stunting was observed on treatments containing simazine and fluometuron (Table 2), indicating that vetch had less tolerance to these herbicides.

These results indicate that pendimethalin, trifluralin, diuron and prometryn might all be satisfactorily used as pre-planting residual herbicides for vetch crops.

Table 2. Vetch growth following applications of pre-planting residual herbicides. Growth was recorded relative to the nil treatment.

Herbicide	Relative growth %
Prometryn 2 kg/ha	100
Crew 2.4 L/ha	100
Stomp 3 L/ha	100
Crew 2.4 L/ha + Diuron 2 kg/ha	100
Stomp 3 L/ha + Diuron 2kg/ha	100
Crew 2.4 L/ha + Prometryn 2 kg/ha	99
Diuron 2kg/ha	99
Simazine 2 kg/ha	99
Crew 2.4 L/ha + Fluometuron 4 L/ha	96
Stomp 3 L/ha + Simazine 2 kg/ha	96
Stomp 3 L/ha + Prometryn 2 kg/ha	95
Stomp 3 L/ha + Fluometuron 4 L/ha	95
Crew 2.4 L/ha + Simazine 2 kg/ha	86
Fluometuron 4 L/ha	81



Herbicide combinations for early removal of a vetch crop 7 weeks after planting.

Post-emergence weed control in vetch crops

A number of herbicides are registered for controlling grass weeds in vetch. These herbicides include Aramo, Correct, Fusilade Forte, FusionSuper, Targa and Verdict.

No herbicides are registered for broad-leaf weed control in vetch crops.

A range of herbicides were screened for broad-leaf weed control in vetch, not all of which could be safely used if a cotton crop was to be planted in the same season. Basagran and simazine had no negative affect on the vetch (Table 3), but simazine has a long soil half-life and a 9-month plant-back to cotton. Fluometuron, prometryn, atrazine and diuron all caused some initial leaf damage to the vetch, but caused no long-term damage. These products could be used with some caution, with lower rates used where possible. These products would ideally be applied as shielded or directed sprays in young vetch. Atrazine also has a long soil half-life and an 18-month plant-back to cotton at the rate used in this experiment. Spinniker, Sencor and Ally all caused unacceptable levels of damage and could not be safely used with vetch.

Table 3. Herbicides applied broadcast, post-planting to vetch.

Herbicide	Phytotoxicity*	
	3 weeks	6 weeks
Simazine 2 kg/ha	0	0
Basagran 2 L/ha	0	0
Fluometuron 4 L/ha	1.4	0.3
Prometryn 2 kg/ha	1.8	0.3
Atrazine 2 kg/ha	1.5	0.4
Diuron 2kg/ha	2.1	0.4
Spinniker 0.2 L/ha	1.4	1.1
Sencor 1.4 L/ha	3.9	3.6
Ally 10 g/ha	4.5	5.0
Nil	0	0

*Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).

Removing vetch crops with herbicides

Vetch crops are normally planted in the autumn/winter before a cotton crop and must be killed prior to cotton planting.

Slashing and incorporating the vetch crop is the best option for removal, as this method returns the maximum amount of available nitrogen to the following cotton crop, while minimising any potential problems with insects and diseases.

There are no herbicides registered for killing a vetch crop. 2,4-D (a range of trade names) is registered for controlling vetches in a range of crops, but the registrations only covers Vic. and SA, not NSW or Qld.

A range of herbicides and herbicide combinations with Roundup PowerMAX were screened for removing a young vetch crop in late winter (Tables 4 & 5), and an older crop at the flowering stage in spring (Table 6).

MCPA 500 at 4 L/ha and Starane at 1 and 2 L/ha gave the best control of young vetch, with better than 95% control observed (Table 4). There was some background vetch emergence on the site from an experiment run in the previous season and it is likely that some of the “surviving” shoots came from seedlings that emerged after the herbicide application.

Table 4. Herbicides for early removal of a vetch crop in late winter (28 July), 7 weeks after planting.

Herbicide	% Vetch kill	
	3 weeks	6 weeks
MCPA 500 4 L/ha	95	98
Starane 2 L/ha	97	97
Starane 1 L/ha	92	96
Roundup PowerMAX 4 L/ha	84	89
MCPA 500 2 L/ha	86	87
Buctril MA 4 L/ha	90	86
Roundup PowerMAX 2 L/ha	77	81
Surpass 2 L/ha	86	80
Buctril MA 2 L/ha	94	66
Buctril 4 L/ha	87	56
Spray.Seed 3.6 L/ha	88	45
Surpass 1 L/ha	72	22
Spray.Seed 2.4 L/ha	82	17
Buctril 2 L/ha	72	14
Nil	0	0

Roundup PowerMAX at 4 L/ha gave a reasonable result, also controlling all other weeds present on

the plots. A range of combinations using lower rates of Roundup PowerMAX in combination with lower rates of some of the other herbicides was also screened (Table 5).

Table 5. Herbicide combinations for early removal of a vetch crop in late winter (28 July), 7 weeks after planting.

Herbicides	% Vetch kill	
	3 weeks	6 weeks
Roundup PowerMAX 1 L/ha + Envoke 10 g/ha	81	96
Roundup PowerMAX 2 L/ha + Envoke 10 g/ha	89	96
Roundup PowerMAX 2 L/ha + Starane 1 L/ha	99	94
Roundup PowerMAX 2 L/ha + Surpass 2 L/ha	97	90
Roundup PowerMAX 2 L/ha + Buctril MA 2 L/ha	98	89
Roundup PowerMAX 1 L/ha + Starane 0.5 L/ha	87	84
Roundup PowerMAX 1 L/ha + Surpass 1 L/ha	86	80
Roundup PowerMAX 2 L/ha + Buctril 2 L/ha	91	79
Roundup PowerMAX 1 L/ha + Buctril MA 1 L/ha	87	61
Roundup PowerMAX 2 L/ha + Hammer 750 mL/ha	80	60
Roundup PowerMAX 2 L/ha + Pledge 30 g/ha	93	56
Roundup PowerMAX 1 L/ha + Buctril 1 L/ha	87	51
Roundup PowerMAX 1 L/ha + Pledge 30 g/ha	80	25
Nil	0	0

The Roundup PowerMAX + Envoke and Roundup PowerMAX + Starane at 1 L/ha combinations both gave good results, although the result for the Starane combination was no improvement over Starane alone at 1 L/ha (Table 4). Envoke was not tested by itself in this experiment.

Cotton was planted into all treatments in early October and no phytotoxicity was observed with any of the treatments. However, the Envoke label specifies a 9-month plant-back period to cotton and so Envoke can not be used to remove vetch prior to a cotton crop.

A later application was made to much larger vetch on 30 Sept., 16 weeks after planting (Table 6).

Envoke at 20 g/ha, Starane and MCPA 500 all gave very good control of large vetch plants. The combination of Roundup PowerMAX + Envoke at 10 g/ha also gave good control and controlled all other weeds present on the plots. The combination gave much better control than Envoke alone at 10 g/ha. However, Envoke has a 9-month plant-back

period to cotton and so can't be used to remove vetch immediately prior to a cotton crop. Starane has a much shorter plant-back to cotton of 14 to 28 days (depending on the application rate). The plant-back to MCPA should be similar, at around 14 days, although the plant-back period to cotton is not specified on the product label.

Table 6. Herbicides for late removal of a vetch crop in spring (30 September), 16 weeks after planting. The crop had begun to naturally senesce, resulting in some plant death on all treatments.

Herbicide	% Vetch kill	
	4 weeks	
Envoke 20 g/ha	100	
Starane 2 L/ha	100	
MCPA 500 4 L/ha	100	
Starane 1 L/ha	100	
Roundup PowerMAX 2 L/ha + Envoke 10 g/ha	100	
Roundup PowerMAX 2 L/ha + MCPA 500 4 L/ha	95	
Envoke 10 g/ha	80	
Staple 120 g/ha	58	
Staple 60 g/ha	38	
Nil	43	

Both Roundup and Envoke may be valuable for controlling volunteer vetch plants in a cotton crop, should these become a problem.

The Roundup PowerMAX + MCPA 500 at 4 L/ha combination also gave a good result and controlled all other weeds, but gave a slightly inferior result to MCPA 500 at 4 L/ha alone. Growers electing to use this combination would have to weigh up the advantage of an increased weed control spectrum with the disadvantage of possibly poorer control of vetch. The results with the Roundup PowerMAX + Envoke combinations in Table 5 suggest that a lower rate of Roundup PowerMAX may have given as good or better control of vetch without compromising the control of other weeds.



Herbicides for late removal of a vetch crop in late September, 16 weeks after planting, when vetch was at the flowering stage.

Summary

Vetch is being increasingly grown as an alternative rotation crop for cotton, capable of adding large amounts of nitrogen to the soil.

Weed management in vetch is problematic, with few registered herbicides for pre-planting applications, and no herbicides registered for controlling broad-leaf weeds in vetch, or for controlling vetch prior to planting cotton.

Many of the herbicide options discussed in this article are off-label. Growers wishing to make an off-label pesticide application must first obtain a minor-use permit from the APVMA for the proposed use.

Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. A wide range of products are registered for controlling weeds in fallows. Spray.Seed and Surpass + glyphosate are registered for controlling weeds prior to planting vetch. There is a 7 - 10 day plant back period restraint following a Surpass application.

A range of herbicides were screened for use with vetch crops. Pendimethalin, trifluralin, diuron and prometryn applied as pre-planting residual herbicides caused no establishment or growth problems.

A range of herbicides are registered for controlling grass weeds in vetch. These herbicides include Correct, FusionSuper, Targa and Verdict.

For post-emergence broad-leaf weed control in vetch, Basagran and simazine had excellent crop safety), but simazine has a 9-month plant-back to cotton. Fluometuron, prometryn and diuron all caused some initial leaf damage to the vetch, but caused no long-term damage. These products could be used with some caution, with lower rates used where possible. They would ideally be applied as shielded or directed sprays in young vetch crops.

A range of herbicides were screened for removing vetch crops. MCPA 500 at 4 L/ha and Starane at 1 and 2 L/ha gave the best control of young vetch.

Envoke at 20 g/ha, Starane and MCPA 500 all gave good control of large vetch plants. However, Envoke has a 9-month plant-back period to cotton. Starane has a much shorter plant-back of 14 to 28 days and MCPA around 14 days.

Both Roundup and Envoke may be valuable for controlling volunteer vetch plants in a cotton crop, should these become a problem.

MANAGING LUCERNE STRIPS IN COTTON

Graham Charles and Robert Mensah
(NSW Dept of Primary Industries)

Contents	Page
Background	14.1
Establishing lucerne strips	14.1
Managing lucerne strips	14.2
Removing lucerne strips	14.2
Summary	14.2

Background

Lucerne strips are valuable for promoting beneficial insects in cotton and as trap crops. They provide a refuge for beneficial insects and spiders which can then be encouraged to move into cotton with the strategic use of Envirofeast® sprays. Used this way, lucerne strips can be an effective management tool, providing beneficial insects that help with the early-season control of *Helicoverpa* spp. in conventional cotton varieties.

Lucerne strips can also be used as an effective trap crop for green mirids and aphids, as these insects prefer lucerne over cotton.



Well managed lucerne can be a useful for managing insects in cotton, and can be a valuable tool for managing weed problems such as nutgrass.

Alternatively, lucerne can be planted in a field adjacent to a cotton field or on a centrally located block on the farm, and still effectively serve as a trap for mirids and aphids as well as enhancing the build up of beneficial insects.

Establishing lucerne strips

Lucerne can be planted as strips within a cotton field. Strips of 8, 12 or 16 rows of lucerne should be planted every 300 rows of cotton. This equates to about 2.0-2.5% of the field area. Alternatively, lucerne can be grown on the borders of a field, using an area equivalent to 5% of the field, or can be planted in a field adjacent to cotton.

A range of lucerne varieties is available. Varieties with good resistance to lucerne aphids, phytophthora root rot and colletotrichum crown rot should be selected. Lucerne should ideally be sown from April to June, and no later than August. August planted lucerne may need an additional irrigation in November of the establishment year. A strong and dense plant stand is needed, so good seed bed preparation is important as lucerne has a very small seed. Seeding rates of 10 to 15 kg/ha (irrigated) or 5 kg/ha (dryland) are required. Irrigated lucerne should be sown on beds (not 1 m hills), using two beds of 4 rows in an 8 row strip, or two beds of 6 rows in a 12 row strip.

Weed control is important in establishing lucerne, as lucerne has a small, relatively slow growing seedling. A range of herbicides is available for use in lucerne but not all can be safely used in cotton. Of the commonly used herbicides of cotton production, trifluralin can be applied pre-planting with lucerne, and some of the grass herbicides such as Sertin Plus® and Fusion Super® are registered for post-emergence grass control.

Prometryn can be applied early post-emergence for broad-leaf weed control in pastures including lucerne (applied after lucerne reaches 5 true leaves). All of the other products registered for broad-leaf weed control in lucerne are likely to damage cotton if drift occurs. Bromoxynil and 2,4-DB for example, could be used over winter but would not be safe to apply to a lucerne strip within a cotton crop.

Refer to the NSW Department of Primary Industries publication “Weed control in lucerne and pastures” for more information on registered products. **Always follow the directions on the product label.**

Lucerne seedlings are susceptible to damage from some insect pests. Blue oat mite, redlegged earth mite, lucerne flea and cutworms can all cause severe damage to seedling and young lucerne stands. Mite damaged seedlings progressively show yellowing and then whitening of the cotyledons and/or leaves. Lucerne flea make small membranous ‘windows’ in the leaves, with ultimately only the skeletons of the leaves remaining. Badly infested strips look whitish.

In severe cases, pests may need to be controlled with pesticides during the first few weeks after seedling emergence. However, the use of pesticides beyond this point would be counter productive, removing the beneficial insects the lucerne has been planted to promote.

Managing lucerne strips

Lucerne needs to be managed to maintain new growth and attractiveness to green mirids and aphids throughout the season. The aphid species that infest lucerne will not infest cotton, but are a food source for predators that can move into the cotton. Half of each lucerne strip should be cut (slashed or mown) every 4 weeks and before the lucerne begins to flower. Cutting should commence in November, and continue throughout the cotton season.

Lucerne needs to be watered to maintain fresh growth and has a similar water requirement to cotton. Irrigation can most easily be timed to coincide with cotton irrigation.

Lucerne should not be allowed to set seed or hay off, as it is much less attractive to insects once this occurs. Volunteer lucerne plants can also be a serious nuisance in following crops. This problem can be avoided by timely slashing, preventing lucerne setting seed.

Apart from being a refuge for beneficial insects and a trap crop for green mirids, lucerne can also be an important contributor to the nitrogen budget, fixing up to 200 kg N per year.

However, poorly managed lucerne strips can be a source of green mirids to cotton and a source of weed seeds.

Weeds can be controlled in established lucerne more than 1 year old (in cotton) with the residual herbicides diuron and prometryn (prometryn is registered for controlling weeds in pastures including lucerne), and grass weeds can be controlled with post-emergence grass herbicides

such as Verdict and Sertin. Bromoxynil and 2,4-DB can also be used to control small broad-leaf weeds in lucerne after cotton picking and before cotton planting.

Removing lucerne strips

Established lucerne strips can be difficult to remove, with scattered plants potentially remaining as weeds in following cotton crops. Volunteer lucerne seedlings can also cause problems if lucerne has been allowed to seed, as none of the residual herbicides which kill lucerne seedlings are safe in cotton.

Established lucerne can be killed either with cultivation or with herbicides. When the soil is dry, heavy cultivation such as a crawler with a cutter bar across the rippers has been shown to be 100% effective in removing established lucerne plants. However, this approach is expensive and slow and the success of this technique requires dry soil and dry weather after treatment.

Herbicides are only effective for controlling lucerne when it is actively growing. Grazon DS[®] is registered for controlling established lucerne at 300-500 mL/ha + Roundup CT[®] at 1.2 L/ha.

However, picloram, one of the components of Grazon DS, has a long plant-back period to cotton and some other rotation crops, and so can't be used to remove lucerne prior to the planting of these crops. There is also a permit from the Australian Pesticides & Veterinary Medicines Authority (APVMA) to control established lucerne with 2,4-D Amine at 3 L/ha (500 g/L) or 2.4 L/ha (625 g/L) or 2,4-D ipa (Surpass[®]) plus glyphosate at 5 L/ha + 1 L/ha (450 g/L). Check the APVMA web site for the current permit status at:

www.apvma.gov.au.

However, none of these formulations of 2,4-D can be safely used near cotton, so these herbicide options are limited to the period after cotton harvest, when no cotton is present. Any 2,4-D application must also be made well before cotton planting as a 14 day plant-back period for cotton planting after herbicide application applies. This 14 day period only commences following rainfall of at least 15 mm. Thorough decontamination of spraying equipment is essential after 2,4-D applications. For optimal control of lucerne, plants should be actively growing and at least 5 cm tall, and preferably 10 to 15 cm tall at the time of herbicide application. Cultivation is likely to give better control than herbicides when moisture is limiting.

Summary

Lucerne strips are valuable for promoting beneficial insects in cotton and as trap crops for green mirids. Lucerne strips can also be an effective tool, providing beneficial insects that help with the early-season control of *Helicoverpa* spp.

Lucerne can be planted as strips within a cotton field or grown on the borders of a field or in a field adjacent to cotton. A range of varieties is available, best sown from April to June. A strong and dense plant stand is needed, so good seed bed preparation is important.

Weed control is important in establishing lucerne, as lucerne has a small, relatively slow growing seedling. A range of herbicides is available for use in lucerne but some can not be safely used in cotton. Of the herbicides commonly used in cotton production, trifluralin can be applied pre-planting with lucerne, and some of the grass herbicides such as Sertin Plus[®] and Fusion Super[®] are registered for post-emergence grass control. Prometryn can be applied early post-emergence for broad-leaf weed control.

Lucerne needs to be managed to maintain new growth and attractiveness to beneficials. Half of each lucerne strip should be cut every 4 weeks before the lucerne begins to flower.

Weeds can be controlled in established lucerne with the residual herbicides diuron and prometryn, and grass weeds can be controlled with post-emergence grass herbicides.

Established lucerne strips can be difficult to remove, with scattered plants potentially remaining as weeds in following cotton crops. Volunteer lucerne seedlings can also cause problems as none of the residual herbicides which kill lucerne seedlings are safe to use in cotton.

Established lucerne can be killed with heavy cultivation or herbicides. Herbicides are only effective for controlling lucerne when it is actively growing. A tank mix of Grazon DS[®] + Roundup CT[®] is registered for controlling established lucerne. However, picloram, one of the components of Grazon DS, has a long plant-back period to cotton and some other rotation crops. There is also a permit from the APVMA to control established lucerne with 2,4-D amine. Check the APVMA web site for the current permit status at: www.apvma.gov.au.

However, none of the 2,4-D formulations can be safely used near cotton, so these herbicide options are limited to the period when no cotton is present.

APPENDICES

Included are the following appendices

J2. Regional Weeds of Cotton

J3. Weed Species Lists

J4. Further Reading

J5. Abbreviations

J6. Glossary

REGIONAL WEEDS OF COTTON

Ian Taylor, Leah MacKinnon and Benita Inchbold
(NSW Agriculture, University of New England & NSW Agriculture)

The following lists contain weeds that have been identified by growers and consultants during recent interviews as being problematic in their particular region. Information in the lists has been supplemented with weed survey data that researchers have compiled over recent years in each of the valleys. The lists are arranged by valley so that consultants/agronomists and growers may be aware of the weeds that have been observed in their particular region. Consultants and agronomists are encouraged to use the regional lists in combination with the weed identification guide so that they are more familiar with the weeds they are likely to encounter in their region. New incursions such as David's spurge have been included in the lists to assist agronomists with recognition of these species and to enhance early detection so that management strategies can be put in place prior to the development of a wide scale problem. While all effort has been made to make the lists as comprehensive as possible it is acknowledged that some species are likely to have been missed. The weeds are sorted by preferred common names as listed in *Plants of Importance to Australia: A Checklist* (Shepherd *et al.* 2001) published by R.G and F.J Richardson. Each of the lists has been divided into major and minor weed species determined by frequency of observation and number of farms that have the weed as a problem. The scientific name is provided for reference, as are comments that either consultants or growers have made. These comments are the personal opinion of some of those interviewed and may not necessarily reflect the views of everyone. They are included to give an indication as to whether the weed problem is increasing or whether the weed species is apparent in a particular situation.

Additional and supplementary information is most welcome and may be directed to the primary author of this J2 section.

Macquarie Valley

Common name	Scientific name	Comments
Major Weeds		
Anoda weed	<i>Anoda cristata</i>	
Australian bindweed	<i>Convolvulus erubescens</i>	
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	along channels
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	late season
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Blue heliotrope	<i>Heliotropium amplexicaule</i>	
Caltrop	<i>Tribulus terrestris</i>	
Common sowthistle	<i>Sonchus oleraceus</i>	late season
Common thornapple	<i>Datura stramonium</i>	
Cotton	<i>Gossypium hirsutum</i>	more of a concern now with Roundup Ready
Couch grass	<i>Cynodon dactylon</i>	
Cowvine	<i>Ipomoea lonchophylla</i>	starting to increase
Dirty Dora	<i>Cyperus difformis</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Fierce thornapple	<i>Datura ferox</i>	
Flaxleaf fleabane	<i>Conyza bonariensis</i>	
Grey raspwort	<i>Haloragis glauca</i>	
Mexican poppy	<i>Argemone ochroleuca</i>	
Mintweed	<i>Salvia reflexa</i>	
Noogoora burr	<i>Xanthium occidentale</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Pigweed	<i>Portulaca oleracea</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Red shank	<i>Amaranthus cruentus</i>	
Rough poppy	<i>Papaver hybridum</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	
Umbrella sedge	<i>Cyperus involucratus</i>	
Wild gooseberry	<i>Physalis minima</i>	
Wild melon	<i>Citrullus lanatus</i>	
Minor Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Bellvine	<i>Ipomoea plebeia</i>	
Caustic weed	<i>Chamaesyce drummondii</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Perennial ground cherry	<i>Physalis virginiana</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Rhynchosia	<i>Rhynchosia minima</i>	
Rough raspwort	<i>Haloragis aspera</i>	
West Indian gherkin	<i>Cucumis anguria</i>	

Upper Namoi Valley

Common name	Scientific name	Comments
Major Weeds		
Australian bindweed	<i>Convolvulus erubescens</i>	late season
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Bellvine	<i>Ipomoea plebeia</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Caltrop	<i>Tribulus terrestris</i>	found on lighter country
Common sowthistle	<i>Sonchus oleraceus</i>	BAD in FALLOW following cereal, some control due to insect host
Common thornapple	<i>Datura stramonium</i>	
Cotton	<i>Gossypium hirsutum</i>	
Cowvine	<i>Ipomoea lonchophylla</i>	
Field bindweed	<i>Convolvulus arvensis</i>	
Fierce thornapple	<i>Datura ferox</i>	problem if it seeds
Flaxleaf fleabane	<i>Conyza bonariensis</i>	in minimum tillage areas, difficult to control
Grey raspwort	<i>Haloragis glauca</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Noogoora burr	<i>Xanthium occidentale</i>	a real problem if it seeds
Nutgrass	<i>Cyperus rotundus</i>	
Rhynchosia	<i>Rhynchosia minima</i>	on some channels, known as native glycene
Rough raspwort	<i>Haloragis aspera</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	black soil
Wild gooseberry	<i>Physalis minima</i>	
Minor Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	isolated
Caustic weed	<i>Chamaesyce drummondii</i>	
Cobbler's peg	<i>Bidens pilosa</i>	spreading, increasing in non-cultivated areas, control difficult
Couch grass	<i>Cynodon dactylon</i>	small areas, but a concern
David's spurge	<i>Euphorbia davidii</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	
Johnson grass	<i>Sorghum halepense</i>	
Mintweed	<i>Salvia reflexa</i>	transported via Pigeon pea seed
Perennial ground cherry	<i>Physalis virginiana</i>	
Pigweed	<i>Portulaca oleracea</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Small flowered mallow	<i>Malva parviflora</i>	
West Indian gherkin	<i>Cucumis anguria</i>	
Wild melon	<i>Citrullus lanatus</i>	

Lower Namoi Valley

Common name	Scientific name	Comments
Major Weeds		
Anoda weed	<i>Anoda cristata</i>	
Bladder ketmia (narrow-eaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Minor Weeds		
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Common sowthistle	<i>Sonchus oleraceus</i>	
Common thornapple	<i>Datura stramonium</i>	
Cowvine	<i>Ipomoea lonchophylla</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Fierce thornapple	<i>Datura ferox</i>	
Mintweed	<i>Salvia reflexa</i>	
Noogoora burr	<i>Xanthium occidentale</i>	
Pigweed	<i>Portulaca oleracea</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	

Gwydir Valley

Common name	Scientific name	Comments
Major Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	becoming an issue
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	increasing
Australian bindweed	<i>Convolvulus erubescens</i>	increasing
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Barnyard grass	<i>Echinochloa species</i>	increasing
Bathurst burr	<i>Xanthium spinosum</i>	
Bellvine	<i>Ipomoea plebeia</i>	
Black bindweed	<i>Fallopia convolvulus</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	increasing
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	increasing, late season control
Caltrop	<i>Tribulus terrestris</i>	
Cobbler's peg	<i>Bidens pilosa</i>	increasing
Common sowthistle	<i>Sonchus oleraceus</i>	
Common thornapple	<i>Datura stramonium</i>	
Cotton	<i>Gossypium hirsutum</i>	more of a concern with Roundup Ready
Cowvine	<i>Ipomoea lonchophylla</i>	late season control, consistently germinating from cotton planting to end of April
Downs nutgrass	<i>Cyperus bifax</i>	increasing
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	problem on channels
Fierce thornapple	<i>Datura ferox</i>	
Grey raspwort	<i>Haloragis glauca</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Mintweed	<i>Salvia reflexa</i>	increasing
Noogoora burr	<i>Xanthium occidentale</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Pigweed	<i>Portulaca oleracea</i>	problem on channels
Polymeria take-all	<i>Polymeria longifolia</i>	increasing
Rhynchosia	<i>Rhynchosia minima</i>	increasing
Sesbania pea	<i>Sesbania cannabina</i>	increasing
Spineless caltrop	<i>Tribulus micrococcus</i>	
Variegated thistle	<i>Silybum marianum</i>	
Wild gooseberry	<i>Physalis minima</i>	
Minor Weeds		
Caustic weed	<i>Chamaesyce drummondii</i>	
Couch grass	<i>Cynodon dactylon</i>	
David's spurge	<i>Euphorbia davidii</i>	
Flaxleaf fleabane	<i>Conyza bonariensis</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	problem on channels
Perennial ground cherry	<i>Physalis virginiana</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Rough raspwort	<i>Haloragis aspera</i>	
West Indian gherkin	<i>Cucumis anguria</i>	
Wild melon	<i>Citrullus lanatus</i>	

Macintyre Valley

Common name	Scientific name	Comments
Major Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Bellvine	<i>Ipomoea plebeia</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	increasing
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	increasing
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Caltrop	<i>Tribulus terrestris</i>	light soils
Caustic weed	<i>Chamaesyce drummondii</i>	increasing
Common sowthistle	<i>Sonchus oleraceus</i>	early season
Common thornapple	<i>Datura stramonium</i>	increasing, light soils
Cotton	<i>Gossypium hirsutum</i>	increasing, head ditches
Couch grass	<i>Cynodon dactylon</i>	
Cowvine	<i>Ipomoea lonchophylla</i>	
Devil's claw	<i>Martynia annua</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Fierce thornapple	<i>Datura ferox</i>	light soils
Flannel weed	<i>Sida cordifolia</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	increasing, high Mg soils
Liverseed grass	<i>Urochloa panicoides</i>	light soils
Mintweed	<i>Salvia reflexa</i>	light soils
Noogoora burr	<i>Xanthium occidentale</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Pigweed	<i>Portulaca oleracea</i>	high Mg soils
Plains spurge	<i>Euphorbia planiticola</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	light soils
Wild gooseberry	<i>Physalis minima</i>	increasing
Wild melon	<i>Citrullus lanatus</i>	dryland cotton
Minor Weeds		
Australian bindweed	<i>Convolvulus erubescens</i>	
Flaxleaf fleabane	<i>Conyza bonariensis</i>	especially dryland & drains; head-ditches
Grey raspswort	<i>Haloragis glauca</i>	
Perennial ground cherry	<i>Physalis virginiana</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	dryland cotton
Rhynchosia	<i>Rhynchosia minima</i>	
Rough raspswort	<i>Haloragis aspera</i>	
Velvetleaf	<i>Abutilon theophrasti</i>	
West Indian gherkin	<i>Cucumis anguria</i>	

St. George

Common name	Scientific name	Comments
Major Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Bellvine	<i>Ipomoea plebeia</i>	increasing
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Caltrop	<i>Tribulus terrestris</i>	
Common sowthistle	<i>Sonchus oleraceus</i>	
Common thornapple	<i>Datura stramonium</i>	
Cotton	<i>Gossypium hirsutum</i>	
Cowpea	<i>Vigna unguiculata</i>	increasing
Cowvine	<i>Ipomoea lonchophylla</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Fierce thornapple	<i>Datura ferox</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	
Grey raspwort	<i>Haloragis glauca</i>	
Mintweed	<i>Salvia reflexa</i>	
Noogoora burr	<i>Xanthium occidentale</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Pigweed	<i>Portulaca oleracea</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Rhynchosia	<i>Rhynchosia minima</i>	
Rough raspwort	<i>Haloragis aspera</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	
Variegated thistle	<i>Silybum marianum</i>	
Wild gooseberry	<i>Physalis minima</i>	
Wild melon	<i>Citrullus lanatus</i>	
Minor Weeds		
Australian bindweed	<i>Convolvulus erubescens</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	
Caustic weed	<i>Chamaesyce drummondii</i>	
Couch grass	<i>Cynodon dactylon</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Perennial ground cherry	<i>Physalis virginiana</i>	
West Indian gherkin	<i>Cucumis anguria</i>	

Dawson/Callide Valleys

Common name	Scientific name	Comments
Major Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	
Bellvine	<i>Ipomoea plebeia</i>	increasing
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Columbus grass	<i>Sorghum alnum</i>	
Common thornapple	<i>Datura stramonium</i>	
Couch grass	<i>Cynodon dactylon</i>	lighter soils
Cowvine	<i>Ipomoea lonchophylla</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Feathertop Rhodes grass	<i>Chloris virgata</i>	
Flannel weed	<i>Sida cordifolia</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	
Johnson grass	<i>Sorghum halepense</i>	
Mintweed	<i>Salvia reflexa</i>	
Mossman river grass	<i>Cenchrus echinatus</i>	
Noogoora burr	<i>Xanthium occidentale</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Phasey bean	<i>Macroptilium lathyroides</i>	
Pigweed	<i>Portulaca oleracea</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Spineless caltrop	<i>Tribulus micrococcus</i>	
Starburr	<i>Acanthospermum hispidum</i>	
Tossa jute	<i>Corchorus olitorius</i>	
Wild gooseberry	<i>Physalis minima</i>	
Minor Weeds		
Anoda weed	<i>Urochloa panicoides</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	
Australian bindweed	<i>Convolvulus erubescens</i>	
Awnless barnyard grass	<i>Echinochloa colona</i>	
Blackberry nightshade	<i>Solanum nigrum</i>	
Caltrop	<i>Tribulus terrestris</i>	
Caustic weed	<i>Chamaesyce drummondii</i>	
Common sowthistle	<i>Sonchus oleraceus</i>	
Cotton	<i>Gossypium hirsutum</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Fierce thornapple	<i>Datura ferox</i>	
Grey raspwort	<i>Haloragis glauca</i>	
Perennial ground cherry	<i>Physalis virginiana</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Rhynchosia	<i>Rhynchosia minima</i>	
Rough raspwort	<i>Haloragis aspera</i>	
West Indian gherkin	<i>Cucumis anguria</i>	
Wild melon	<i>Citrullus lanatus</i>	
Yellow nutgrass	<i>Cyperus esculentus</i>	

Emerald /Central Queensland

Common name	Scientific name	Comments
Major Weeds		
Bellvine	<i>Ipomoea plebeia</i>	
Bladder ketmia (broad-leaf)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	
Boggabri weed	<i>Amaranthus mitchelli</i>	
Columbus grass	<i>Sorghum alnum</i>	fields & drains, spreads in irrigation water
Common sowthistle	<i>Sonchus oleraceus</i>	in winter crops
Cowvine	<i>Ipomoea lonchophylla</i>	
Crownbeard	<i>Verbesina encelioides</i>	
Giant pigweed	<i>Trianthema portulacastrum</i>	problem on head ditches
Johnson grass	<i>Sorghum halepense</i>	
Native jute	<i>Corchorus trilocularis</i>	
Native rosella	<i>Abelmoschus ficulneus</i>	
Nutgrass	<i>Cyperus rotundus</i>	
Parthenium weed	<i>Parthenium hysterophorus</i>	
Polymeria take-all	<i>Polymeria longifolia</i>	
Rhynchosia	<i>Rhynchosia minima</i>	
Sesbania pea	<i>Sesbania cannabina</i>	
Summer grass	<i>Digitaria ciliaris</i>	
Minor Weeds		
Annual ground cherry	<i>Physalis ixocarpa</i>	
Annual polymeria	<i>Polymeria pusilla</i>	
Anoda weed	<i>Anoda cristata</i>	
Australian bindweed	<i>Convolvulus erubescens</i>	
Awnless barnyard grass	<i>Echinochloa colona</i>	
Barnyard grass	<i>Echinochloa crus-galli</i>	
Bathurst burr	<i>Xanthium spinosum</i>	in gravel soils
Blackberry nightshade	<i>Solanum nigrum</i>	
Bladder ketmia (narrow-leaf)	<i>Hibiscus trionum</i> var. <i>trionum</i>	
Button grass	<i>Dactyloctenium radulans</i>	mainly tail-drains and head-ditches
Caltrop	<i>Tribulus terrestris</i>	mostly on head-ditches
Caustic weed	<i>Chamaesyce drummondii</i>	
Common thornapple	<i>Datura stramonium</i>	
Cotton	<i>Gossypium hirsutum</i>	
Couch grass	<i>Cynodon dactylon</i>	
Downs nutgrass	<i>Cyperus bifax</i>	
Dwarf amaranth	<i>Amaranthus macrocarpus</i>	
Fierce thornapple	<i>Datura ferox</i>	
Grey raspwort	<i>Haloragis glauca</i>	
Liverseed grass	<i>Urochloa panicoides</i>	
Mintweed	<i>Salvia reflexa</i>	
Noogoora burr	<i>Xanthium occidentale</i>	
Perennial ground cherry	<i>Physalis virginiana</i>	
Pigweed	<i>Portulaca oleracea</i>	
Prickly paddy melon	<i>Cucumis myriocarpus</i>	
Rough raspwort	<i>Haloragis aspera</i>	problem in dryland not irrigation in CQ
Spineless caltrop	<i>Tribulus micrococcus</i>	
West Indian gherkin	<i>Cucumis anguria</i>	
Wild gooseberry	<i>Physalis minima</i>	
Wild melon	<i>Citrullus lanatus</i>	

WEED SPECIES LISTS

Stephen Johnson and Susan Hazlewood
(University of New England)

The following lists of over 200 plant species can be found in cotton fields and in the areas that surround them. As such, not all the species outlined are of economic importance to cotton crops. Volunteer crop species such as volunteer sorghum and chickpea have been included, but one of the largest 'weed' species of cultivated cotton, volunteer cotton (*Gossypium hirsutum* and less commonly *Gossypium barbadense* i.e. Pima cotton) has not.

The plant species have been sorted by scientific name, for example *Cyperus rotundus* (Table 1) and by common name, for example nutgrass (Table 2). Both tables also contain either the common or scientific names respectively as a cross-reference. The family name and whether the species is a monocot (for example a grass, sedge, lily or other species) or a broad-leaf have been recorded in both tables.

The format of scientific names follows the Flora of NSW series while the common names are those outlined by Shepherd *et al.* (2001) *Plants of Importance to Australia. A checklist*. Refer to the further reading section for information on these two references.

We welcome your suggestions on other species that need to be added to the list. Please contact the primary author of this J3 section to register these suggestions. These registrations will be added when the list is updated in the future.

Table 1. Plant species that may be weeds in cotton fields and in surrounding areas.
These species are sorted by scientific name.

Scientific name	Common Name	Family	Broad leaf/ Monocot
<i>Abelmoschus ficulneus</i>	Native rosella	Malvaceae	Broad leaf
<i>Abutilon malvifolium</i>	Bastard marshmallow	Malvaceae	Broad leaf
<i>Abutilon theophrasti</i>	Swamp Chinese lantern/Velvetleaf	Malvaceae	Broad leaf
<i>Abutilon tubulosum</i>	Abutilon	Malvaceae	Broad leaf
<i>Aeschynomene indica</i>	Budda pea	Fabaceae	Broad leaf
<i>Alternanthera denticulata</i>	Lesser joyweed	Amaranthaceae	Broad leaf
<i>Alternanthera nodiflora</i>	Common joyweed	Amaranthaceae	Broad leaf
<i>Alternanthera pungens</i>	Khaki weed	Amaranthaceae	Broad leaf
<i>Amaranthus hybridus</i>	Slim amaranth/Redshank	Amaranthaceae	Broad leaf
<i>Amaranthus interruptus</i>	Native amaranth	Amaranthaceae	Broad leaf
<i>Amaranthus macrocarpus</i> var. <i>macrocarpus</i>	Dwarf amaranth	Amaranthaceae	Broad leaf
<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	Dwarf amaranth	Amaranthaceae	Broad leaf
<i>Amaranthus mitchellii</i>	Boggabri weed	Amaranthaceae	Broad leaf
<i>Amaranthus powellii</i>	Powell's amaranth	Amaranthaceae	Broad leaf
<i>Amaranthus retroflexus</i>	Redroot amaranth	Amaranthaceae	Broad leaf
<i>Amaranthus viridis</i>	Green amaranth	Amaranthaceae	Broad leaf
<i>Ammi majus</i>	Bishop's weed/Queen Anne's lace	Apiaceae	Broad leaf
<i>Anoda cristata</i>	Anoda weed	Malvaceae	Broad leaf
<i>Arctotheca calendula</i>	Capeweed	Asteraceae	Broad leaf
<i>Argemone ochroleuca</i> subsp. <i>ochroleuca</i>	Mexican poppy	Papaveraceae	Broad leaf
<i>Asphodelus fistulosus</i>	Onion weed	Liliaceae	Monocot
<i>Avena fatua</i>	Wild oat/Black oat	Poaceae	Monocot
<i>Avena sterilis</i> subsp. <i>ludoviciana</i>	Ludo wild oat	Poaceae	Monocot
<i>Bidens pilosa</i>	Cobbler's pegs/Sticky beak	Asteraceae	Broad leaf
<i>Bidens subalternans</i>	Greater beggar's ticks	Asteraceae	Broad leaf
<i>Boerhavia dominii</i>	Tarvine	Nyctaginaceae	Broad leaf
<i>Brachiaria eruciformis</i>	Sweet summer grass	Poaceae	Monocot
<i>Brassica tournefortii</i>	Mediterranean turnip/Wild turnip	Brassicaceae	Broad leaf
<i>Brassica x napus</i> var. <i>napus</i>	Rape/Volunteer canola	Brassicaceae	Broad leaf
<i>Bromus catharticus</i>	Prairie grass	Poaceae	Monocot
<i>Bulbine bulbosa</i>	Bulbine lily	Asphodelaceae	Monocot
<i>Carduus nutans</i> subsp. <i>nutans</i>	Nodding thistle	Asteraceae	Broad leaf
<i>Carthamus lanatus</i>	Saffron thistle	Asteraceae	Broad leaf
<i>Cenchrus incertus</i>	Spiny burrgrass	Poaceae	Monocot
<i>Centaurea solstitialis</i>	St. Barnaby's thistle	Asteraceae	Broad leaf
<i>Chamaesyce drummondii</i>	Caustic weed	Euphorbiaceae	Broad leaf
<i>Chenopodium album</i>	Fathen	Chenopodiaceae	Broad leaf
<i>Chloris virgata</i>	Feathertop Rhodes grass	Poaceae	Monocot
<i>Cicer arietinum</i>	Chickpea volunteer	Fabaceae	Broad leaf
<i>Cichorium intybus</i>	Chicory	Asteraceae	Broad leaf
<i>Ciclospermum leptophyllum</i>	Slender celery	Apiaceae	Broad leaf
<i>Cirsium vulgare</i>	Spear thistle	Asteraceae	Broad leaf
<i>Citrullus lanatus</i> var. <i>lanatus</i>	Wild melon/Paddy melon	Cucurbitaceae	Broad leaf
<i>Cleome viscosa</i>	Tickweed	Capparaceae	Broad leaf
<i>Commelina benghalensis</i>	Hairy wandering Jew	Commelinaceae	Monocot
<i>Commelina cyanea</i>	Scurvy weed/Wandering Jew	Commelinaceae	Monocot
<i>Convolvulus arvensis</i>	Field bindweed	Convolvulaceae	Broad leaf
<i>Convolvulus erubescens</i>	Australian bindweed	Convolvulaceae	Broad leaf
<i>Conyza bonariensis</i>	Flax-leaf fleabane	Asteraceae	Broad leaf
<i>Conyza canadensis</i> var. <i>canadensis</i>	Canadian fleabane	Asteraceae	Broad leaf
<i>Corchorus olitorius</i>	Tossa jute/Jute	Tiliaceae	Broad leaf
<i>Corchorus trilocularis</i>	Native jute	Tiliaceae	Broad leaf
<i>Coriandrum sativum</i>	Coriander volunteer	Apiaceae	Broad leaf
<i>Coronopus didymus</i>	Lesser swinecress	Brassicaceae	Broad leaf
<i>Crotalaria dissitiflora</i> subsp. <i>dissitiflora</i>	Grey rattlepod	Fabaceae	Broad leaf
<i>Crotalaria goreensis</i>	Gambia pea	Fabaceae	Broad leaf
<i>Cucumis anguria</i> var. <i>anguria</i>	West Indian gherkin/Burr gherkin	Cucurbitaceae	Broad leaf
<i>Cucumis myriocarpus</i>	Prickly paddy melon	Cucurbitaceae	Broad leaf
<i>Cullen tenax</i>	Emu foot/Verbena	Fabaceae	Broad leaf
<i>Cuscuta campestris</i>	Golden dodder	Convolvulaceae	Broad leaf
<i>Cynodon dactylon</i>	Couch	Poaceae	Monocot
<i>Cyperus alterniflorus</i>	Tall sedge	Cyperaceae	Monocot
<i>Cyperus bifax</i>	Downs nutgrass	Cyperaceae	Monocot
<i>Cyperus concinnus</i>	Trim sedge	Cyperaceae	Monocot
<i>Cyperus difformis</i>	Dirty Dora	Cyperaceae	Monocot
<i>Cyperus eragrostis</i>	Umbrella sedge	Cyperaceae	Monocot
<i>Cyperus iria</i>	Rice flatsedge	Cyperaceae	Monocot

Scientific name	Common Name	Family	Broad leaf/ Monocot
<i>Cyperus rotundus</i>	Nutgrass	Cyperaceae	Monocot
<i>Cyperus victoriensis</i>	Yelka	Cyperaceae	Monocot
<i>Dactyloctenium radulans</i>	Button grass	Poaceae	Monocot
<i>Datura ferox</i>	Fierce thornapple	Solanaceae	Broad leaf
<i>Datura inoxia</i>	Downy thornapple	Solanaceae	Broad leaf
<i>Datura stramonium</i>	Common thornapple	Solanaceae	Broad leaf
<i>Daucus glochidiatus</i>	Australian carrot	Apiaceae	Broad leaf
<i>Digitaria ciliaris</i>	Summer grass	Poaceae	Monocot
<i>Dinebra retroflexa</i>	Dinebra grass	Poaceae	Monocot
<i>Echinochloa colona</i>	Awnless barnyard grass	Poaceae	Monocot
<i>Echinochloa crus-galli</i>	Barnyard grass	Poaceae	Monocot
<i>Echium plantagineum</i>	Paterson's curse	Boraginaceae	Broad leaf
<i>Echium vulgare</i>	Viper's bugloss	Boraginaceae	Broad leaf
<i>Eleusine indica</i>	Crowsfoot grass	Poaceae	Monocot
<i>Emex australis</i>	Spiny emex/Three-cornered Jack	Polygonaceae	Broad leaf
<i>Eragrostis cilianensis</i>	Stink grass	Poaceae	Monocot
<i>Euphorbia davidii</i>	David's spurge	Euphorbiaceae	Broad leaf
<i>Euphorbia helioscopia</i>	Sun spurge	Euphorbiaceae	Broad leaf
<i>Euphorbia peplus</i>	Petty spurge	Euphorbiaceae	Broad leaf
<i>Euphorbia planiticola</i>	Plains spurge	Euphorbiaceae	Broad leaf
<i>Fallopia convolvulus</i>	Black bindweed	Polygonaceae	Broad leaf
<i>Flaveria australasica</i>	Speedy weed	Asteraceae	Broad leaf
<i>Fumaria officinalis</i>	Common fumitory	Fumariaceae	Broad leaf
<i>Fumaria parviflora</i>	Small-flowered fumitory	Fumariaceae	Broad leaf
<i>Glycine max</i>	Soybean volunteer	Fabaceae	Broad leaf
<i>Gnaphalium pensylvanicum</i>	Cudweed	Asteraceae	Broad leaf
<i>Haloragis aspera</i>	Rough raspwort/Haloragis take-all	Haloragaceae	Broad leaf
<i>Haloragis glauca</i>	Grey raspwort/Raspweed	Haloragaceae	Broad leaf
<i>Helianthus annuus</i>	Sunflower volunteer	Asteraceae	Broad leaf
<i>Heliotropium amplexicaule</i>	Blue heliotrope	Boraginaceae	Broad leaf
<i>Heliotropium europaeum</i>	Common heliotrope	Boraginaceae	Broad leaf
<i>Hibiscus trionum</i> var. <i>trionum</i>	Bladder ketmia narrow-leaf	Malvaceae	Broad leaf
<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Bladder ketmia wide-leaf (red flowered)	Malvaceae	Broad leaf
<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Bladder ketmia wide-leaf (yellow flowered)	Malvaceae	Broad leaf
<i>Hypericum perforatum</i>	St. John's wort	Clusiaceae	Broad leaf
<i>Ibicella lutea</i>	Yellow-flowered devils claw	Martyniaceae	Broad leaf
<i>Ipomoea lonchophylla</i>	Cowvine/Peachvine	Convolvulaceae	Broad leaf
<i>Ipomoea panduranta</i>	Wild potato vine	Convolvulaceae	Broad leaf
<i>Ipomoea plebeia</i>	Bellvine	Convolvulaceae	Broad leaf
<i>Ipomoea purpurea</i>	Common morning glory	Convolvulaceae	Broad leaf
<i>Lablab purpureus</i>	Lablab bean volunteer	Fabaceae	Broad leaf
<i>Lactuca serriola</i>	Prickly lettuce	Asteraceae	Broad leaf
<i>Lamium amplexicaule</i>	Deadnettle	Lamiaceae	Broad leaf
<i>Lavatera plebeia</i>	Australian hollyhock	Malvaceae	Broad leaf
<i>Lepidium africanum</i>	Common peppergrass	Brassicaceae	Broad leaf
<i>Leptochloa digitata</i>	Umbrella canegrass	Poaceae	Monocot
<i>Leptochloa fusca</i>	Brown beetle grass	Poaceae	Monocot
<i>Linum usitatissimum</i>	Linseed volunteer	Linaceae	Broad leaf
<i>Macroptilium lathyroides</i>	Phasey bean	Fabaceae	Broad leaf
<i>Malva parviflora</i>	Small-flowered mallow/Marshmallow	Malvaceae	Broad leaf
<i>Malvastrum americanum</i>	Spiked malvastrum	Malvaceae	Broad leaf
<i>Martynia annua</i>	Devil's claw	Martyniaceae	Broad leaf
<i>Medicago polymorpha</i>	Burr medic	Fabaceae	Broad leaf
<i>Melinis repens</i>	Red Natal grass	Poaceae	Monocot
<i>Mimosa pudica</i>	Common sensitive plant	Mimosaceae	Broad leaf
<i>Neonotonia wightii</i>	Glycine/Tinaroo glycine	Fabaceae	Broad leaf
<i>Oenothera affinis</i>	Long-flowered evening primrose	Onagraceae	Broad leaf
<i>Oenothera indecora</i> subsp. <i>bonariensis</i>	Short-flowered evening primrose	Onagraceae	Broad leaf
<i>Oxalis chnoides</i>	Oxalis	Oxalidaceae	Broad leaf
<i>Oxalis perennans</i>	Native oxalis	Oxalidaceae	Broad leaf
<i>Oxalis pes-caprae</i>	Soursob	Oxalidaceae	Broad leaf
<i>Panicum decompositum</i>	Native millet	Poaceae	Monocot
<i>Panicum maximum</i>	Guinea grass	Poaceae	Monocot
<i>Parthenium hysterophorus</i>	Parthenium weed	Asteraceae	Broad leaf
<i>Persicaria maculosa</i>	Redshank	Polygonaceae	Broad leaf
<i>Persicaria prostrata</i>	Creeping knotweed	Polygonaceae	Broad leaf
<i>Phalaris paradoxa</i>	Paradoxa grass	Poaceae	Monocot
<i>Phyla nodiflora</i>	Lippia	Verbenaceae	Broad leaf
<i>Phyllanthus virgatus</i>	Phyllanthus	Euphorbiaceae	Broad leaf

Scientific name	Common Name	Family	Broad leaf/ Monocot
<i>Physalis ixocarpa</i>	Ground cherry/Chinese lantern	Solanaceae	Broad leaf
<i>Physalis minima</i>	Wild gooseberry/Chinese lantern	Solanaceae	Broad leaf
<i>Physalis virginiana</i>	Perennial ground cherry/Chinese lantern	Solanaceae	Broad leaf
<i>Poa annua</i>	Annual poa/Winter grass	Poaceae	Monocot
<i>Polygonum aviculare</i>	Wireweed/Knotweed	Polygonaceae	Broad leaf
<i>Polymeria longifolia</i>	Polymeria/Polymeria take-all	Convolvulaceae	Broad leaf
<i>Polymeria pusilla</i>	Polymeria/Annual polymeria	Convolvulaceae	Broad leaf
<i>Portulaca oleracea</i>	Pigweed/Red pigweed	Portulacaceae	Broad leaf
<i>Pratia darlingensis</i>	Darling pratia/Matted pratia	Campanulaceae	Broad leaf
<i>Proboscidea louisianica</i>	Purple-flowered devils claw	Martyniaceae	Broad leaf
<i>Raphanus raphanistrum</i>	Wild radish	Brassicaceae	Broad leaf
<i>Rapistrum rugosum</i>	Turnip weed	Brassicaceae	Broad leaf
<i>Rhynchosia minima</i>	Rhynchosia/Ryncho	Fabaceae	Broad leaf
<i>Ricinus communis</i>	Castor oil plant	Euphorbiaceae	Broad leaf
<i>Rumex crispus</i>	Curled dock	Polygonaceae	Broad leaf
<i>Salsola kali</i>	Soft roly-poly	Chenopodiaceae	Broad leaf
<i>Salvia reflexa</i>	Mintweed	Lamiaceae	Broad leaf
<i>Senecio daltonii</i>	Dalton weed/Dalton's groundsel	Asteraceae	Broad leaf
<i>Senecio lautus</i> subsp. <i>dissectifolius</i>	Variable groundsel	Asteraceae	Broad leaf
<i>Senna occidentalis</i>	Coffee senna	Caesalpiniaceae	Broad leaf
<i>Sesbania cannabina</i>	Sesbania pea	Fabaceae	Broad leaf
<i>Sida acuta</i>	Spiny-head sida	Malvaceae	Broad leaf
<i>Sida cordifolia</i>	Flannel weed	Malvaceae	Broad leaf
<i>Sida fibulifera</i>	Pin sida	Malvaceae	Broad leaf
<i>Sida rhombifolia</i>	Paddy's lucerne	Malvaceae	Broad leaf
<i>Sida spinosa</i>	Spiny sida	Malvaceae	Broad leaf
<i>Silybum marianum</i>	Variegated thistle	Asteraceae	Broad leaf
<i>Sinapis arvensis</i>	Charlock	Brassicaceae	Broad leaf
<i>Sisymbrium irio</i>	London rocket	Brassicaceae	Broad leaf
<i>Sisymbrium officinale</i>	Hedge mustard	Brassicaceae	Broad leaf
<i>Sisymbrium orientale</i>	Indian hedge mustard	Brassicaceae	Broad leaf
<i>Sisymbrium thellungii</i>	African turnip weed	Brassicaceae	Broad leaf
<i>Solanum americanum</i>	Glossy nightshade	Solanaceae	Broad leaf
<i>Solanum elaeagnifolium</i>	Silver-leaved nightshade	Solanaceae	Broad leaf
<i>Solanum esuriale</i>	Quena	Solanaceae	Broad leaf
<i>Solanum nigrum</i>	Blackberry nightshade	Solanaceae	Broad leaf
<i>Sonchus asper</i> subsp. <i>glaucescens</i>	Rough sowthistle/Prickly sowthistle	Asteraceae	Broad leaf
<i>Sonchus oleraceus</i>	Common sowthistle/Milk thistle	Asteraceae	Broad leaf
<i>Sorghum bicolor</i>	Sorghum volunteer	Poaceae	Monocot
<i>Sorghum halepense</i>	Johnson grass	Poaceae	Monocot
<i>Sorghum x alrum</i>	Columbus grass	Poaceae	Monocot
<i>Tetragonia tetragonioides</i>	New Zealand spinach	Aizoaceae	Broad leaf
<i>Teucrium integrifolium</i>	Teucry weed/Peak Downs curse	Lamiaceae	Broad leaf
<i>Trianthema portulacastrum</i>	Giant pigweed/Black pigweed	Aizoaceae	Broad leaf
<i>Tribulus micrococcus</i>	Spineless caltrop/Yellow vine	Zygophyllaceae	Broad leaf
<i>Tribulus terrestris</i>	Caltrop	Zygophyllaceae	Broad leaf
<i>Typha domingensis</i>	Narrow-leaf cumbungi	Typhaceae	Monocot
<i>Typha orientalis</i>	Broad-leaf cumbungi	Typhaceae	Monocot
<i>Urochloa panicoides</i>	Liverseed grass	Poaceae	Monocot
<i>Urochloa praetervisa</i>	Large armgrass/Velvet-leaved summer grass	Poaceae	Monocot
<i>Urochloa subquadriflora</i>	Green summer grass	Poaceae	Monocot
<i>Urtica incisa</i>	Scrub nettle/Stinging nettle	Urticaceae	Broad leaf
<i>Verbena bonariensis</i>	Purpletop	Verbenaceae	Broad leaf
<i>Verbena rigida</i>	Veined verbena	Verbenaceae	Broad leaf
<i>Verbesina encelioides</i> subsp. <i>encelioides</i>	Crownbeard	Asteraceae	Broad leaf
<i>Vicia faba</i>	Broad bean/Faba bean volunteer	Fabaceae	Broad leaf
<i>Vicia monantha</i>	Spurred vetch	Fabaceae	Broad leaf
<i>Vigna lanceolata</i> var. <i>filiformis</i>	Maloga bean	Fabaceae	Broad leaf
<i>Vigna lanceolata</i> var. <i>lanceolata</i>	Maloga bean	Fabaceae	Broad leaf
<i>Vigna lanceolata</i> var. <i>latifolia</i>	Maloga bean	Fabaceae	Broad leaf
<i>Vigna luteola</i>	Dalrymple vigna	Fabaceae	Broad leaf
<i>Vigna radiata</i> var. <i>setulosa</i>	Mung bean volunteer	Fabaceae	Broad leaf
<i>Wahlenbergia stricta</i>	Tall bluebell	Campanulaceae	Broad leaf
<i>Xanthium italicum</i>	Italian cocklebur/Hunter burr	Asteraceae	Broad leaf
<i>Xanthium occidentale</i>	Noogoora burr	Asteraceae	Broad leaf
<i>Xanthium orientale</i>	Californian burr	Asteraceae	Broad leaf
<i>Xanthium spinosum</i>	Bathurst burr	Asteraceae	Broad leaf
<i>Zea mays</i>	Maize volunteer	Poaceae	Monocot

Table 2. Plant species that may be weeds in cotton fields and in surrounding areas.
These species are sorted by common name.

Common Name	Scientific name	Family	Broad leaf/ Monocot
Abutilon	<i>Abutilon tubulosum</i>	Malvaceae	Broad leaf
African turnip weed	<i>Sisymbrium thellungii</i>	Brassicaceae	Broad leaf
Annual poa/Winter grass	<i>Poa annua</i>	Poaceae	Monocot
Anoda weed	<i>Anoda cristata</i>	Malvaceae	Broad leaf
Australian bindweed	<i>Convolvulus erubescens</i>	Convolvulaceae	Broad leaf
Australian carrot	<i>Daucus glochidiatus</i>	Apiaceae	Broad leaf
Australian hollyhock	<i>Lavatera plebeia</i>	Malvaceae	Broad leaf
Awnless barnyard grass	<i>Echinochloa colona</i>	Poaceae	Monocot
Barnyard grass	<i>Echinochloa crus-galli</i>	Poaceae	Monocot
Bastard marshmallow	<i>Abutilon malvifolium</i>	Malvaceae	Broad leaf
Bathurst burr	<i>Xanthium spinosum</i>	Asteraceae	Broad leaf
Bellvine	<i>Ipomoea plebeia</i>	Convolvulaceae	Broad leaf
Bishop's weed/Queen Anne's lace	<i>Ammi majus</i>	Apiaceae	Broad leaf
Black bindweed	<i>Fallopia convolvulus</i>	Polygonaceae	Broad leaf
Blackberry nightshade	<i>Solanum nigrum</i>	Solanaceae	Broad leaf
Bladder ketmia narrow-leaf	<i>Hibiscus trionum</i> var. <i>trionum</i>	Malvaceae	Broad leaf
Bladder ketmia wide-leaf (red flowered)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Malvaceae	Broad leaf
Bladder ketmia wide-leaf (yellow flowered)	<i>Hibiscus trionum</i> var. <i>vesicarius</i>	Malvaceae	Broad leaf
Blue heliotrope	<i>Heliotropium amplexicaule</i>	Boraginaceae	Broad leaf
Boggabri weed	<i>Amaranthus mitchellii</i>	Amaranthaceae	Broad leaf
Broad bean/Faba bean volunteer	<i>Vicia faba</i>	Fabaceae	Broad leaf
Broad-leaf cumbungi	<i>Typha orientalis</i>	Typhaceae	Monocot
Brown beetle grass	<i>Leptochloa fusca</i>	Poaceae	Monocot
Budda pea	<i>Aeschynomene indica</i>	Fabaceae	Broad leaf
Bulbine lily	<i>Bulbine bulbosa</i>	Asphodelaceae	Monocot
Burr medic	<i>Medicago polymorpha</i>	Fabaceae	Broad leaf
Button grass	<i>Dactyloctenium radulans</i>	Poaceae	Monocot
Californian burr	<i>Xanthium orientale</i>	Asteraceae	Broad leaf
Caltrop	<i>Tribulus terrestris</i>	Zygophyllaceae	Broad leaf
Canadian fleabane	<i>Conyza canadensis</i> var. <i>canadensis</i>	Asteraceae	Broad leaf
Capeweed	<i>Arctotheca calendula</i>	Asteraceae	Broad leaf
Castor oil plant	<i>Ricinus communis</i>	Euphorbiaceae	Broad leaf
Caustic weed	<i>Chamaesyce drummondii</i>	Euphorbiaceae	Broad leaf
Charlock	<i>Sinapis arvensis</i>	Brassicaceae	Broad leaf
Chickpea volunteer	<i>Cicer arietinum</i>	Fabaceae	Broad leaf
Chicory	<i>Cichorium intybus</i>	Asteraceae	Broad leaf
Cobbler's pegs/Sticky beak	<i>Bidens pilosa</i>	Asteraceae	Broad leaf
Coffee senna	<i>Senna occidentalis</i>	Caesalpiniaceae	Broad leaf
Columbus grass	<i>Sorghum x alnum</i>	Poaceae	Monocot
Common fumitory	<i>Fumaria officinalis</i>	Fumariaceae	Broad leaf
Common heliotrope	<i>Heliotropium europaeum</i>	Boraginaceae	Broad leaf
Common joyweed	<i>Alternanthera nodiflora</i>	Amaranthaceae	Broad leaf
Common morning glory	<i>Ipomoea purpurea</i>	Convolvulaceae	Broad leaf
Common peppercress	<i>Lepidium africanum</i>	Brassicaceae	Broad leaf
Common sensitive plant	<i>Mimosa pudica</i>	Mimosaceae	Broad leaf
Common sowthistle/Milk thistle	<i>Sonchus oleraceus</i>	Asteraceae	Broad leaf
Common thornapple	<i>Datura stramonium</i>	Solanaceae	Broad leaf
Coriander volunteer	<i>Coriandrum sativum</i>	Apiaceae	Broad leaf
Couch	<i>Cynodon dactylon</i>	Poaceae	Monocot
Cowvine/Peachvine	<i>Ipomoea lonchophylla</i>	Convolvulaceae	Broad leaf
Creeping knotweed	<i>Persicaria prostrata</i>	Polygonaceae	Broad leaf
Crownbeard	<i>Verbesina encelioides</i> subsp. <i>encelioides</i>	Asteraceae	Broad leaf
Crowsfoot grass	<i>Eleusine indica</i>	Poaceae	Monocot
Cudweed	<i>Gnaphalium pensylvanicum</i>	Asteraceae	Broad leaf
Curled dock	<i>Rumex crispus</i>	Polygonaceae	Broad leaf
Dalrymple vigna	<i>Vigna luteola</i>	Fabaceae	Broad leaf
Dalton weed/Dalton's groundsel	<i>Senecio daltonii</i>	Asteraceae	Broad leaf
Darling pratia/Matted pratia	<i>Pratia darlingensis</i>	Campanulaceae	Broad leaf
David's spurge	<i>Euphorbia davidii</i>	Euphorbiaceae	Broad leaf
Deadnettle	<i>Lamium amplexicaule</i>	Lamiaceae	Broad leaf
Devil's claw	<i>Martynia annua</i>	Martyniaceae	Broad leaf
Dinebra grass	<i>Dinebra retroflexa</i>	Poaceae	Monocot
Dirty Dora	<i>Cyperus difformis</i>	Cyperaceae	Monocot
Downs nutgrass	<i>Cyperus bifax</i>	Cyperaceae	Monocot
Downy thornapple	<i>Datura innoxia</i>	Solanaceae	Broad leaf
Dwarf amaranth	<i>Amaranthus macrocarpus</i> var. <i>pallidus</i>	Amaranthaceae	Broad leaf
Dwarf amaranth	<i>Amaranthus macrocarpus</i> var. <i>macrocarpus</i>	Amaranthaceae	Broad leaf

Common Name	Scientific name	Family	Broad leaf/ Monocot
Emu foot/Verbena	<i>Cullen tenax</i>	Fabaceae	Broad leaf
Fathen	<i>Chenopodium album</i>	Chenopodiaceae	Broad leaf
Feathertop Rhodes grass	<i>Chloris virgata</i>	Poaceae	Monocot
Field bindweed	<i>Convolvulus arvensis</i>	Convolvulaceae	Broad leaf
Fierce thornapple	<i>Datura ferox</i>	Solanaceae	Broad leaf
Flannel weed	<i>Sida cordifolia</i>	Malvaceae	Broad leaf
Flax-leaf fleabane	<i>Conyza bonariensis</i>	Asteraceae	Broad leaf
Gambia pea	<i>Crotalaria goreensis</i>	Fabaceae	Broad leaf
Giant pigweed/Black pigweed	<i>Trianthema portulacastrum</i>	Aizoaceae	Broad leaf
Glossy nightshade	<i>Solanum americanum</i>	Solanaceae	Broad leaf
Glycine/Tinaroo glycine	<i>Neonotonia wightii</i>	Fabaceae	Broad leaf
Golden dodder	<i>Cuscuta campestris</i>	Convolvulaceae	Broad leaf
Greater beggar's ticks	<i>Bidens subalternans</i>	Asteraceae	Broad leaf
Green amaranth	<i>Amaranthus viridis</i>	Amaranthaceae	Broad leaf
Green summer grass	<i>Urochloa subquadriflora</i>	Poaceae	Monocot
Grey raspwort/Raspweed	<i>Haloragis glauca</i>	Haloragaceae	Broad leaf
Grey rattlepod	<i>Crotalaria dissitiflora</i> subsp. <i>dissitiflora</i>	Fabaceae	Broad leaf
Ground cherry/Chinese lantern	<i>Physalis ixocarpa</i>	Solanaceae	Broad leaf
Guinea grass	<i>Panicum maximum</i>	Poaceae	Monocot
Hairy wandering Jew	<i>Commelina benghalensis</i>	Commelinaceae	Monocot
Hedge mustard	<i>Sisymbrium officinale</i>	Brassicaceae	Broad leaf
Indian hedge mustard	<i>Sisymbrium orientale</i>	Brassicaceae	Broad leaf
Italian cocklebur/Hunter burr	<i>Xanthium italicum</i>	Asteraceae	Broad leaf
Johnson grass	<i>Sorghum halepense</i>	Poaceae	Monocot
Khaki weed	<i>Alternanthera pungens</i>	Amaranthaceae	Broad leaf
Lablab bean volunteer	<i>Lablab purpureus</i>	Fabaceae	Broad leaf
Large armgrass/Velvet-leaved summer grass	<i>Urochloa praetervisa</i>	Poaceae	Monocot
Lesser joyweed	<i>Alternanthera denticulata</i>	Amaranthaceae	Broad leaf
Lesser swinecress	<i>Coronopus didymus</i>	Brassicaceae	Broad leaf
Linseed volunteer	<i>Linum usitatissimum</i>	Linaceae	Broad leaf
Lippia	<i>Phyla nodiflora</i>	Verbenaceae	Broad leaf
Liverseed grass	<i>Urochloa panicoides</i>	Poaceae	Monocot
London rocket	<i>Sisymbrium irio</i>	Brassicaceae	Broad leaf
Long-flowered evening primrose	<i>Oenothera affinis</i>	Onagraceae	Broad leaf
Ludo wild oat	<i>Avena sterilis</i> subsp. <i>ludoviciana</i>	Poaceae	Monocot
Maize volunteer	<i>Zea mays</i>	Poaceae	Monocot
Maloga bean	<i>Vigna lanceolata</i> var. <i>filiformis</i>	Fabaceae	Broad leaf
Maloga bean	<i>Vigna lanceolata</i> var. <i>lanceolata</i>	Fabaceae	Broad leaf
Maloga bean	<i>Vigna lanceolata</i> var. <i>latifolia</i>	Fabaceae	Broad leaf
Mediterranean turnip/Wild turnip	<i>Brassica tournefortii</i>	Brassicaceae	Broad leaf
Mexican poppy	<i>Argemone ochroleuca</i> subsp. <i>ochroleuca</i>	Papaveraceae	Broad leaf
Mintweed	<i>Salvia reflexa</i>	Lamiaceae	Broad leaf
Mung bean volunteer	<i>Vigna radiata</i> var. <i>setulosa</i>	Fabaceae	Broad leaf
Narrow-leaf cumbungi	<i>Typha domingensis</i>	Typhaceae	Monocot
Native amaranth	<i>Amaranthus interruptus</i>	Amaranthaceae	Broad leaf
Native jute	<i>Corchorus trilocularis</i>	Tiliaceae	Broad leaf
Native millet	<i>Panicum decompositum</i>	Poaceae	Monocot
Native oxalis	<i>Oxalis perennans</i>	Oxalidaceae	Broad leaf
Native rosella	<i>Abelmoschus ficulneus</i>	Malvaceae	Broad leaf
New Zealand spinach	<i>Tetragonia tetragonioides</i>	Aizoaceae	Broad leaf
Nodding thistle	<i>Carduus nutans</i> subsp. <i>nutans</i>	Asteraceae	Broad leaf
Noogoora burr	<i>Xanthium occidentale</i>	Asteraceae	Broad leaf
Nutgrass	<i>Cyperus rotundus</i>	Cyperaceae	Monocot
Onion weed	<i>Asphodelus fistulosus</i>	Liliaceae	Monocot
Oxalis	<i>Oxalis chnoodes</i>	Oxalidaceae	Broad leaf
Paddy's lucerne	<i>Sida rhombifolia</i>	Malvaceae	Broad leaf
Paradoxa grass	<i>Phalaris paradoxa</i>	Poaceae	Monocot
Parthenium weed	<i>Parthenium hysterophorus</i>	Asteraceae	Broad leaf
Paterson's curse	<i>Echium plantagineum</i>	Boraginaceae	Broad leaf
Perennial ground cherry/Chinese lantern	<i>Physalis virginiana</i>	Solanaceae	Broad leaf
Petty spurge	<i>Euphorbia peplus</i>	Euphorbiaceae	Broad leaf
Phasey bean	<i>Macroptilium lathyroides</i>	Fabaceae	Broad leaf
Phyllanthus	<i>Phyllanthus virgatus</i>	Euphorbiaceae	Broad leaf
Pigweed/Red pigweed	<i>Portulaca oleracea</i>	Portulacaceae	Broad leaf
Pin sida	<i>Sida fibulifera</i>	Malvaceae	Broad leaf
Plains spurge	<i>Euphorbia planiticola</i>	Euphorbiaceae	Broad leaf
Polymeria/Annual polymeria	<i>Polymeria pusilla</i>	Convolvulaceae	Broad leaf
Polymeria/Polymeria take-all	<i>Polymeria longifolia</i>	Convolvulaceae	Broad leaf

Common Name	Scientific name	Family	Broad leaf/ Monocot
Powell's amaranth	<i>Amaranthus powellii</i>	Amaranthaceae	Broad leaf
Prairie grass	<i>Bromus catharticus</i>	Poaceae	Monocot
Prickly lettuce	<i>Lactuca serriola</i>	Asteraceae	Broad leaf
Prickly paddy melon	<i>Cucumis myriocarpus</i>	Cucurbitaceae	Broad leaf
Purple-flowered devils claw	<i>Proboscidea louisianica</i>	Martyniaceae	Broad leaf
Purpletop	<i>Verbena bonariensis</i>	Verbenaceae	Broad leaf
Quena	<i>Solanum esuriale</i>	Solanaceae	Broad leaf
Rape/Volunteer canola	<i>Brassica x napus</i> var. <i>napus</i>	Brassicaceae	Broad leaf
Red Natal grass	<i>Melinis repens</i>	Poaceae	Monocot
Redroot amaranth	<i>Amaranthus retroflexus</i>	Amaranthaceae	Broad leaf
Redshank	<i>Persicaria maculosa</i>	Polygonaceae	Broad leaf
Rhynchosia/Ryncho	<i>Rhynchosia minima</i>	Fabaceae	Broad leaf
Rice flatsedge	<i>Cyperus iria</i>	Cyperaceae	Monocot
Rough raspwort/Haloragis take-all	<i>Haloragis aspera</i>	Haloragaceae	Broad leaf
Rough sowthistle/Prickly sowthistle	<i>Sonchus asper</i> subsp. <i>glaucescens</i>	Asteraceae	Broad leaf
Saffron thistle	<i>Carthamus lanatus</i>	Asteraceae	Broad leaf
Scrub nettle/Stinging nettle	<i>Urtica incisa</i>	Urticaceae	Broad leaf
Scurvy weed/Wandering Jew	<i>Commelina cyanea</i>	Commelinaceae	Monocot
Sesbania pea	<i>Sesbania cannabina</i>	Fabaceae	Broad leaf
Silver-leaved nightshade	<i>Solanum elaeagnifolium</i>	Solanaceae	Broad leaf
Slender celery	<i>Ciclospermum leptophyllum</i>	Apiaceae	Broad leaf
Slim amaranth/Redshank	<i>Amaranthus hybridus</i>	Amaranthaceae	Broad leaf
Small-flowered evening primrose	<i>Oenothera indecora</i> subsp. <i>bonariensis</i>	Onagraceae	Broad leaf
Small-flowered fumitory	<i>Fumaria parviflora</i>	Fumariaceae	Broad leaf
Small-flowered mallow/Marshmallow	<i>Malva parviflora</i>	Malvaceae	Broad leaf
Soft roly-poly	<i>Salsola kali</i>	Chenopodiaceae	Broad leaf
Sorghum volunteer	<i>Sorghum bicolor</i>	Poaceae	Monocot
Soursob	<i>Oxalis pes-caprae</i>	Oxalidaceae	Broad leaf
Soybean volunteer	<i>Glycine max</i>	Fabaceae	Broad leaf
Spear thistle	<i>Cirsium vulgare</i>	Asteraceae	Broad leaf
Speedy weed	<i>Flaveria australasica</i>	Asteraceae	Broad leaf
Spiked malvastrum	<i>Malvastrum americanum</i>	Malvaceae	Broad leaf
Spineless caltrop/Yellow vine	<i>Tribulus micrococcus</i>	Zygophyllaceae	Broad leaf
Spiny burgrass	<i>Cenchrus incertus</i>	Poaceae	Monocot
Spiny emex/Three-cornered Jack	<i>Emex australis</i>	Polygonaceae	Broad leaf
Spiny sida	<i>Sida spinosa</i>	Malvaceae	Broad leaf
Spiny-head sida	<i>Sida acuta</i>	Malvaceae	Broad leaf
Spurred vetch	<i>Vicia monantha</i>	Fabaceae	Broad leaf
St. Barnaby's thistle	<i>Centaurea solstitialis</i>	Asteraceae	Broad leaf
St. John's wort	<i>Hypericum perforatum</i>	Clusiaceae	Broad leaf
Stink grass	<i>Eragrostis cilianensis</i>	Poaceae	Monocot
Summer grass	<i>Digitaria ciliaris</i>	Poaceae	Monocot
Sunflower volunteer	<i>Helianthus annuus</i>	Asteraceae	Broad leaf
Sun spurge	<i>Euphorbia helioscopia</i>	Euphorbiaceae	Broad leaf
Swamp Chinese lantern/Velvetleaf	<i>Abutilon theophrasti</i>	Malvaceae	Broad leaf
Sweet summer grass	<i>Brachiaria eruciformis</i>	Poaceae	Monocot
Tall bluebell	<i>Wahlenbergia stricta</i>	Campanulaceae	Broad leaf
Tall sedge	<i>Cyperus alterniflorus</i>	Cyperaceae	Monocot
Tarvine	<i>Boerhavia dominii</i>	Nyctaginaceae	Broad leaf
Teucry weed/Peak Downs curse	<i>Teucrium integrifolium</i>	Lamiaceae	Broad leaf
Tickweed	<i>Cleome viscosa</i>	Capparaceae	Broad leaf
Tossa jute/Jute	<i>Corchorus olitorius</i>	Tiliaceae	Broad leaf
Trim sedge	<i>Cyperus concinnus</i>	Cyperaceae	Monocot
Turnip weed	<i>Rapistrum rugosum</i>	Brassicaceae	Broad leaf
Umbrella canegrass	<i>Leptochloa digitata</i>	Poaceae	Monocot
Umbrella sedge	<i>Cyperus eragrostis</i>	Cyperaceae	Monocot
Variable groundsel	<i>Senecio lautus</i> subsp. <i>dissectifolius</i>	Asteraceae	Broad leaf
Variegated thistle	<i>Silybum marianum</i>	Asteraceae	Broad leaf
Veined verbena	<i>Verbena rigida</i>	Verbenaceae	Broad leaf
Viper's bugloss	<i>Echium vulgare</i>	Boraginaceae	Broad leaf
West Indian gherkin/Burr gherkin	<i>Cucumis anguria</i> var. <i>anguria</i>	Cucurbitaceae	Broad leaf
Wild gooseberry/Chinese lantern	<i>Physalis minima</i>	Solanaceae	Broad leaf
Wild melon/Paddy melon	<i>Citrullus lanatus</i> var. <i>lanatus</i>	Cucurbitaceae	Broad leaf
Wild oat/Black oat	<i>Avena fatua</i>	Poaceae	Monocot
Wild potato vine	<i>Ipomoea panduranta</i>	Convolvulaceae	Broad leaf
Wild radish	<i>Raphanus raphanistrum</i>	Brassicaceae	Broad leaf
Wireweed/Knotweed	<i>Polygonum aviculare</i>	Polygonaceae	Broad leaf
Yelka	<i>Cyperus victoriensis</i>	Cyperaceae	Monocot
Yellow-Flowered devils claw	<i>Ibicella lutea</i>	Martyniaceae	Broad leaf

FURTHER READING

Compiled by: **Stephen Johnson**
(University of New England)

The following lists contain a number of references that may assist the reader in various aspects of weed identification, biology and general management. Many of the references are available at large libraries or can be purchased from various publishers. The following sections are covered in the reference list: -

General plant identification,
Botanical identification/Taxonomy,
General biology and management,
Scientific journal publications and
Other useful references.

General plant identification

- Auld, B. A. and Medd, R. W. (1987). *Weeds. An Illustrated Botanical Guide to the Weeds of Australia*. Inkata Press, Melbourne. pp. 255.
- Cunningham, G. M., Mulham, W. E., Milthorpe, P. L. and Leigh, J. H. (1981). *Plants of Western New South Wales*. Inkata Press, Melbourne. pp. 776.
- Shepherd, R. C. H., Richardson, R. G. and Richardson, F. J. (2001). *Plants of Importance to Australia. A checklist*. Richardson, Meredith, Victoria. pp. 358.
- Wilson, B. J., Hawton, D. and Duff, A. A. (1995). *Crop Weeds of Northern Australia*. Queensland Department of Primary Industries, Brisbane. pp. 160.
- Wood, P., Cahill, M., Marlow, G. and Douglas, N. (compilers) (2000). *Weeds: The Ute Guide, Northern Grain Belt Edition*. Queensland Department of Primary Industries, Brisbane. pp. 190. (This guide is based on *Crop Weeds of Northern Australia*).

Botanical identification/Taxonomy

This is a list of books commonly used by botanists to identify and classify plants. Only those related to New South Wales and Queensland have been included.

- Harden, G. J. (editor) (1990). *Flora of New South Wales, Volume 1*. University of NSW Press, Kensington. pp 601.
- Harden, G. J. (editor) (1991). *Flora of New South Wales, Volume 2*. University of NSW Press, Kensington. pp 574.
- Harden, G. J. (editor) (1992). *Flora of New South Wales, Volume 3*. University of NSW Press, Kensington. pp 717.
- Harden, G. J. (editor) (1993). *Flora of New South Wales, Volume 4*. University of NSW Press, Kensington. pp 775.
- Stanley, T. D. and Ross, E. M. (1995). *Flora of South-Eastern Queensland, Volume 1*. Queensland Department of Primary Industries, Brisbane. pp. 545.
- Stanley, T. D. and Ross, E. M. (1986). *Flora of South-Eastern Queensland, Volume 2*. Queensland Department of Primary Industries, Brisbane. pp. 622.
- Stanley, T. D. and Ross, E. M. (1986). *Flora of South-Eastern Queensland, Volume 3*. Queensland Department of Primary Industries, Brisbane. pp. 532.

General biology and management

This list contains theses and books with sections on weeds that occur in Australian cotton farming systems.

- Groves, R. H., Shepherd, R. C. H. and Richardson, R. G. (editors) (1995). *The Biology of Australian Weeds, Volume 1*. Richardson, Melbourne. pp. 314.
- Johnson, S. B. (2000). Biology and management of the 'take-all' weed, *Polymeria longifolia* (Peaks Downs curse), in cotton. Doctor of Philosophy thesis. University of New England, Armidale. pp. 291. (Available through the University of New England or by contacting the author).
- Kleinschmidt, H. E. and Johnson, R. W. (1977). *Weeds of Queensland*. Australian Government Publishing Service, Brisbane. pp. 469.
- McWhorter, C. G. and Abernathy, J. R. (1992). *Weeds of Cotton: Characterization and Control*. The Cotton Foundation Reference Book Series, Number 2. The Cotton Foundation. Memphis, Tennessee, USA. pp. 631.
- Osten, V. A. (1996). *Haloragis aspera* Lindley (raspweed). Master of Agricultural Science thesis. The University of Queensland. pp. 177. (Available through the University of Queensland or by contacting the author).
- Panetta, F. D., Groves, R. H. and Shepherd, R. C. H. (editors.) (1998). *The Biology of Australian Weeds, Volume 2*. Richardson, Melbourne. pp. 327.
- Parsons, W. T. and Cuthbertson, E. G. (2001). *Noxious Weeds of Australia, 2nd edition*. CSIRO Publishing, Collingwood, Melbourne. pp. 698.

Scientific journal publications

This list covers weed research performed in cotton farming systems in Australia. The journals can be accessed at a university library or by contacting the author. A search of other scientific journals like *Plant Protection Quarterly*, *Weed Research*, *Weed Science* and *Weed Technology* may yield other overseas information.

- Charles, G. W. (1991). A grower survey of weeds and herbicide use in the New South Wales cotton industry. *Australian Journal of Experimental Agriculture*, **31**, 387-392.
- Charles, G. W. (1995). Nutgrass (*Cyperus rotundus* L.) control in cotton (*Gossypium hirsutum* L.). *Australian Journal of Experimental Agriculture*, **35**, 633-639.
- Charles, G. W. (1997). Herbicide strategies for reducing nutgrass (*Cyperus rotundus* L.) density in cotton (*Gossypium hirsutum* L.). *Australian Journal of Experimental Agriculture*, **37**, 231-241.
- Charles, G. W., Murison, R. D. and Harden, S. (1998). Competition of noogoora burr (*Xanthium occidentale*) and fierce thornapple (*Datura ferox*) with cotton (*Gossypium hirsutum*). *Weed Science*, **46**, 442-446.

Other useful references

This list contains a number of general references, many of which have been published since 1995 in the *Australian Cottongrower* or in *Cotton Conference Proceedings*.

- Baskaran, S. and Kennedy, I. (1999). Minimizing the environmental impact of cotton herbicides. *The Australian Cottongrower*, **20**, no. 1, 54-58.
- Charles, G. W. (1996). Sustainable weed management on permanent beds. *Proceedings of the 8th Australian Cotton Conference*, Broadbeach, Queensland. pp. 507-512.
- Charles, G. W. (1996). Understanding the weed seed menace. *The Australian Cottongrower*, **17**, no. 6, 26-28.
- Charles, G. W. (1997). *Controlling nutgrass in cotton*. CRC Newsletter, 3, no. 1. Cooperative Research Centre for Sustainable Cotton Production, Narrabri.
- Charles, G. W. (1998). The economics of chipping large weeds. *The Australian Cottongrower*, **19**, no. 2, 42-44.
- Charles, G. W. (1998). Sorting out cotton weed control options. *The Australian Cottongrower*, **19**, no. 4, 13-17.
- Charles, G. W. (1998). Weed management in farming systems. *Proceedings of the 1998 Cropping Systems Forum*. Eds. I. Rochester and H. Dugdale. Co-operative Research Centre for Sustainable Cotton Production, Narrabri.
- Charles, G. (1999). Velvetleaf: A potentially serious weed. *The Australian Cottongrower*, **20**, no. 3, 70-71.
- Charles, G. (1999). Weed alert: Budda pea. *The Australian Cottongrower*, **20**, no. 5, 18-20.
- Charles, G. W. (1999). Weed management systems for cotton production. *Proceedings of the Cotton Co-operative Research Centre Conference*. CSIRO, Narrabri.
- Charles, G. (2000). Growing experience Roundup Ready cotton. *The Australian Cottongrower*, **21**, no. 5, 24-29.
- Charles, G. (2001). David's spurge: A new cotton weed. *The Australian Cottongrower*, **22**, no. 5, 10-12.
- Charles, G. (2001). Herbicides for use in pigeon pea crops. *The Australian Cottongrower*, **22**, no. 6, 50-53.
- Charles, G. (2002). Using precision spraying technology for weed management. *The Australian Cottongrower*, **23**, no. 1, 50-52.
- Charles, G. W., Constable, G. A. and Kennedy, I. R. (1995). Current and future weed control practices in cotton: the potential use of transgenic herbicide resistance. In *Herbicide-Resistant Crops and Pastures in Australian Farming Systems*. Editors. G. D. McLean and G. Evans. Bureau of Resource Sciences, Canberra. pp. 89-100.
- Charles, G., Hickman, M., Llewellyn, D. and Constable, G. (1998). 2,4-D tolerant cotton in the field. *The Australian Cottongrower*, **19**, no. 5, 44-46.
- Charles, G. W., Hickman, M., Llewellyn, D. and Constable, G. (1998). Field evaluation of transgenic 2,4-D tolerant cotton. *Proceedings of the 9th Australian Cotton Conference*, Broadbeach, Queensland. pp. 193-201.
- Charles, G., Mensah, R. and Cook, T. (1999). Lucerne strips for managing cotton pests. *The Australian Cottongrower*, **20**, no. 4, 16-18.
- Hardin, B. (1999). Underground biocontrol allies. *The Australian Cottongrower*, **20**, no. 1, 29-32.
- Hawkey, D. J. (1995). *Effects of irrigation water on weed seed populations in cotton fields in the Macquarie Valley*. Bachelor of Rural Science Honours Thesis, University of New England. Armidale, NSW.
- Hickman, M., Rochester, I., Tennakoon, S., Hare, C., Hulugalle, N., Charles, G., Allen, S., Nehl, D., Scott, F., Cooper, J. and Conteh, A. (1998). Rotation crops: What is the impact on an irrigated farming system? *Proceedings of the 9th Australian Cotton Conference*, Broadbeach, Queensland. pp. 49-59.
- Inglis, G. (1999). Benchmarking the cotton industry. *The Australian Cottongrower*, **20**, no. 2, 10-12.

- Johnson, S. B., Charles, G. W. and Sindel, B. M. (2000). The emerging problem of cotton related weeds (Family Malvaceae). *Proceedings of the 10th Australian Cotton Conference*. Brisbane. pp. 335-336.
- Johnson, S. B., Sindel, B. M. and Jessop, R. S. (1999). The ecology of *Polymeria longifolia* in cotton. *Proceedings of the 12th Australian Weeds Conference*. Editors. A. C. Bishop, M. Boersma and C. D. Barnes. Tasmanian Weed Society, Devonport, Tasmania. pp. 196-197.
- Johnson, S. B., Sindel, B. M. and Jessop, R. S. (2000). Polymeria - trying to stop it taking all. *Proceedings of the 10th Australian Cotton Conference*. Brisbane. pp. 343-349.
- Johnson, S. B., Sindel, B. M. and Jones, C. E. (1998). Polymeria take-all: A perennial problem. *The Australian Cottongrower*, **19**, no. 5, 37-43.
- Johnson, S., Sindel, B. and Jones, C. (1998). Pesky polymeria - the perennial problem. *Proceedings of the 9th Australian Cotton Conference*. Broadbeach, Queensland. pp. 187-192.
- Kerby, T. and Voth, R. (1999). Roundup Ready cotton development in the US. *The Australian Cottongrower*, **20**, no. 4, 36-38.
- Kiernan, R. and Bryant, M. (1999). Precision patch spraying of weeds. *The Australian Cottongrower*, **20**, no. 2, 68.
- McRae, C. (1998). Using fungi to control weeds. *The Australian Cottongrower*, **19**, no. 1, 51-54.
- Nicol, A. (1998). Biopesticides: Cheap and nasty to weeds. *The Australian Cottongrower*, **19**, no. 6, 95-97.
- Osten, V. A., Adkins, S. W. and Walker, S. R. (1996). The biology of the 'take-all' weed, *Haloragis aspera* (raspweed). *Proceedings of the Eleventh Australian Weeds Conference*, Melbourne. Editor. R. C. H. Shepherd. pp. 105-107.
- Randall, R. P. (1998). *Weed science weed list*. <http://www.agric.wa.gov.au/progserv/plants/weeds/weeds/weedlist.htm>.
- Roberts, G. (1998). Cotton weed management: Is rotation crop stubble a friend or foe? *The Australian Cottongrower*, **19**, no. 2, 64-68.
- Roberts, G. (1998). Management of weeds in a cotton system. *Proceedings of the 9th Australian Cotton Conference*, Broadbeach, Queensland. pp. 145-152.
- Roberts, G. (1998). Targeting weeds with precision agriculture - future possibilities. *Proceedings of the 1998 Cropping Systems Forum*. Editors. I. Rochester and H. Dugdale. Co-operative Research Centre for Sustainable Cotton Production, Narrabri.
- Roberts, G. (1999). Herbicide tolerant cotton - preparing for change. *Proceedings of the 12th Australian Weeds Conference*. Editors. A. C. Bishop, M. Boersma and C. D. Barnes. Tasmanian Weed Society, Devonport, Tasmania. pp. 618-622.
- Roberts, G. (2000). Precision agriculture provides on-the-go targeting of weeds in cotton. *The Australian Cottongrower*, **21**, no. 2, 79-81.
- Roberts, G. (2001). Integrated cotton weed management. *The Australian Cottongrower*, **22**, no. 2, 37-39.
- Roberts, G. N. and Gibb, D. (1998). Herbicide control of mintweed (*Salvia reflexa*) in cotton production systems. *Proceedings of the 9th Australian Agronomy Conference*. Wagga Wagga. pp. 597-598.
- Roberts, G. and Hickman M. (2000). Herbicide control of unwanted cotton plants. *The Australian Cottongrower*, **21**, no. 4, 8-10.
- Storrie, A., Hickman, M., Cook, T. and Alston, C. (1998). The effect of low rates of fallow herbicides on cotton. *The Australian Cottongrower*, **19**, no. 1, 9-13.
- Suskiz, J. (2000). Fungal protein slows broadleaf weeds. *The Australian Cottongrower*, **21**, no. 3, 81-83.
- Widderick, M., Sindel, B. and Walker, S. (1999). Distribution, importance and management of *Sonchus oleraceus* (common sowthistle) in the northern cropping region of Australia. *Proceedings of the 12th Australian Weeds Conference*. Editors. A. C. Bishop, M. Boersma and C. D. Barnes. Tasmanian Weed Society, Devonport, Tasmania. pp. 198.
- Wilshire, B. (1999). A sprayer with real time intelligence. *The Australian Cottongrower*, **20**, no. 2, 42-44.

ABBREVIATIONS

ACRI	Australian Cotton Research Institute
ai	active ingredient
ae	acid equivalent
cm	centimetre(s)
CRDC	Cotton Research and Development Corporation
DAT	days after treatment
DF	dry flowables
EC	emulsifiable concentrates
g	grams(s)
g/kg	grams per kilogram
g/L	grams per litre
ha	hectare(s)
hr	hour(s)
IWM	Integrated Weed Management
kg	kilogram(s)
kg/ha	kilogram(s) per hectare
L/ha	litre(s) per hectare
m	metre(s)
m²	square metre
mg	milligram(s)
mL	millilitre(s)
ml/ha	millilitres per hectare
mm	millimetre(s)
NRA	National Registration Authority
p.	page
post-em	post-emergence
pp.	pages
pre-em	pre-emergence
SC	suspension concentrate
SP	soluble powder
sp.	species (singular)
spp.	species (plural)
sub. sp.	sub species
var.	variety
WDG	water-dispersible granule
WP	wettable powder

GLOSSARY

Compiled by: **Leah MacKinnon**
(University of New England)

absorption

the process by which a herbicide passes from one system into another, eg. from the soil solution into a plant root cell or from the leaf surface into the leaf cells.

active ingredient

the biologically active part of the chemical present in a herbicide formulation primarily responsible for its phytotoxicity and which is identified as the active ingredient on the product label.

adsorption

the process by which a herbicide associates with a surface, e.g. a soil colloidal surface.

allelopathic

the adverse effect on the growth of plants or microorganisms caused by the action of chemicals produced by other living or decaying plants.

annual

a plant which completes its life cycle within one year after germination.

application window

the specific crop or weed growth stage to which a herbicide can be applied.

awn

a stiff, bristle-like projection on the seed head of some grasses.

axil

the angle between a leaf or a branch and the stem axis from which it arises.

banded treatment

applied to a linear restricted strip on or along crop rows, rather than continuous over the field.

biennial

a plant which completes its life cycle within two years after germination.

biotypes

a population within a species that has a distinct genetic variation. Biotypes often have physical lifecycle or herbicide susceptibility differences.

broad-leaf weed (see dicots).**common name (chemical)**

a generic name for a chemical compound.

common name (plant)

a name that a weed is commonly known by. A weed may be known by several common names.

community

the populations of species living in a common ecosystem.

competition

the active acquisition of limited resources by an organism which results in a reduced supply, and consequently reduced growth, of the organisms in a common environment.

contact herbicide

a herbicide that causes injury to only the plant tissue to which it is applied, or a herbicide that is not appreciably translocated within plants.

cotyledon

the seed leaf, the primary leaf of the embryo and the first leaf observed above the soil surface.

defoliant

a chemical that causes the leaves to abscise from a plant.

dicot

abbreviated term for dicotyledon; preferred in scientific literature over broad-leaf to describe plants.

dicotyledon

a member of the Dicotyledonae; one of two classes of angiosperms usually characterised by the following: two seed leaves (cotyledons), leaves with net venation, and root systems with tap roots.

directed application

precise application to a specific area or plant organ, such as, to a row or bed, or to the leaves or stems of plants.

directed sprays

see directed application.

dispersible granule	a dry granular formulation that will separate or disperse to form a suspension when added to water.	flushing	light irrigation - particularly used soon after planting pre-irrigated cotton if the surface soil dries too rapidly for emerging cotton seedlings.
dormancy	temporary suppression of growth which may be of advantage in surviving ultimately unfavourable conditions.	foliar activity	the term used to describe post-emergent herbicide effects on the leaves of plants.
ecology	the science concerning the relationship between organisms and environment.	formulation	(i) herbicide preparation supplied by a manufacturer for practical use; (ii) the process, carried out by manufacturers.
economic threshold	a level of expenditure above which it is no longer financially beneficial to continue an activity.	fourth true-leaf	the first four leaves after the cotyledons, prior to the unfurling of the fifth leaf - last possible cotton growth stage for the safe over-the-top application of glyphosate in Roundup Ready cotton.
ecosystem	a biotic system maintained by the balance of organic life with its environment.	germination	the initiation of growth in seeds.
efficacy	the degree of which a herbicide controls a weed.	Group A herbicide	these post-emergence grass herbicides act through inhibiting acetyl-coA carboxylase, leading to membrane disruption in the plant.
emergence	the event in seedling establishment when a shoot becomes visible by pushing through the soil surface.	Group B herbicide	these herbicides inhibit acetolactate synthase.
emulsifiable concentrates (EC)	where the active ingredient is dissolved in an organic solvent to which an emulsifier has been added to make the solution mix readily with water.	Group C herbicide	these herbicides inhibit photosynthesis at photosystem II.
fallow, fallows, fallow land	(i) the period of time between crops, or, (ii) area of land set aside from a cropping regime - can be summer, winter or longer.	Group D herbicide	these herbicides inhibit tubulin formation, effectively inhibiting plant growth.
Family	of taxonomy, a category level below an 'order' but above a 'genus'. One uniting genera assessed as having been derived from a common ancestral stock, or from a single genus, when no other genera are believed related.	Group E herbicide	these herbicides inhibit mitosis.
field capacity	the percentage (expressed on the basis of weight or volume) of water remaining in a soil.	Group F herbicide	these herbicides inhibit carotenoid biosynthesis.
flowable	a two-phase formulation containing solid herbicide suspended in liquid, and that forms a suspension when added to water.	Group G herbicide	these herbicides inhibit protoporphyrinogen oxidase.
		Group H herbicide	these herbicides inhibit protein synthesis.
		Group I herbicide	these herbicides disrupt cell growth.
		Group J herbicide	these herbicides inhibit fat synthesis.

Group K herbicide

these herbicides have multiple modes of action inhibiting growth and root elongation.

Group L herbicide

these herbicides inhibit photosynthesis at photosystem I.

Group M herbicide

these herbicides inhibit EPSP synthase.

Group N herbicide

these herbicides inhibit glutamine synthetase.

half-life

the time taken for a herbicide to be degraded by 50%.

herbicide

a chemical substance or cultured biological organism designed to interfere with specific chemical processes in plants.

herbicide drift

the drift of a herbicide off-target, or from where it was applied.

herbicide registration

before herbicides can be sold, supplied, distributed or used in Australia, they must be registered by the National Registration Authority (NRA). The registration process is governed by Commonwealth legislation and undertaken according to accepted scientific principles and through rigorous independent analysis by several government agencies and the NRA.

in-crop

refers to (i) period of time from crop emergence to crop defoliation, or (ii) within a crop area.

inflorescence

the part of a floral shoot where the flowers are segregated as more or less distinct units.

Integrated Weed Management

a set of management tools or options that, when used in conjunction with each other, result in a sustainable system of whole-farm management of weeds.

inter-row cultivation

the act of cultivation between the plant lines.

label

the directions for using a herbicide approved as a result of the registration process.

lateral (root system)

the secondary roots attached to the tap root generally in a horizontal plane.

lateral movement

movement of a herbicide through soil, generally in a horizontal plane, from the original site of application.

lay-by

the last application and incorporation of herbicides prior to canopy closure.

leaching

the movement of a substance downward or out of the soil as the result of water movement.

lifecycle

the timing of various stages in the life of a plant e.g. emergence, flowering, seed set.

ligule

a projection at the junction of the leaf blade and leaf sheath in grasses.

lobe

a rounded projection generally of a leaf, hence lobed.

microbial activity

the action of soil microbes in degrading herbicides.

mode of action

method or process by which a herbicide can have an impact upon a plant, or a plant process or pathway.

monocot

abbreviated term for monocotyledon.

monocotyledon

a member of Monocotyledonae; one of two classes of angiosperms, usually characterised by the following: one seed leaf (cotyledon), leaves with parallel venation, root systems arising adventitiously and usually diffuse (fibrous).

node	a joint of a stem from which leaves and branches arise.	post-emergence (POST)	applied after the emergence of the specified crop.
non-selective herbicide	a herbicide that is generally toxic to all plants treated.	post-emergent	period of time after the emergence of crop seedlings.
noxious weed	a plant regulated or identified by law, as being undesirable, troublesome, and difficult to control. Precise definition varies according to legal interpretations.	pre-emergence (PRE)	applied to the soil before emergence of the specified crop.
overtop application		pre-emergent	period of time before the emergence of crop seedlings.
over-the-top application	a broadcast or banded application applied over the canopy of crops.	pre-irrigation	refers to irrigating before planting a crop.
pathogen	an organism that causes a disease in another organism.	pre-plant application	applied before planting a crop, either as a foliar application to control existing vegetation or as a soil application.
perennial	living more than two years, usually flowering each year.	preplant incorporated (PPI)	applied and blended into the soil before seeding.
persistent herbicide	a herbicide that, when applied at the recommended rate, will have an impact upon susceptible crops planted in normal rotation after harvesting the treated crop, or that interferes with regrowth of native vegetation in non-crop sites for an extended period of time.	ratoon cotton	cotton regrown from left-over root stock from a previous season.
pH	the negative logarithm of the hydrogen-ion concentration of a soil. The degree of acidity (or alkalinity) of a soil as determined by means of a glass, quinhydrone, or other suitable electrode or indicator, at a specified moisture content or soil-water ratio, and expressed in terms of the pH scale.	re-cropping interval	period of time between crops (particularly related to time after residual herbicide use).
phloem	the living tissue in plants that functions primarily to transport metabolic compounds from the site of synthesis or storage to the site of utilization.	residual herbicides & residuals	herbicides that have a time-span of impact (i.e. injure or kill germinating weed seedlings) on plant growth well after the application of the herbicide. Different herbicides have different time-spans of impact, (different residual effects), can remain in the soil profile for long periods of time, and can be moved around in the soil by irrigation, rainfall events or groundwater movement. (see 'persistent herbicide' Glossary above).
phytotoxic	injurious or lethal to plants.	resistant populations	whereby the repeated use of one herbicide, or other herbicides with the same mode of action, has removed susceptible plants but has allowed the survivors to grow and multiply, producing a resistant population of plants.
plant-back periods	recommended periods of time, after the use of herbicides, that will avoid damage to crops.	rhizome	an underground stem, usually horizontal, producing leafy shoots and roots.
population	in ecology, a group of individuals of any one species.	root pruning	the reduction of the root mass that can occur by either mechanical (cultivation) or chemical means.

seed bank

the number of seeds, accumulated over time, present in the soil.

selective herbicide

a chemical that is more toxic to some plant species than to others.

shielded sprays

herbicides applied to the interrow areas, beneath a protective shield.

soil moisture

the amount of water in the soil (wet weight minus dry weight).

soil organic matter

the organic fraction of the soil: includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

soluble concentrate

a liquid formulation that forms a solution when added to water.

soluble granule

a dry granular formulation that forms a solution when added to water.

soluble powder

a dry formulation that forms a solution when added to water .

species composition

the number of species within a community of plants.

species shift

the selection and increase of naturally tolerant weed species.

spot spraying

targeting of individual weeds with herbicides.

spray drift

movement of airborne spray from the intended areas of application. see 'herbicide drift' Glossary above.

suppression

a degree of reduction of plant growth, but not death.

surfactant

a material that improves the emulsifying, dispersing, spreading, wetting or other properties of a liquid by modifying its surface characteristics.

susceptibility

the sensitivity to, or, degree to which, a plant is injured by a herbicide treatment.

suspension concentrates (SC)

suspension concentrates are also referred to as flowable concentrates. They are formulated by dispersing small particles in a liquid, usually water. Dispersing and suspending agents are added during formulation to keep these particles suspended in solution.

synergism

an interaction of two or more factors such that the effect, when combined, is greater than the predicted effect, based on the response to each factor applied separately.

synergist

for herbicides - a non-herbicidal compound used to increase the phytotoxicity of a herbicide by a physiological mechanism.

systemic

the property of pesticides that penetrate and disperse throughout a plant.

tap root

the primary descending root.

target site

the particular plant process to which a treatment is directed.

target species

the plant species selected for treatment.

thresholds

a defined level beyond which action should occur.

tolerance

ability to continue normal growth or function when exposed to a potentially harmful agent.

toxicity

the quality, or potential, of a substance to cause injury, illness, or other undesirable effects.

trade name

a trademark or other designation by which a commercial product is identified.

transgenic varieties
varieties of cotton that have been genetically modified, in this case, herbicide tolerant varieties of cotton that have been genetically modified to enhance their tolerance of specific herbicides - e.g. Roundup Ready cotton.

translocated herbicide
a herbicide that is moved within the plant. Translocated herbicides may be either phloem mobile or xylem mobile.

translocation
the process whereby a chemical is absorbed into the plant, via the leaves or roots, and is then moved to other parts of the plant.

vegetative reproduction
the reproduction of a plant via stems, leaves and rhizomes.

viability (seed)
the potential of a seed to be able to germinate.

volunteer cotton
are plants that have germinated, emerged and established unintentionally.

watering-up
refers to irrigating after planting - a method used to establish a cotton crop.

weed escapes
weeds that have survived a weed management method.

weed spectrum
the different species of weeds present within a community or given area.

wettable powder (WP)
a finely divided dry formulation that can be readily suspended in water.

wetting agent
(i) a substance that serves to reduce the interfacial tensions and causes spray solutions or suspensions to make better contact with treated surfaces (see surfactant);
(ii) a substance in a wettable powder formulation that causes it to wet readily when added to water.

xylem
the non-living tissue in plants that functions primarily to conduct water and mineral nutrients from roots to the shoot.

References:

- Ahrens, W.H. (editor) (1994). *Herbicide Handbook*, Seventh Edition, Weed Science Society of America, Illinois, USA.
- Chambers, A. & Andreini, M. (editors) (2001). *Field Crop Herbicides Guide 6*. Kondinin Group, Cloverdale, WA.
- Debenham, C. *The Language of Botany*, The Society for Growing Australian Plants.
- Parsons, W.T. & Cuthbertson, E.G. (2001). *Noxious Weeds of Australia*, Second Edition, CSIRO Publishing, Collingwood, Victoria.

MANAGING COWVINE IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
The morning glory family in cotton	H2.1
The cowvine plant	H2.1
Strategies for managing cowvine	H2.3
Herbicides for controlling cowvine	H2.3
Residual herbicides for cowvine control in cotton	H2.4
Post-emergence control of cowvine with residual herbicides in cotton	H2.5
Controlling cowvine with non-residual herbicides	H2.6
Herbicide combinations for controlling cowvine in cotton	H2.8
Alternative residual herbicides for managing cowvine in fallows and rotation crops	H2.10
Managing cowvine in the farming system	H2.11
Summary	H2.12

The morning glory family

Cowvine (*Ipomoea lonchophylla*), also known as peachvine, is a member of the Convolvulaceae family. It is a native Australian plant, closely related to sweet potato (*Ipomoea batatas*). Other morning glories that are problems in cotton include bellvine (*Ipomoea plebeia*) and common morning glory (*Ipomoea purpurea*).

The cowvine plant

Cowvine is a common weed throughout the cotton industry, although it tends to be a far bigger problem in some areas than others.

Cowvine is an annual weed that grows over the warmer months. Seedlings emerge all year round following rain, but are killed by frosts. A flush of cowvine seedlings normally occurs after every rainfall and irrigation event, even in mid-winter.

Cowvine seedlings have unusual, very strongly lobed, "V" shaped cotyledon leaves. The plant is easily identified from the cotyledon shape at this stage. Seedlings grow rapidly after emergence during warm weather, and develop long, twining branches. Large plants may be 3 or 4 m in diameter. Flowering can start early in plant growth, when plants have only 2 or 3 true leaves. Under

hot conditions, flowering can commence within a week of seedling emergence. Flowers continue to be produced throughout the plant's life. Three or four seeds are produced in each seed capsule.

Observations on small and larger plants found 206 seeds on a cowvine plant 0.2 m in diameter, and 791 seeds on a plant 2.8 m in diameter. Larger and older plants could produce many more seeds.



Cowvine is a member of the morning glory family. It is a vine weed, which can be a major problem in cotton, tangling amongst cotton plants, causing problems for inter-row cultivation and harvesting machinery.

Cowvine seeds have a strong dormancy mechanism and can remain viable in the soil for many years (Table 1).

Table 1. Emergence of cowvine seeds grown in a glasshouse at 15 – 35 °C.

Seed age at planting	Emergence %			
	0 - 100 days	100 - 300 days	300 - 600 days	600 - 900 days
Fresh	9	0	0	1
58 days	14	3	1	5
1 year	5	25	13	10
3 years	6	21	16	2

Large numbers of cowvine seeds may be present in the soil seedbank. Soil cores on a heavily infested field found between 1000 and 2500 cowvine seeds/m² in the 0 - 30 cm soil zone. Seeds occur predominantly in the 0 - 30 cm soil zone (80%) in a cultivated field, corresponding to the plow-zone, although some seeds were found down to 1 metre (Table 2).

Table 2. Distribution of cowvine seeds in the soil. Samples were taken from the hill and furrow areas of an irrigated cotton field.

Soil depth zone	Distribution %	
	Hill	Furrow
0 - 10 cm	40	50
10 - 20 cm	24	18
20 - 30 cm	16	11
30 - 40 cm	0	4
40 - 50 cm	4	4
50 - 100 cm	16	13

Few cowvine seeds are able to emerge from more than 5 cm depth in the soil, although a small proportion may emerge from as deep as 15 cm (Table 3).

Table 3. Cumulative emergence of cowvine seedlings from seeds placed at varying depths in the soil. Seeds were mechanically scarified to promote germination.

Soil depth	Emergence %		
	1 month	6 months	1 year
0 cm	25	25	30
1 cm	30	35	60
2 cm	45	50	50
3 cm	35	50	50
4 cm	30	50	55
5 cm	5	5	20
7.5 cm	0	0	0
10 cm	0	0	10
15 cm	0	5	5
20 cm	0	0	0

Cowvine seedlings are slow to emerge from depth and will be vulnerable to cultivation and drying cycles. Seeds may also emerge through soil cracks, or emerge after re-distribution in the soil profile following deep cultivation or re-listing of a field as these seeds may remain viable in the soil for many years. Seed samples taken from the 10-20 cm and 20-30 cm soil zones of a heavily infested field had similar viability to seeds from the 0-10 cm soil zone, showing that these seeds were viable and seedlings could emerge if opportunity arose.

This distribution of seeds in the soil profile means that less than 25% of the cowvine seeds present in an infested field are likely to germinate at any one time. In a field infested with 1500 seeds/m² for example, this would equate to less than 375 seedlings/m² being able to emerge at any time. However, far fewer than 375 seedlings actually emerge due to the strong seed dormancy characteristic already discussed. Population dynamics and seed density from a typical irrigated cotton field are shown in Figure 1.

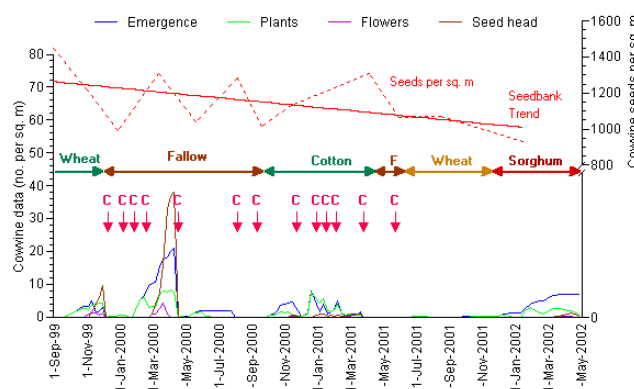


Figure 1. Population dynamics of cowvine in an irrigated cotton field. The cropping sequence over the 3 seasons is indicated. The sorghum crop was grown to allow the use of atrazine herbicide to manage the cowvine problem. Cultivation events are indicated by a "C" with an arrow.

In this field (Figure 1), the density of cowvine seeds in the soil (0 - 30 cm zone), decreased by 36% (or 12% per year), from 1447 to 930 seeds/m² over the three seasons. A total of only 62 cowvine seedlings emerged during this time. The remaining seeds were lost through predation by insects and microbial breakdown. The highest level of emergence was 22 seedlings/m², in the cotton crop in mid-December, 2000. The cowvine plants that established from these seedlings produced a total of 176 new seeds/m² over the three seasons, with most seeds produced during a summer fallow in March and April 2000.



Strategies for managing cowvine

Small cowvine plants are readily controlled by shallow cultivation (to 5 cm) and herbicides in fallows, cereal and sorghum crops, but can be difficult to control in broad-leaf crops such as cotton.

The primary difficulty with managing cowvine, both in-crop and in-fallow, is the tendency for small numbers of cowvine seedlings to emerge continuously, all year round, when soil moisture is adequate, coupled with a short generation period and strong seed dormancy. While a single generation of cowvine seedlings can easily be managed in most situations, most growers find it difficult to manage new germinations every few weeks throughout the summer. In the example of Figure 1, the field was cultivated 5 times over 4 months, between December 1999 and April 2000, yet cowvine plants still established and produced 38 new seeds/m² during this period. Cowvine was a problem in all cropping phases in this field (cotton, wheat and sorghum), as well as in the fallow.

Consequently, while cowvine can be managed with shallow cultivation or non-residual herbicides alone, an integrated approach, using cultivation, non-residual and residual herbicides in combination is necessary for managing this weed. The use of more disruptive, deep cultivation is problematic, as it will bury many of the cowvine seeds already at the soil surface, but may also bring up large numbers of viable seeds that were previously too deeply buried to be of any importance.

The aim of all management programs must be to reduce the size of the cowvine seedbank by ensuring that cowvine plants are always controlled before they produce viable seed.

Herbicides for controlling cowvine

A wide range of herbicides and herbicide combinations were assessed on cowvine growing in a fallow situation in autumn 2000. Many of these herbicides could not be used in cotton, but might be used in fallow or rotation crops. The herbicides were applied to emerged cowvine plants.

The best post-emergence control was observed with Atrazine, Diuron, Gesagard, Simazine, Basta and Oxytril (Table 4), and herbicide combinations that included these herbicides (Table 5). Of these herbicides, only diuron and prometryn can be safely used in cotton. Atrazine and simazine may be used with some rotation crops.

Table 4. Percentage kill of cowvine plants that emerged on the border of a field following rain in March 2000. Control was assessed on May 1, 28 days after spraying.

Treatment	% Weed kill
Diuron 1 L/ha	100
Oxytril 2.0 L/ha	100
Oxytril 1.0 L/ha	97
Diuron 2 L/ha	97
Atrazine 4 L/ha	97
Atrazine 2 L/ha	97
Basta 2.0 L/ha	93
Grazon 1.0 L/ha	90
Oxytril 0.5 L/ha	90
Gesagard 1 L/ha	87
Gesagard 2 L/ha	87
Simazine 2L/ha	80
Basta 1.0 L/ha	80
Basta 0.5 L/ha	63
Grazon 0.25 L/ha	57
Roundup CT 4 L/ha	53
Simazine 1L/ha	50
Starane 1.0 L/ha	43
Grazon 0.5 L/ha	40
Zoliar 1.5 kg/ha	30
MSMA (800 g/L) 2 L/ha	27
Roundup CT 2 L/ha	20
Starane 0.25 L/ha	20
Starane 0.5 L/ha	20
MSMA (800 g/L) 1 L/ha	7
Untreated	7

Note. Cowvine seedlings emerged over the following weeks and a range of ages and sizes were present at spraying, most plants were between 2 leaves and 60 cm in diameter. Most plants were actively growing but some were moisture stressed at the time of spraying on April 3.

Table 5. Percentage kill of cowvine plants in a fallow using herbicide combinations. Details are given in Table 4.

Treatment	% Weed kill
Basta 1 L + Diuron (800 g/L) 2 L/ha	97
Diuron 2 L + MSMA 1 L/ha	97
Gesagard 1 L + Grazon 100 ml/ha	97
Gesagard 2 L + MSMA 1 L/ha	93
Basta 0.5 L + Gesagard 1 L/ha	90
Roundup CT 2 L + Diuron 2 L/ha	90
Basta 1 L + Grazon 100 ml	87
Roundup CT 2 L + Gesagard 2 L/ha	87
Basta 1 L + Zoliar 1 kg/ha	80
Zoliar 1 kg + Grazon 100 ml/ha	23
Zoliar 1 kg + Starane 0.25 L/ha	17
Roundup CT 1 L + Grazon 100 ml/ha	13
Untreated	7

Atrazine was used in the sorghum crop shown in Figure 1. The grower was very satisfied with the resulting control of cowvine, although some cowvine seedlings still emerged, grew and set seed. Cotton growers should always be aware of the plant-back from these products to cotton. Atrazine, in particular, has a very slow breakdown rate in dry soils, and can persist for long periods in dry conditions.



A fallow field heavily infested with cowvine and bladder ketmia. The cowvine plants were very small (below) but some had already flowered and set seed.



Residual herbicides for cowvine control in cotton

While diuron and prometryn are effective in controlling cowvine post-emergence, none of the residual herbicides that can be used in cotton were effective in controlling cowvine pre-emergence. Gesagard, trifluralin and diuron have some residual pre-emergent activity on cowvine but a high proportion of cowvine seedlings still emerged through maximum label rate applications of these herbicides (Table 6).

Table 6. Cumulative emergence of cowvine seedlings following applications of pre-emergent herbicides in pots.

Treatment	Emergence %		
	4 weeks	8 weeks	12 weeks
Gesagard 4.5 L/ha	18%	20%	20%
Trifluralin 2.8 L/ha	22%	27%	28%
Diuron 3.5 L/ha	22%	28%	29%
Dual 2 L/ha	27%	32%	33%
Cotoran 5.6 L/ha	29%	30%	31%
Zoliar 2 kg/ha	31%	34%	36%
Zoliar 4 kg/ha	31%	34%	36%
Cotogard 5 L/ha	31%	34%	38%
Stomp 3 L/ha	41%	43%	45%
Untreated	30%	32%	34%

Not all seedlings that emerge survive, even in the absence of herbicides. Zoliar didn't affect the emergence of cowvine seedlings, but did reduce the survival of the seedlings after emergence, killing around 64% of emerged seedlings soon after emergence (Table 7). However, the efficacy of Zoliar is highly affected by soil moisture level. Consequently, its effectiveness in the field is likely to be quite variable, depending on the soil moisture level following cowvine seedling emergence.

Table 7. The survival of cowvine seedlings following applications of residual herbicides applied pre-emergence in pots. Establishment percentage should be compared with the emergence percentage in Table 6.

Treatment	Establishment %		
	4 weeks	8 weeks	12 weeks
Zoliar 4 kg/ha	10%	11%	14%
Gesagard 4.5 L/ha	16%	17%	18%
Diuron 3.5 L/ha	17%	20%	21%
Zoliar 2 kg/ha	20%	24%	25%
Trifluralin 2.8 L/ha	21%	24%	26%
Dual 2 L/ha	23%	28%	29%
Cotoran 5.6 L/ha	26%	28%	29%
Cotogard 5 L/ha	27%	30%	33%
Stomp 3 L/ha	36%	39%	41%
Untreated	25%	27%	28%

Zoliar also gave the best suppression of cowvine in the field in cotton, but the results were variable and less than ideal (Table 8).

Table 8. Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicides. Emergence of cowvine seedlings was recorded during the cotton season (planting to mid-January, 2002). The results are an average from experiments, at Moree and Dirranbandi.

Treatments	Seedlings/m ²
Untreated	12.2
Dual 2 L/ha	11.8
Gesagard 2.5 L/ha	11.1
Gesagard 5 L/ha	10.3
Diuron 1.5 L/ha	10.3
Cotogard 5 L/ha	9.3
Cotogard 2.5 L/ha	8.8
Cotoran 2.5 L/ha	8.2
Cotoran 5 L/ha	6.6
Diuron 3 L/ha	6.5
Zoliar 1 kg/ha	6.3
Zoliar 4 kg/ha	4.1
Zoliar 2 kg/ha	3.1

Zoliar at 2 kg/ha reduced cowvine seedling density by 74% in experiments in irrigated cotton at Moree and Dirranbandi (Table 8), but this still left 3 seedlings/m², more cowvine plants than can be tolerated in cotton. Diuron and Cotoran gave the best results of the other herbicides. Best results were observed early in the season, with poorer control on all treatments later in the season, as the effective herbicide levels in the fields declined.

Cowvine control improved with all herbicides as the herbicide rates increased, but high herbicide rates are not always safe in cotton. No herbicide damage to the cotton was observed at Moree, but significant damage occurred following rain early in the cotton season at Dirranbandi. The worst damage was with the 2 and 4 kg/ha rates of Zoliar and the 3 kg/ha rate of diuron. The cotton plant stand was reduced by these herbicide applications, especially in the tail-ditch end of the field, where water had backed up.

Results from a range of herbicide combinations at the same experimental sites gave the best cowvine control with a combination of diuron and Zoliar, or prometryn and Zoliar (Table 9). These combinations gave similar levels of cowvine control, but with improved crop safety, compared to the results from the high levels of diuron or Zoliar alone.

Table 9. Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicide combinations. Cowvine emergence was recorded from cotton planting to mid-January 2002, on experiments, situated at Moree and Dirranbandi.

Treatments	Seedlings/m ²
Gesagard 2.5 L/ha + Diuron 1.5 L/ha	8.80
Cotogard 2.5 L/ha + Dual 2 L/ha	7.36
Gesagard 2 L/ha + Diuron 1.5 L/ha + Zoliar 1 kg/ha	6.41
Cotogard 2.5 L/ha + Diuron 1.5 L/ha	6.39
Diuron 1.5 L/ha + Dual 2 L/ha	6.36
Cotoran 2.5 L/ha + Dual 2 L/ha	6.31
Cotoran 2.5 L/ha + Diuron 1.5 L/ha	6.26
Gesagard 2.5 L/ha + Dual 2 L/ha	5.64
Cotogard 2.5 L/ha + Zoliar 1 kg/ha	5.46
Gesagard 2 L/ha + Diuron 1.5 L/ha + Dual 2 L/ha	5.31
Cotogard 2 L/ha + Cotogard 2.5 L/ha	5.19
Cotoran 2.5 L/ha + Zoliar 1 kg/ha	4.87
Diuron 1.5 L/ha + Zoliar 1 kg/ha	3.99
Gesagard 2.5 L/ha + Zoliar 1 kg/ha	3.84

Post-emergence control of cowvine with residual herbicides in cotton

Diuron and prometryn were both effective for controlling emerged cowvine seedlings and small plants in cotton, but gave less than 100% control on some occasions, especially with larger plants (compare Tables 10 and 11, for example). Generally, the addition of a surfactant is necessary to get the best control of emerged cowvine seedlings.

MSMA (Daconate) was commonly tank mixed with residual herbicides for post-emergence control of morning glory seedlings in the US, but is not necessary or desirable for controlling cowvine with diuron or prometryn. MSMA itself has little activity on cowvine (Table 4).

Table 10. Control of cowvine growing in pots using post-emergence herbicides applied to plants at 4 and 11 leaves.

Herbicide	% Weed kill	
	4 leaves	11 leaves
Cotoran (500 g/L) 2.8 L/ha	0	25
Diuron (500 g/L) 1.8 L/ha	95	94
Gesagard (500 g/L) 2.2 L/ha	40	100
Staple 120 g/ha	0	0
Untreated	0	0

Diuron and prometryn must be applied as shielded or directed sprays in cotton, applied to avoid contact with the crop foliage. Most product labels only allow diuron application in crop after the cotton is 30 cm high. Prometryn may be able to be applied after the crop reaches 15 cm. Check the product labels for specific use directions. Always

follow the label directions. Fluometuron did not adequately control cowvine when applied at 2.8 L/ha, but was more effective at the higher rate (5.6 L/ha, Table 11). The level of control was improved when MSMA was tank mixed at 1 or 2 L/ha, but the level of control was still inferior to that achieved with diuron or prometryn.

Table 11. Cowvine control with herbicides applied post-emergence to plants with 2, 4, 6 and 12 leaves, growing in pots.

Herbicide	% Weed kill 6 weeks after spraying			
	2 leaves	4 leaves	6leaves	12 leaves
Cotoran (500 g/L) 2.8 L/ha	25	27	75	50
Cotoran (500 g/L) 5.6 L/ha	75	100	100	62
Diuron (500 g/L) 2 L/ha	75	62	100	50
Diuron (500 g/L) 4 L/ha	75	100	100	75
Gesagard (500 g/L) 2.2 L/ha	100	100	100	100
Gesagard (500 g/L) 4.4 L/ha	100	100	100	100
Staple 30 g/ha	0	0	0	0
Staple 60 g/ha	0	0	0	12
Staple 120 g/ha	0	25	0	0
Roundup CT 1 L/ha	0	50	12	12
Roundup CT 2 L/ha	0	50	12	87
Roundup CT 4 L/ha	100	87	87	100
Untreated	0	4	0	0

Controlling cowvine with non-residual herbicides

With the commercial release of Roundup Ready[®] cotton, many growers have found that Roundup Ready Herbicide[®] can be effective for controlling cowvine seedlings in young Roundup Ready cotton even though this weed is not on the product label. Growers have generally found that Roundup at the maximum label rate is effective on cowvine seedlings at the cotyledon stage and up to 2 or 3 true leaves, but is much less effective on older plants.

Glyphosate can be equally effective for controlling cowvine seedlings growing in conventional cotton, but glyphosate is difficult to apply to small cowvine plants in conventional cotton, without risking damage to the cotton plants from herbicide drift or off-target spray. Glyphosate can not be applied as a shielded or directed spray in conventional cotton before the crop reaches 20 cm in height. (Check specific use directions on the product label). Crop safety is much better with shielded applications in conventional and Roundup Ready cotton later in the season, but cowvine plants may be too large to be controlled by glyphosate by this time.

However, the window for glyphosate application to cowvine seedlings may be larger than has often appeared to be the case. The 2 L/ha application of glyphosate (Table 11) gave no control on seedling cowvine, but 87% control of larger plants (12-leaf stage). Glyphosate applications at 2 L/ha also gave good control of cowvine plants at 10 leaves (Table 12) and 22 leaves (Table 13).

Table 12. Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2 and 10 leaves. At the 10-leaf stage, the centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray.

Herbicide	%Weed kill after 6 weeks		
	2 Leaves full spray	10 Leaves full spray	centre covered
Roundup CT 1 L/ha	87	25	0
Roundup CT 2 L/ha	100	100	62
Roundup CT 3 L/ha	100	100	75
Basta 2 L/ha	100	100	12
Basta 4 L/ha	100	100	37
Bromoxynil 2 L/ha	100	75	0
Bromoxynil 4 L/ha	100	100	0
Untreated	0	0	0

Table 13. Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2, 9 and 22 leaves. The centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray at the 22-leaf stage.

Herbicide	%Weed kill after 8 weeks			
	2 Leaves full spray	9 leaves full spray	22 Leaves full spray	centre covered
Roundup CT 1 L/ha	62	12	25	0
Roundup CT 2 L/ha	50	87	87	12
Basta 1 L/ha	100	100	100	12
Basta 2 L/ha	100	100	100	25
Bromoxynil 1 L/ha	12	12	12	25
Bromoxynil 2 L/ha	0	37	75	12
Untreated	0	0	12	12

The problem of poor control of cowvine with glyphosate sometimes observed in the field probably relates to two factors; the growing conditions of the plants, and incomplete spray coverage. Glyphosate is most effective on actively growing plants and never as effective on weeds that are stressed. The most likely cause of stress to cowvine plants growing in cotton is moisture stress, as small cowvine seedlings compete for moisture with larger, established cotton plants. Cowvine plants of any size will be difficult to control with glyphosate in cotton in hot, dry conditions,

when the plants are not actively growing. Small cowvine plants sprayed soon after an irrigation or rainfall event should be much more easily controlled with glyphosate. Incomplete spray coverage is more difficult to avoid, as some cowvine plants emerge in the cotton row, where they are partially shielded by the cotton plants, and are difficult to spray when using a directed spray or a shielded sprayer. Larger plants may also be difficult to control when some branches are twined in the cotton row, and so avoid the spray.

Although glyphosate does translocate in plants away from the point of spray contact, translocation of glyphosate in cowvine plants appears to be quite limited. The percentage kill of cowvine plants was much lower on plants that were partially sprayed (Table 12 and 13), compared to the kill of plants that were fully sprayed.

Some growers have raised the possibility of using spray additives or different glyphosate formulations to improve the control of cowvine. Data from a glasshouse study showed few differences between glyphosate formulations, although there was an improvement in cowvine control from adding 0.2% of a non-ionic surfactant (Turbo Plus) to Roundup CT (Table 14).

Table 14. Control of cowvine in a pot experiment using Roundup CT with spray additive or a different glyphosate formulation. Plants were at 4 and 6 leaves at spraying.

Herbicide	Additive	% Weed kill 6 weeks after spraying	
		4 leaves	14 leaves
Roundup CT 2.2 L/ha		25	25
Roundup CT 2.2 L/ha	0.2% Turbo Plus	37	50
Roundup CT 2.2 L/ha	1% Turbo Plus	50	12
Roundup CT 2.2 L/ha	0.2% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	1% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	2% Boost	25	0
Roundup CT 2.2 L/ha	5% Boost	25	12
Roundup CT 2.2 L/ha	2% Urea	25	0
Roundup CT 2.2 L/ha	5% Urea	25	0
Roundup Max 2 L/ha		12	0
Roundup Ready 1.4 kg/ha		25	0
Credit & Bonus 1.9 L/ha		12	0
Untreated		0	0

The overall control rate was quite poor in this experiment. The reason for this is not understood, but is typical of the variability of results sometimes observed in the field with glyphosate and some other herbicides on this weed. Nevertheless, the cowvine plants were strongly affected by the glyphosate applications. Most plants that were not killed by the herbicides had only 2 or 3 live leaves

6 weeks after spraying. Unsprayed plants were much larger.

A similar effect was observed with Staple and Envoke, with a reduction in cowvine growth following an over-the-top applications (Table 15). These herbicides did not reliably kill cowvine seedlings but did suppress regrowth for up to 6 weeks after application.

Table 15. Control of cowvine in a pot experiment using non-residual, over-the-top herbicides sprayed at 4, 8 and 16 leaves. The number of alive leaves per plant was observed 4 weeks after spraying

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	16 leaves	4 leaves	8 leaves	16 leaves
Roundup Ready 1.5 kg/ha	100	100	75	0	0	2
Staple 120 g/ha	0	37	12	33	21	51
Envoke 15 g/ha	12	0	12	27	10	15
Untreated	0	0	0	60	81	104

Table 16. Control of cowvine in a pot experiment using Envoke applied over-the-top at 3 and 17 leaves. The number of alive leaves per plant was observed 6 weeks after spraying.

Herbicide	% Weed kill		Leaf number after 4 weeks	
	3 leaves	17 leaves	3 leaves	17 leaves
Envoke 5 g/ha	0	0	41	70
Envoke 10 g/ha	0	80	29	16
Envoke 15 g/ha	0	75	20	5
Envoke 20 g/ha	12	100	14	0
Untreated	0	0	74	57

Envoke was more effective at higher rates and a broadcast application gave good suppression even on larger cowvine plants (Table 16). However, this result on larger plants was not duplicated in the field where it was not possible to get full spray coverage of larger cowvine plants in a cotton crop.

Similarly variable results were observed with diuron, Cotoran and Gesagard (Tables 10 and 11). Growers should be prepared to use an alternative control strategy, such as cultivation, to manage cowvine seedlings in case of an unsatisfactory spray result.

Basta and bromoxynil are two other non-residual herbicides that might become available for over-the-top use with transgenic, herbicide tolerant cotton varieties, should varieties with these tolerances become commercially available. Basta tolerant cotton varieties are currently being developed, but will not be commercially available for several years. Both these herbicides are effective for controlling cowvine; Basta at 1 L/ha and bromoxynil at 4 L/ha. Oxytril® could be used instead of bromoxynil on the bromoxynil tolerant cotton and is effective on cowvine at lower rates (Table 4).

These two herbicides have the advantages that they are safe to use at any growth stage on tolerant cotton varieties and that they are equally effective on seedling and larger cowvine plants. They have the disadvantage that they are both relatively expensive, and they do not translocate well, needing full plant coverage to be fully effective. The control of cowvine plants partially sprayed with Basta and bromoxynil was much lower than the control of fully sprayed plants (Tables 12 and 13).



Glyphosate can be applied through spray shields to the area between the cotton rows in conventional and Roundup Ready cotton varieties. The spray shields prevent the herbicide contacting the foliage of the crop.

Herbicide combinations for controlling cowvine in cotton

A range of pre- and post-emergence herbicides and herbicide combinations for cowvine control were assessed in 5 field experiments over 3 seasons. No single herbicide or herbicide combination was able to give season long cowvine control, but excellent results were achieved using a range of management tools in combination.

The exact mix of weed management tools needed in any given field depends on a range of factors, including season conditions, weed pressure (density and sequential germinations) and the range of other weeds present in the field.

WEEDpak

section **H2**

Of the residual planting herbicides, Zoliar and diuron gave the best early-season control of cowvine (28 Oct, Table 17). However, the control achieved by these herbicides declined rapidly as the season progressed, and large numbers of cowvine seedlings were generally present by mid- to late-November.

Control of these seedlings was most readily achieved using an over-the-top Roundup Ready Herbicide application to Roundup Ready cotton at the 4-leaf stage. The decline in activity of the pre-planting residual herbicides was such that they had little effect on the emergence of cowvine seedlings following the Roundup Ready Herbicide application. Consequently, these residual herbicides were of little value where a 4-leaf Roundup application was made, with similar densities of cowvine seedlings following the Roundup application regardless of the presence or absence of pre-planting residual herbicides (16 Nov, Table 17). The pre-planting residual herbicides would be of much more value in a non-Roundup Ready field.

Table 17. Early-season control of cowvine in a field experiment. The Roundup Ready crop was planted on 1 October and Roundup Ready Herbicide® was applied over-the-top of the crop on 28 October 2004.

Pre-planting herbicide		Seedlings/m ²	
23 Sep 04	4-leaf spray on 28 Oct 04	28 Oct	16 Nov
Diuron 2 kg/ha +			
Zoliar 1 kg/ha	Roundup 1.5 kg/ha	0.4	0.03
Diuron 2 kg/ha	Roundup 1.5 kg/ha	0.4	0.05
Cotogard 2 kg/ha	Roundup 1.5 kg/ha	0.5	0.06
Zoliar 2 kg/ha	Roundup 1.5 kg/ha	0.6	0.09
Untreated	Roundup 1.5 kg/ha	1.1	0.07



Cowvine can be very difficult to manage in conventional or Roundup Ready UNR (ultra narrow row) cotton which does not allow inter-row cultivation, or shielded or directed spray applications.

It is important that the emergence of cowvine seedlings in the crop is monitored following the 4-leaf Roundup application. Few seedlings are likely to emerge until rainfall or irrigation occurs, and most emerging seedlings can be controlled by inter-row cultivation or a Roundup applications during this window. However, seedlings that do emerge and remain untreated will be difficult to control once they are at the 6 - 8 leaf stage or larger. Large germinations of cowvine can occur following rainfall events and the management of the crop should be driven by the observed cowvine pressure, with treatments scheduled as required.

Applications of glyphosate, prometryn and diuron can all be effective in controlling cowvine seedlings later in crop life, provided the seedlings are actively growing and good spray coverage is achieved. Staple and Envoke can also give useful suppression of cowvine seedlings. In the experiment in Table 17, rainfall occurred following the Roundup Ready application and cowvine numbers steadily increased. A mid-season herbicide application was applied in mid-December with combinations of diuron, Roundup and Envoke. All herbicides and combinations reduced the cowvine density by at least 75%, with the combinations including diuron giving better than 95% control (Table 18).

Table 18. Mid-season control of cowvine in a field experiment. The field was assessed on 16 December, herbicide was applied as a directed spray on 17 December, and the cowvine density was again assessed on 12 January 2005. The % reduction in the cowvine density is shown

Mid-season spray 17 Dec	Seedlings/m ²		% Reduction
	16 Dec	12 Jan	
Diuron 2 kg/ha	0.5	0.02	95
Roundup Ready 1.5 kg/ha +			
Diuron 2 kg/ha + Envoke 5 g/ha	0.8	0.03	96
Roundup Ready 1.5 kg/ha +			
Diuron 2 kg/ha	0.8	0.03	97
Roundup Ready 1.5 kg/ha	0.7	0.15	80
Roundup Ready 1.5 kg/ha +			
Envoke 5 g/ha	0.8	0.18	77

The value of these herbicide combinations is not clear. Combinations are often used to improve the spectrum of weeds controlled with a single application, or to improve efficacy on difficult to control weeds. With Roundup Ready cotton, the temptation is to add something to the Roundup to improve its control on those weeds on which it is less effective. Often, however, the addition of another herbicide to glyphosate will reduce the efficacy of the glyphosate and may damage the crop. A reduction in glyphosate efficacy almost

always occurs when herbicides such as diuron and prometryn are added to glyphosate, regardless of the formulations used. The addition of ammonium sulphate may improve glyphosate efficacy in these combinations, but is of limited value.

The herbicide combinations in this experiment improved the cowvine control compared to using Roundup Ready Herbicide alone, but didn't improve control over diuron alone. Results from a pot experiment were inconsistent, but suggested that the combination of residual and Roundup Ready Herbicide could give improved control of cowvine in some situations (Table 19). Nevertheless, this combination may give reduced control of other weeds that might be present. Factors that could improve the result with a combination of Roundup Ready Herbicide and a residual are:

- Addition of a suitable spray adjuvant
- High water rates (at least 100 L/ha), and
- Ensuring that the combination is applied to the target as quickly as possible after mixing

Table 19. Control of cowvine in a pot experiment using post-emergence combinations. Plants were sprayed at 2 and 12 leaves and assessed 6 weeks after spraying.

Herbicide	% Weed kill after 6 weeks	
	2 leaves	12 leaves
Roundup Ready 1.5 kg/ha	100	69
Diuron 0.5 kg/ha	87	62
Diuron 1 kg/ha	50	37
Diuron 2 kg/ha	100	62
Diuron 0.5 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Diuron 1 kg/ha + Roundup Ready 1.5 kg/ha	87	87
Diuron 2 kg/ha + Roundup Ready 1.5 kg/ha	100	100
Gesagard 0.5 kg/ha	87	75
Gesagard 1 kg/ha	87	87
Gesagard 2 kg/ha	100	75
Gesagard 0.5 kg/ha + Roundup Ready 1.5 kg/ha	75	75
Gesagard 1 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Gesagard 2 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Untreated	0	0

In most situations it will also be necessary to apply a layby residual herbicide prior to canopy closure to control cowvine seedlings that emerge late in the crop. A combination of prometryn and Roundup Ready Herbicide was applied to all treatments in this experiment in late January and

resulted in 100% control of all cowvine plants. Plants which emerged after canopy closure had no impact on the crop and were controlled immediately after picking.

These results showed that a cowvine management program that combined good farming practices, Roundup Ready and residual herbicides, and inter-row cultivation could effectively control cowvine in a heavily infested commercial field where management inputs were able to respond to weed pressure.



Inter-row cultivation is a valuable component of an integrated weed management system for controlling cowvine and other weeds.

Alternative residual herbicides for managing cowvine in fallows and rotation crops

Tordon 242 was the only alternative residual herbicide tested which resulted in a long-term reduction in the germination of bellvine seeds (Table 20). Tordon 242 can be applied to cereal and linseed crops, but picloram, one of the constituents of Tordon 242, is toxic to cotton and has a long residual life in the soil (can be up to 300 days half-life). Consequently, there is a minimum 12 month plant-back period to cotton for Tordon 242. None of the other alternative residual herbicides had any effect on cowvine germination

Table 20. Cowvine seedling emergence following applications of residual herbicides.

Herbicide	% Cumulative cowvine germination			
	1 week	2 weeks	4 weeks	1 year
Tordon 242 1 L/ha	3	8	13	17
Spinnaker 400 ml/ha	32	57	62	66
Harmony M 45 g/ha	35	56	59	67
Sencor (750 g/kg) 470 g/ha	47	59	62	67
Lontrel (300 g/L) 500 ml/ha	51	57	60	67
Ally 7 g/ha	47	61	62	69
Simazine (900 g/kg) 2.2 kg/ha	50	63	65	72
Atrazine (900 g/kg) 3.3 kg/ha	44	66	69	77
Untreated	37	61	64	68

Managing cowvine in the farming system

While cowvine can be controlled by cultivation and a range of herbicides, it is not easy to control in a farming system due to:

- strong seed dormancy,
- long seed life in the seedbank,
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Population dynamics of a typical field were presented in Figure 1. Results from a seedbank experiment are shown in Figures 2 and 3. These treatments were designed to simulate the effect of a standard herbicide management system (Figure 2) and a heavier management system (Figure 3) in back-to-back cotton.

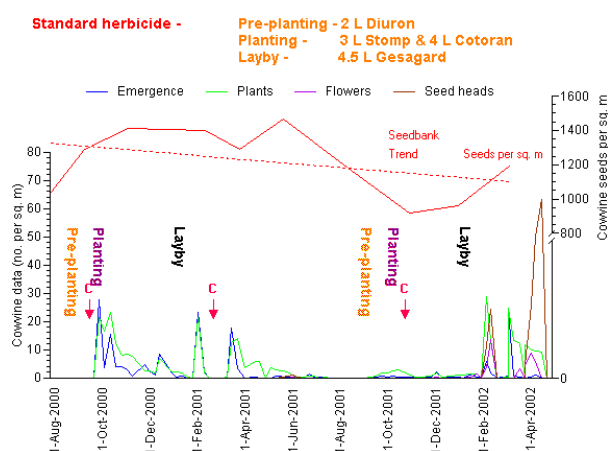


Figure 2. Population dynamics of cowvine under a standard herbicide regime. Cultivation events are indicated by a "C" with an arrow.

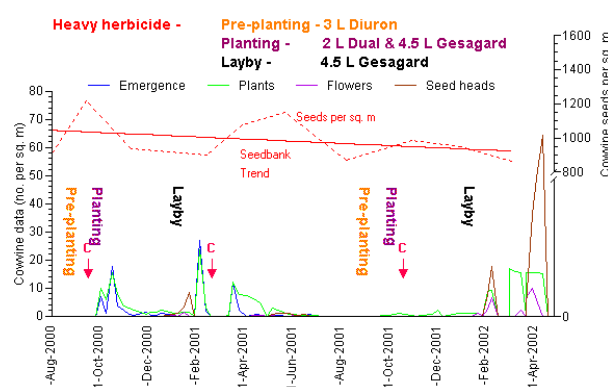


Figure 3. Population dynamics of cowvine under a heavier herbicide regime. Cultivation events are indicated by a "C" with an arrow.

As with the earlier data of Figure 1, there has been a downward trend in the seedbank population of cowvine seeds in both treatments in the two seasons of the experiment. Nevertheless, some cowvine seedlings emerged in both systems, grew, and on several occasions set seed. Totals of 310 and 321 cowvine seeds/m² were produced on the standard and heavy management systems over the two seasons. These seeds were mostly produced towards the end of the cotton season, when the effective levels of the residual herbicide had declined, with most seeds produced in the dry conditions of autumn 2002.

The management of cowvine in these systems should improve over time, provided the number of cowvine seeds in the seedbank continues to decline. Failure to control the cowvine on just one occasion could result in the seedbank increasing back to previous levels. The seedbank is only declining at around 10% per year. It will be many years before cowvine ceases to be a problem in this field.

Cowvine seeds can float and move in irrigation water. However, the number of seeds that do move in irrigation water is quite low, representing

only a small fraction of the number of seeds present in an infested field. Consequently, seed movement in irrigation water is not an issue, except as a source of infestation for previously clean fields.



A heavy infestation of young cowvine plants on an irrigation channel. These plants will produce large numbers of seeds that can move in the irrigation water and spread the weed to previously clean fields.

Summary

Cowvine is an annual weed that is a problem both in crops and in fallows. Cowvine can be controlled by cultivation and a range of herbicides. It is not easy to control in a farming system due to a number of characteristics, including:

- strong seed dormancy
- long seed life in the seedbank
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Typically, around 1000 to 2000 cowvine seeds per m² are present in the seedbank of a heavily infested field. These seeds occur predominantly in the 0 to 30 cm soil zone. Seeds can emerge all year round and plants may flower within a week of germination.

None of the pre-emergence residual herbicides were effective in controlling cowvine. Best results were achieved with combinations of diuron and Zoliar, and prometryn and Zoliar. These combinations reduced the in-field infestation of cowvine by around 75%. Post-emergence, diuron and prometryn consistently give the best control of cowvine of the herbicides normally used in cotton. Glyphosate can be effective in controlling cowvine seedlings in conventional and Roundup Ready cotton. Glyphosate is most effective on actively growing cowvine seedlings. Good control of older, actively growing plants with glyphosate is possible.

An effective cowvine management system will use all the available control options (cultivation, chipping and herbicides) in combination. Management of this weed will be an on-going process over many seasons.

MANAGING NUTGRASS IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Contents	Page
The four steps for weed management	H3.1
The nutgrass (<i>Cyperus</i>) family	H3.2
Nutgrass (<i>C. rotundus</i>)	H3.2
Downs nutgrass (<i>C. bifax</i>)	H3.2
Yelka (<i>C. victoriensis</i>)	H3.3
Tall sedge (<i>C. alterniflorus</i>)	H3.3
Trim sedge (<i>C. concinnus</i>)	H3.3
Dirty Dora (<i>C. difformis</i>)	H3.3
Umbrella sedge (<i>C. eragrostis</i>)	H3.3
Rice flatsedge (<i>C. iria</i>)	H3.3
Understanding nutgrass (<i>C. rotundus</i>)	H3.12
Biological control of nutgrass	H3.12
Treatment options	H3.13
IWM tools for nutgrass control	H3.13
Cultivation	H3.13
Residual herbicides	H3.14
Norflurazon (Zoliar®, Group F)	H3.14
Imazapyr (eg. Arsenal, Group B)	H3.15
Contact herbicides	H3.16
MSMA (eg. Daconate, Group K)	H3.16
Halosulfuron-methyl (Semptra, Group B)	H3.17
Glyphosate (various trade names, Group M)	H3.17
Herbicide efficacy on the major weeds	H3.18
Factors that influence Zoliar efficacy	H3.19

Contents	Page
Factors that influence glyphosate efficacy	H3.20
Nutgrass age	H3.21
Stressed plants	H3.21
Low temperatures	H3.22
Low soil moisture	H3.22
Cultivation	H3.22
Glyphosate rate	H3.22
Water quality	H3.22
Water rate	H3.23
Additives	H3.23
Tank mixing	H3.24
Re-spraying interval	H3.24
Herbicide combinations	H3.25
Spraying equipment	H3.25
Crop competition	H3.25
Developing an IWM program for nutgrass	H3.26
A management program for heavy infestations	H3.29
A management program for light infestations	H3.29
Summary	H3.30
Case studies of grower experiences with nutgrass	
Nutgrass on Kilmarnock	H3.31
Nutgrass control on Norwood	H3.32
Nutgrass control on Auscott Narrabri	H3.33



A heavy “nutgrass” infestation in cotton. The field was infested with four different species. The cotton was infested with downs nutgrass and yelka. Dirty Dora and umbrella sedge infested the head ditch.

The four steps for weed management

A successful weed management program is built in four steps. These are:

- **positive identification** of the weed
- **assessment** of the extent of the problem
- targeted **treatment** of the weed, integrating all available management tools, and
- **evaluation** of the farming system, making modifications as required to ensure success.

The nutgrass (*Cyperus*) family

Positive identification is the first step in managing any problem weed, as different management techniques may be needed to control different weeds, even though the weeds may be closely related.

Nutgrass belongs to the genus *Cyperus*, of which 38 species are reported to occur in the cotton growing areas of Australia. Of these, 19 species are native to Australia and the remaining 19 species have been introduced.¹ Three of these species are commonly found in or around cotton fields (Table 1), while another five species occasionally occur around cotton fields (Table 2).

Table 1. Nutgrass species commonly found in and around cotton fields.

Botanical name	Common name
<i>C. bifax</i> C. B. Clarke	downs nutgrass
<i>C. rotundus</i> L.	nutgrass
<i>C. victoriensis</i> C. B. Clarke	yelka

Table 2. Nutgrass species occasionally found around cotton fields.

Latin name	Common name
<i>C. alterniflorus</i> R. Br.	Tall sedge
<i>C. concinnus</i> R. Br.	Trim sedge
<i>C. difformis</i> L.	Dirty Dora
<i>C. eragrostis</i> Lam.	Umbrella sedge
<i>C. iria</i> L.	Rice flatsedge

This article primarily focuses on the control and management of nutgrass (*C. rotundus*) as by far the most difficult to control of these weeds. Management information for the other species is discussed throughout the article.

Nutgrass (*C. rotundus*) (see p. H3.4)

Nutgrass, called purple nutsedge in the USA, is an introduced, strongly competitive perennial weed that grows from underground tubers. It is an international weed and is a major problem in a range of crops, and especially irrigated farming systems.

Nutgrass favours lighter soil and wetter conditions, but grows well on both dryland and irrigated soils throughout the cotton industry.

It may be relatively short, at 10 - 15 cm, but can grow up to 60 cm high in irrigated cotton. Nutgrass has dark green leaves and stems that are triangular throughout their length. It has a dark purple flower head that is up to 10 cm in diameter and lightens in colour with age. Nutgrass grows in

very dense patches, with little space between shoots. Densities of up to 14000 tubers and 2200 shoots/m² have been recorded in irrigated Australian cotton. It can reduce cotton yields by up to 90% at these densities.

Nutgrass can be positively identified from the purple colouration on the outer leaves at the base of the plant stem, around the basal bulb. This colouration is seen by stripping back one or two leaves from the base of the nutgrass shoot. Purple colouration persists through several layers of outer leaves, while the inner leaves are light green and then white.

Nutgrass produces large numbers of seeds, but the seed has very low viability (only 1 or 2%) and the seedlings are weak and easily controlled by herbicides such as trifluralin and pendimethalin. Nutgrass plants rarely establish from seed; reproduction is almost always by vegetative propagation through new tubers.

A single nutgrass plant can produce up to 2000 new tubers in a single season. The first tubers are initiated about four weeks after the nutgrass shoots first emerge. These new tubers then produce new shoots that produce new tubers etc. Most tubers are in the top 15 cm of the soil, although tubers can emerge from 30 - 40 cm depth.

Nutgrass is frost susceptible and becomes dormant over winter when conditions are sufficiently cool. Plants re-establish in spring from dormant tubers. Nutgrass tubers may remain dormant in the soil for several years, but require moisture to survive. Tubers are easily killed by desiccation in a dry soil.

Downs nutgrass (*C. bifax*) (see p. H3.5)

Downs nutgrass is a native Australian species and is abundant in much of the flood susceptible, watercourse country.

It is similar to nutgrass, but is generally taller at 60 - 80 cm, its leaves and stems are a lighter green in colour, and its seed head is larger (up to 20 cm across) and lighter in colour, starting off brown or orange and fading with age. Its stems are triangular over their full length, but unlike nutgrass, the outer leaves at the base of the stem are light green, and the inner leaves white.

Downs nutgrass produces a large quantity of viable seeds. Typically, it also produces 5 to 20 new tubers per plant each season, and establishes from both seed and tubers. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation. New downs nutgrass infestations can occur from seeds carried in floodwater and fodder.

¹ Lazarides M. Cowley K. and Hohnen P. (1997). CSIRO handbook of Australian weeds, CSIRO Publishing, Collingwood, Vic.

Downs nutgrass grows at much lower density than nutgrass and is much less competitive, although downs nutgrass may be more obvious in cotton due to its greater height.

Yelka (*C. victoriensis*) (see p. H3.6)

Yelka is native Australian species that occurs in the watercourse country and is common on roadsides.

It has erect, dark green stems 100 - 120 cm tall with few leaves. The stems are circular at the base, but become more triangular towards the top. Yelka may have a small, purple flower head, with a few short leaves below the flower, but often the flower head is absent. It grows at low densities, produces few seeds and tubers, and is not very competitive. Most tubers are found in the top 10 cm of the soil and are easily killed by desiccation in a dry soil.

Tall sedge (*C. alterniflorus*) (see p. H3.7)

Tall sedge is a perennial native Australian species that occurs sporadically in wet areas such as river and creek banks, lagoons and irrigation ditches.

Mature plants are around 1 m tall and can form large, dense tussocks. The stems are almost circular at the base but become triangular throughout most of their length.

Tall sedge produces rhizomes and masses of seed, but does not spread rapidly. It can be a nuisance in irrigation channels and water storages.

Trim sedge (*C. concinnus*) (see p. H3.8)

Trim sedge is a native Australian species that occurs sporadically on wet areas and table drains.

It grows to around 50 - 60 cm high and produces both seed and rhizomes. Its stems are triangular throughout their length.

Dirty Dora (*C. difformis*) (see p. H3.9)

Dirty Dora is another native Australian species that invades wet areas. It is a major problem weed in rice and cane production in Australia.

Dirty Dora grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. It tends to be relatively short, up to 50 cm, and is a paler, yellowy colour. The stems of dirty

Dora are strongly triangular throughout their length.

Small numbers of small plants may occur throughout cotton fields without being noticeable. Dirty Dora plants have germinated from soil samples taken from fields where the plant has never been observed to occur.

Umbrella sedge (*C. eragrostis*) (see p. H3.10)

Umbrella sedge is an introduced species that invades wet areas and can be a problem in water storages and irrigation channels.

Umbrella sedge grows from seed and is readily spread by seed. Even small plants can produce large quantities of viable seed. It has no underground tubers. Plants are generally around 30 - 50 cm tall, although they can grow to 1 m. The stems are almost circular at the base but become triangular throughout most of their length.

Once established, umbrella sedge plants can grow to form a large tussock.

Rice flatsedge (*C. iria*) (see p. H3.11)

Rice flatsedge is a native annual sedge that occurs in wet areas such as table drains and irrigation channels. It grows to 60 to 80 cm in height and produces large quantities of seed. Its stems are strongly triangular throughout their length.



Nutgrass is a strongly competitive perennial weed that grows from tubers.



Downs nutgrass is a native perennial weed commonly found in the watercourse country. It is not very competitive with cotton, but can be very obvious due to its height and colourful flower heads.



Yelka is a native weed commonly found on roadsides and waste areas. It is tall, but has few leaves and grows at relatively low densities.



Tall sedge is a native weed occasionally found on river and creek banks, irrigation channels and water storages. It can form large, dense tussocks.



Trim sedge occurs sporadically on wet areas and table drains.



Dirty Dora is a native species that invades wet areas. It produces masses of seed and can spread very quickly.



Umbrella sedge is an introduced weed that invades wet areas and spreads rapidly from seed.



Rice flatsedge is a native species that invades wet areas.

Understanding nutgrass (*C. rotundus*)

Nutgrass produces and survives from vegetative tubers in the soil. These tubers are up to 10 mm in diameter and up to 20 mm in length. Tubers are formed at the end of underground rhizomes that develop from each vegetative plant. A new plant develops from each tuber. Tubers appear to be formed in chains, but each tuber gives rise to a vegetative plant, which gives rise to new tubers, and so on.

These tubers can become dormant in winter or during dry conditions and can survive for years in the soil, extracting moisture through their roots. However, they are vegetative plant structures and cannot survive without water. Tubers are rapidly killed if they are exposed to very dry soil or are exposed at the soil surface after their roots are cut. Tubers without roots in moist soil die within a few hours when exposed at the soil surface in the middle of summer.

Tubers can be found throughout the soil profile, but are most common in the 0-10 cm soil layer. The results from 120 soil cores are shown in Table 3. Cores were from heavily infested fields in the Moree and Wee Waa areas. No tubers were detected below 40 cm, although a small number of tubers have been found at up to 1m depth. These tubers probably fell down cracks in the soil and are of no importance, except when they become exposed by deep cultivation, erosion, earth works, or after levelling.

Table 3. Distribution of nutgrass tubers down the soil profile (0 to 100 cm). Percentage found in each soil layer.

	Soil depth (cm)			
	0 - 10	10 - 20	20 - 30	30 - 40
Field 1	66	25	7	1
Field 2	50	38	10	2
Field 3	42	42	14	3
Average	53	35	11	2

Emergence from tubers placed at depth in a sandy soil and a black soil are shown in Table 4. Nutgrass shoots emerged readily from tubers down to 20 cm in depth, with some emergence from 40 cm in the sandy soil. Emergence was slower from the lower depths and was much slower in the black soil. The results from the sandy soil show that shoots could emerge from at least 40 cm in a black soil, where shoots emerge through cracks in the soil. Poor emergence was observed from tubers placed on the soil surface, which were probably killed by desiccation.

Table 4. Percentage emergence and days to emergence from tubers placed at depth in sandy and black soils in pots.

Depth (cm)	Sandy soil		Black soil	
	Emergence	Days	Emergence	Days
0	43	13	0	
2.5	100	9	100	7
5	100	9	75	18
7.5	100	12		
10	100	12	100	41
12.5	100	11		
15	100	14	100	54
20	100	18	75	51
25			0	
30	0		0	
40	25	38	0	
50			0	

Post-emergence observations indicated that the depth of the tuber did not affect subsequent plant growth.

Biological control of nutgrass

A range of organisms attack nutgrass, including rust, head smut, scale insects and a caterpillar that bores down through the stem (*Bactra trunculenta*). Feral pigs and other animals will also dig for and eat nutgrass tubers. These organisms normally have little impact on nutgrass infestations, attacking only a small proportion of plants, but can be found in large numbers in heavy nutgrass infestations.

The possibility of biological control of nutgrass has been examined in a number of countries, but has not been effective in significantly reducing weed numbers.



Leaf rust on nutgrass (top left), and downy mildew (bottom left) and stem rust on yelka plants (right).



Nutgrass affected by smut. This is of little importance, however, as nutgrass spreads primarily by tubers not from seeds.



Nutgrass tubers and shoots parasitised by a scale insect (white spheres).

Treatment options

Nutgrass can only be managed using a long-term, integrated weed management (IWM) approach. There are a number of tools that help control nutgrass, and practices that enhance control. These tools need to be used in combination. There are also a number of practices that should be avoided whenever possible.

One of the key components of an effective IWM strategy for nutgrass is to develop a 'whole-farm' approach. It is essential that nutgrass infestations are managed not just in-field, but also on roadways, channels, storages, non-cotton fields and waste areas. Strict field hygiene protocols are needed, especially where large areas of nutgrass are present in non-cotton areas and it is not practical to control the nutgrass on these areas. Nutgrass rarely establishes from seed. Most infestations are caused by tubers being spread from field to field and farm to farm by machinery. It is common to see nutgrass plants initially establish at the end of a field, where they have fallen from cultivators that were previously operating in

infested fields. Subsequent cultivation passes spread the infestations throughout the fields.

More information on IWM is covered in the **Integrated Weed Management (IWM) Guidelines for Australian Cotton Production** in **WEEDpak**.

IWM tools for nutgrass control

Nutgrass can be controlled using:

- cultivation,
- residual herbicides,
- contact herbicides, and
- crop competition.

Cultivation

Mechanical cultivation can be very effective in controlling nutgrass, but it is also the most common means of spreading nutgrass. All too often nutgrass tubers and plants are lifted by a cultivator only to be transplanted further down the field.

Cultivation is effective in controlling nutgrass when it severs all the roots from the tubers, provided that the soil is sufficiently dry to kill the tubers. If the soil is not dry, nutgrass plants will rapidly re-establish after cultivation, and may be spread by the cultivator to new parts of the field or to new fields.

Inter-row cultivation is usually ineffective in controlling nutgrass in cotton, as cultivation generally occurs at relatively high soil moisture content to avoid excessively damaging the cotton, and is not deep enough to fully sever the roots of nutgrass plants and tubers.



Inter-row cultivation can be useful for suppressing very heavy nutgrass infestations, but has the major limitation that it can't control nutgrass in the cotton plant line.

Inter-row cultivation in lightly infested fields will often spread nutgrass and exacerbate the problem. Cultivation of lightly infested fields should

be avoided where possible, or the cultivator should be lifted over nutgrass patches or cleaned down after passing through nutgrass patches. A small amount of time spent in cleaning down cultivation machinery can save large costs in time and money required to control the weed in the future.

Multiple inter-row cultivation passes can be used to suppress nutgrass in heavily infested fields, where the spread of tubers is of no importance. Multiple cultivation passes will help the cotton to establish and produce a crop. There will, however, be no lasting reduction in the nutgrass population, which will need to be controlled by another means at a later date.



A trailing ripper set up for heavy cultivation of nutgrass after picking. Note the steel cable across the rippers (top photo) designed to cut the nutgrass roots during ripping.

Heavy cultivation (cultivation to at least 30 cm) is most effective in controlling nutgrass when the soil is completely dry following a cotton or rotation crop. A crop such as lucerne is ideal for completely drying out the soil in the nutgrass root zone. Cultivation should be timed to occur in mid-summer when no rain is forecast and the lucerne crop has dried the soil as much as possible. Heavy cultivation in these conditions can almost completely eliminate a nutgrass infestation from a field. The main limitation to control is the cost of the operation and the practical depth of cultivation.

Cultivation that disturbs the hills prior to planting can also be useful, as it appears to delay nutgrass emergence.

Residual herbicides

Norflurazon (Zoliar[®], Group F)²

Zoliar is the only residual herbicide currently registered for controlling nutgrass (*Cyperus* sp.) in cotton. It is highly persistent, with a half-life of up to 180 days³. Zoliar requires thorough soil incorporation and needs to be used over at least 3 consecutive seasons.



Nutgrass affected by Zoliar, as indicated by the white leaves. Most plants have been severely affected by Zoliar, and some plants in the background have been killed by the herbicide.

Zoliar is registered for application at 2.8 to 4.2 kg/ha, depending on soil type and whether Zoliar was applied in the previous season. Zoliar should be applied at the higher rate in the first season (depending on soil type), but the rate can be reduced in following years. Ideally, it is applied to nutgrass patches in autumn prior to a cotton crop planted in spring. Lower rates should be used if application occurs closer to planting.

Zoliar is readily adsorbed to clay and organic matter in the soil and is relatively immobile. Its efficacy is affected by soil pH and clay content. High rates are required on heavy, alkaline clay soils, but much lighter rates should be used on sandy and acid soils.

² Herbicides are grouped according to mode of action and the risk of weeds developing resistance to the herbicide. Always try to avoid using repeated applications of herbicides belonging to the same herbicide group.

More information on herbicide groups is covered in **Managing Herbicide Resistance in Cotton in WEEDpak**.

³ Technical information for all products was compiled from label information and from information from the Herbicide Handbook (1994) Seventh Edition. Ed. William H. Ahrens, Weed Science Society of America, Champaign, Illinois, USA.

WEEDpak

section **H3**

Zoliar's activity is triggered by a rainfall or irrigation event. It is readily absorbed through plant roots when the soil is wet (near or above field capacity), but is not absorbed from a dry soil.

Zoliar acts on the plant's photosynthetic pathways and destroys chlorophyll and lipids in the cell membranes, and cell proteins. This has the effect of turning affected leaves white. The affected leaves and plants die if this effect lasts sufficiently long.

It is common under Australian conditions for Zoliar to become less active again within a few days of the triggering rainfall or irrigation event. When this happens, the plant recovers from the herbicidal effect and resumes growing. Sections of white along the length of a leaf can indicate Zoliar activity has occurred in the past. Some suppression of nutgrass does continue at lower soil moisture levels.



This grass plant has been affected by Zoliar, but will probably recover as some leaves are still photosynthesising.

Zoliar has the primary advantage that it needs to be applied only once for the season and is most effective during wetter conditions, when the nutgrass would otherwise be most actively growing, and other control measures are difficult or impossible to implement. Zoliar also has the advantage of being equally effective across both hills and furrows.

In addition to controlling nutgrass, Zoliar controls a broad range of grass and broadleaf weeds. Zoliar is relatively expensive, but the cost can be partly offset by substituting Zoliar for some of the other residual herbicides that would normally be used. For example, the grass herbicides such as trifluralin and pendimethalin should not be required in a field treated with Zoliar.



The wheat in this patch was killed by Zoliar that was applied in an earlier season.

Unfortunately, Zoliar is also active against a range of other crop plants. The plant-back period to cereal crops is 30 months after a single herbicide application; a longer plant-back period is required following multiple applications. Zoliar is best suited to heavily infested fields because of its cost and the limitations with rotation crops.

Imazapyr (eg. Arsenal[®], Group B)

Arsenal is registered for controlling nutgrass (*Cyperus* spp.) in non-crop situations. It inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition rapidly leads to plant death. Arsenal is a residual soil sterilant, effective in controlling most plant species. It is both root and shoot absorbed, and can act as a contact herbicide as well as a residual herbicide.



Arsenal will kill cotton and rotation crops for years after application. It should never be applied in-crop or in an area where soil or water movement could carry the herbicide into a sensitive area.

Arsenal is highly persistent, with a half-life of up to 142 days. It can control weeds for up to 3 years when applied at the registered rate. It is ideal for controlling nutgrass patches on roadways, the outsides of channel banks, and other non-crop areas.

When applying Arsenal to a nutgrass patch, it is good practice to apply the herbicide to an area 1 or 2 metres larger than the obviously infested area. This ensures that all nutgrass plants are controlled by the application. All too often the Arsenal controls the nutgrass in the sprayed patch, but treatment fails because a few plants remain outside the sprayed area and the infestation re-develops from these plants.

Arsenal is weakly adsorbed to soil and can move many metres from the site of application. It should never be applied in-crop or in an area where soil or water movement can carry the herbicide into a sensitive area, such as in the rotobuck area, or on the inside of ditches and channels.

Contact herbicides

MSMA (eg. Daconate[®], Group K)

Daconate can be a useful tool for nutgrass management, as it can be applied over-the-top of cotton, or as a directed spray. It is normally applied to small cotton in spring, although it can be applied up until flowering. Daconate can not be applied after the crop commences flowering.

Daconate is readily absorbed into nutgrass foliage and rapidly affects plants. It does not necessarily kill nutgrass plants but will suppress nutgrass growth, allowing the cotton to establish and shade the weed. Daconate is also effective in controlling a range of other weeds.

Daconate is an arsenical compound (contains arsenic). It has little soil activity but has a half-life of about 180 days in soil. Arsenic build up in the soil is not a problem when it is used in accordance with the label directions.

Table 5. Yield reduction in cotton sprayed over-the-top with Daconate[®] in November and December.

Date	Yield reduction (%)
Late November	2
Early December	13
Late December	18

Daconate is not completely safe to cotton. It can burn cotton leaves and delay cotton growth. To reduce this crop damage, Daconate should be applied as a directed spray to young cotton where possible, rather than an over-the-top application. Daconate should be directed to avoid the growing terminal of the cotton plants.

Damage to older cotton can be more serious as shown in Table 5. Nevertheless, in a field heavily infested with nutgrass, Daconate when properly applied, does far more damage to the nutgrass than it does to the cotton, with the end result that a Daconate application helps the establishing cotton and ultimately improves cotton yields.

Daconate should be applied during hot conditions, as the efficacy is temperature related. That is, Daconate is more effective under hotter rather than cooler conditions. Daconate is also more damaging to cotton as temperatures increase. Growers should consider using lower rates when spraying Daconate over-the-top of cotton under very hot conditions, especially later in the season. Label recommendations suggest that Daconate should be applied under hot, dry conditions, at temperatures above 25°C. This temperature requirement means that Daconate should not be applied under cool, cloudy conditions, as it is unlikely to be effective under these conditions.

WEEDpak

section H3

Temperature variation within a day, however, does not have much effect on the efficacy of Daconate as shown in Table 6. Daconate is absorbed into the plant and has its herbicidal effect over time, so that efficacy is more affected by the temperature over a number of hours following spraying, rather than the actual temperature at the time of spraying.

Table 6. Yield reduction on cotton sprayed over-the-top with Daconate® at different temperatures and times on the same days.

	Time		
	6 am	10 am	3 pm
15 December Temperature (°C)	14	22	26.5
Yield reduction (%)	20	22	26
22 December Temperature (°C)	19.9	26	35
Yield reduction (%)	24	22	19

Halosulfuron-methyl (Sempra®, Group B)

Sempra is registered for controlling nutgrass in cotton, but must be applied through a shielded sprayer, to avoid herbicide contact to the cotton. Sempra inhibits acetolactate synthase, a key enzyme in the plant's metabolic pathway. This inhibition stops plant growth and plant death occurs 14 to 21 days after application.

Sempra does not persist for long in the soil, with a half-life of up to 34 days. However, most rotation crops are very sensitive to Sempra and the recommended plant-back period to rotation crops is 24 months.

Sempra has the advantage that it kills nutgrass plants reasonably quickly and can be very effective early in the cotton season. However, Sempra does not tend to translocate through the nutgrass rhizomes. Consequently, Sempra does not give good control of tubers attached to sprayed plants and gives little control of unsprayed nutgrass in the plant-line when it is applied through a shielded sprayer, as shown in Table 7.



Sempra® applied through a shielded sprayer (foreground plot) controlled nutgrass in the furrow (sprayed area), but gave little control of the unsprayed plant-line.

Table 7. Reduction in leaf number and tuber number of sprayed and unsprayed nutgrass plants attached to sprayed plants. Plants were grown in divided pots and sprayed 4 or 10 weeks after first shoot emergence. They had on average 59 and 153 leaves at spraying, respectively.

Sempra rate (g/ha)	Nutgrass age	Sprayed	Unsprayed
Reduction in leaf number (%)			
70 g	4 weeks	12	0
	10 weeks	0	0
140 g	4 weeks	56	0
	10 weeks	56	0
Reduction in number of viable tubers (%)			
70 g	4 weeks	58	0
	10 weeks	39	0
140 g	4 weeks	92	0
	10 weeks	79	23

Glyphosate (various trade names, Group M)

Glyphosate is registered for controlling nutgrass in cotton. In conventional cotton, glyphosate must be applied through a shielded sprayer, with the spray nozzles positioned so as to **avoid any spray contacting** the cotton foliage. Glyphosate can be applied pre-cotton emergence, in-crop as a shielded spray, at defoliation, or after picking. Roundup Ready Herbicide® can be applied over-the-top of Roundup Ready® cotton up to the 4th true cotton leaf, but must not be applied to the foliage of older Roundup Ready plants. Glyphosate cannot be applied to Roundup Ready cotton at defoliation. For more information, refer to **Managing Roundup Ready® Cotton** and **SPRAYpak/ Spray Application in WEEDpak**.

Glyphosate inhibits EPSP synthase, which prevents protein synthesis and kills the plant. Glyphosate is effective against most plants, but the herbicidal effect is quite slow, often taking 2 to 3 weeks. Glyphosate is far more effective when applied to rapidly growing plants. Spray failures can occur when glyphosate is applied to stressed plants. This is particularly true with nutgrass, where glyphosate applications to stressed plants are often ineffective.

Glyphosate is rapidly adsorbed and inactivated on contact with the soil. Consequently, it has no residual effect, although its breakdown in the soil is comparatively slow, with a half-life of 47 days.

Glyphosate can be effective in controlling nutgrass. It translocates within the sprayed nutgrass plant and also to attached tubers and plants. This translocation means that glyphosate can kill the nutgrass plants it is sprayed on, but can also kill attached tubers and nutgrass plants in the cotton row that were not sprayed.



Glyphosate applied through a shielded sprayer controlled nutgrass in the furrow and controlled some nutgrass in the unsprayed cotton plant-line.

Herbicide efficacy on the major species

Zoliar is effective against all nutgrass species, as it is effective against both tubers and seedlings. Heavy rates of Zoliar are necessary to control plants growing from tubers, but much lighter rates of Zoliar should be adequate to control seedlings, with application timed to occur prior to expected weed germination. Much shallower soil incorporation should also be used for seedling control, as seedlings will not emerge from more than a few mm depth. Lighter rates, shallowly applied should give good control of species that only grow from seed such as dirty Dora, umbrella sedge and rice flatsedge.

Arsenal is equally effective against all nutgrass species, controlling seedlings and emerging shoots.

The three major species, nutgrass, Downs nutgrass and yelka have differing sensitivities to the contact herbicides. All herbicides are more effective on younger rather than older plants (Tables 8, 9 & 10).

Table 8. Herbicide efficacy of the contact herbicides on nutgrass (*C. rotundus*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	0
		2.8 L	25
	Sempra	70 g	46
		140 g	100
8 weeks	Roundup CTXtra	1 L	96
		2 L	100
	Daconate	1.4 L	0
		2.8 L	0
	Sempra	70 g	8
		140 g	0
	Roundup CTXtra	1 L	81
		2 L	87

Daconate, which suppresses nutgrass, is much more effective on Downs nutgrass and yelka.

Sempra is effective on young nutgrass plants, especially at the higher rate, but is much less effective on older plants. Sempra is more effective on downs nutgrass and yelka, but the same trend occurs with age, being more effective on younger plants.

Table 9. Herbicide efficacy of the contact herbicides on downs nutgrass (*C. bifax*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	29
		2.8 L	50
	Sempra	70 g	67
		140 g	75
8 weeks	Roundup CTXtra	1 L	92
		2 L	100
	Daconate	1.4 L	44
		2.8 L	50
	Sempra	70 g	11
		140 g	25
	Roundup CTXtra	1 L	94
		2 L	100

WEEDpak

section **H3**

Glyphosate gave good control of all species at both growth stages, although results in the field are not always so consistent.

Table 10. Herbicide efficacy of the contact herbicides on yelka (*C. victoriensis*) grown in pots. Plants were sprayed 4 or 8 weeks after first shoot emergence.

Age	Herbicide	Rate/ha	% Kill
4 weeks	Daconate	1.4 L	100
		2.8 L	75
	Sempra	70 g	69
		140 g	100
8 weeks	Roundup CTXtra	1 L	87
		2 L	100
	Daconate	1.4 L	42
		2.8 L	50
	Sempra	70 g	0
		140 g	37
	Roundup CTXtra	1 L	100
		2 L	87

Factors that affect Zoliar efficacy

Zoliar is best suited to light, acid soils, where it is very effective at relatively light rates. In Arizona (USA), for example, Zoliar is very effective when applied post-cotton emergence at 1.5 kg/ha, but will kill cotton if applied pre-planting at this rate. Lighter rates should be used when applying Zoliar to light acid soils in Australia.



Cotton and nutgrass on a light, acid soil in Arizona severely affected by 1.5 kg of Zoliar.

Zoliar can behave quite unpredictably in alkaline, heavy clay soils, and must be applied at higher rates on these soils to be effective (4 kg/ha in the first season with lower rates used in subsequent seasons). In some situations, it appears that Zoliar is some how “bound-up” in the soil for some weeks after application, apparently becoming effective only six or so weeks after application. The length of this time period is influenced by soil moisture.

Consequently, it is recommended that Zoliar be applied to alkaline, heavy clay soils in about May, prior to a cotton crop. Thorough incorporation is essential for best results. This is most easily achieved by broadcasting Zoliar before listing. Zoliar is then thoroughly incorporated into the hills through listing, although the Zoliar rate in the furrows may be relatively low.

Good results have been achieved by applying very heavy rates of Zoliar to heavily infested nutgrass patches in fields, and on head and tail ditches. These rates could not be safely used on lighter soils.

Results from an experiment using very heavy rates of Zoliar are shown in Table 11. In this experiment Zoliar was applied over-the-top of 4-leaf cotton. Use of these rates is contrary to the pesticide label. To use higher than label rates, growers must first obtain a use permit from the NRA (National Registration Authority).

The combination of Zoliar applied pre-planting and glyphosate applied in-crop gave the most effective control of nutgrass in this experiment. The very high rates of Zoliar did cause significant leaf damage to the cotton (applied over-the-top of young cotton), but did not adversely affect crop yield.

Table 11. Shielded Roundup and heavy rates of Zoliar for nutgrass control applied over 2 seasons. The initial nutgrass infestation averaged 456 tubers/m². Specific permit permission must be obtained from the NRA before pesticides can be used outside the label recommendation.

	Rate/ha	Tubers per m ²	Lint yield (kg/ha)
Untreated	-	1213	1467
Roundup CT	2.4	1076	1674
Zoliar	4	434	1564
Zoliar	16	133	1791
Roundup CT + Zoliar	2.4 + 4	152	1600
Roundup CT + Zoliar	2.4 + 16	35	1759

Factors that influence glyphosate efficacy

Glyphosate seldom gives 100% control of nutgrass in the field, even under the best conditions. One reason for this is that a nutgrass population includes plants at all stages of growth, including dormant tubers, shoots that have not emerged above the soil surface at the time of spraying, and newly emerging shoots. The emerged shoots are difficult or impossible to spray due to their small size and because they are often protected from the spray by other plant material. The problem of spray penetration can be a major limitation to control of a dense stand of nutgrass.

An apparent spray failure with glyphosate may not be caused by poor herbicide efficacy, but by the emergence of new nutgrass shoots from previously dormant tubers and from plants that were not sprayed. This is especially true with early season glyphosate applications, as new shoots may continue to emerge through to early summer. These shoots are connected to previously dormant tubers that were not previously susceptible to treatment. The emergence of new shoots after spraying should not be viewed as a spray failure but as an opportunity to treat a new portion of the nutgrass population. A dense nutgrass infestation can contain up to 14 000 tubers/m², but will have only about 2200 shoots/m². This means that a high proportion of tubers may not be directly connected to live shoots.

Repeated treatments are the only sure way of controlling nutgrass with glyphosate.

Growers should always aim to apply at least two in-crop shielded applications of glyphosate in cotton. These applications should be timed to occur after irrigation in about mid-December and mid-January, before the canopy closes. Ideally the second application should occur about four weeks after new shoots begin to emerge following the first glyphosate application.

Nutgrass age

Nutgrass plants are most susceptible to glyphosate when they are young, and become progressively more tolerant as they age. Freshly emerged shoots are much easier to kill than are mature plants. This is shown in the data in Tables 8 and 13. Flowering has little impact on glyphosate susceptibility, but flowering plants are much less susceptible than are younger plants.

However, except during early spring, or after cultivation or a successful herbicide application, a nutgrass population includes plants at all stages of plant maturity. Almost from the moment the first shoot appears in spring, nutgrass plants produce new tubers that produce new plants, that produce new tubers, and so on. These new tubers are initiated within days of the first shoot emergence. Viable new tubers and new plants can be formed within 4 to 6 weeks of the first shoot emerging. Consequently, at any point in the season, a nutgrass population includes freshly emerged shoots, through to mature plants. The potentially rapid increase in a nutgrass population is shown in Figure 1. Competition from cotton can greatly reduce this rate of reproduction in the cotton row. Vigorously growing cotton may also shade the furrow and compete strongly with the nutgrass.

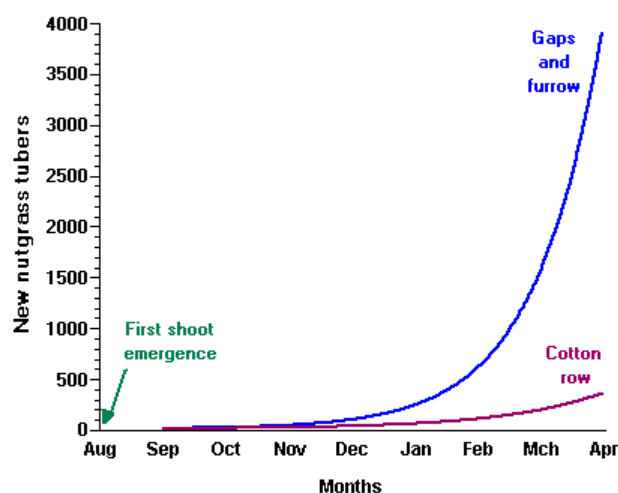


Figure 1. Nutgrass tuber production in cotton starting from a single tuber in spring. Nutgrass is intolerant of shading and produces fewer tubers in the cotton row.

The glyphosate labels generally recommend that spraying be delayed until nutgrass plants reach at least 20% flowering, in about February. This recommendation is based on a misunderstanding of the need for nutgrass to be flowering before herbicide application. This misunderstanding assumes that older nutgrass plants are more sensitive to glyphosate and that nutgrass plants translocate assimilates to their attached tubers after flowering in autumn. Neither of these assumptions is correct.

Unlike many other perennial plants, nutgrass does not predominantly move assimilates (nutrients) down to its roots and tubers in autumn prior to plant dormancy. The movement of assimilates in nutgrass is a continuous process and is more apparent in younger plants than older plants. Almost from initial shoot emergence, nutgrass produces new tubers and assimilates are being continuously moved down to the roots and tubers, to provide for the production of these new roots and tubers. Consequently, glyphosate translocation to attached tubers occurs equally well at all stages of the season, although glyphosate is more effective in killing young plants and tubers than older plants.

Ideally, glyphosate should be applied to nutgrass within 4 to 6 weeks of first shoot emergence. This timing gives the best kill of plants and attached tubers, and ensures that plants are controlled before they reproduce, **provided that plants are not stressed at spraying**. Stressed plants are far less susceptible to glyphosate, and are unlikely to be killed by an application.

Stressed plants

Nutgrass is capable of very rapid growth, but is very easily stressed by factors such as low temperatures, low soil moisture, cultivation and other herbicides. Like most weeds, nutgrass is far more susceptible to glyphosate when the weed is rapidly growing. Even very high rates of glyphosate are likely to be ineffective in controlling nutgrass when it is stressed.

Moisture stressed plants are best controlled by cultivation. Where this is not possible or not practical, spraying should be delayed until after plants have resumed normal growth.

Low temperatures

While early spring may seem to be an ideal time to apply glyphosate to nutgrass, there have been many spray failures at this time caused by the nutgrass being stressed by low temperatures.

Glyphosate applications can be very effective in warm to hot conditions in October and November, but are likely to be ineffective when temperatures drop too soon after application. For effective control, hot conditions must continue for at least a week after spraying. A drop in temperature, or cool nights, may result in a spray failure.

Similarly, cool conditions in autumn are likely to result in spray failures.

Reliable control of nutgrass can generally be achieved from mid-November onwards, although this date will be earlier in the northern regions and can be much later in the cooler areas. Nevertheless, spraying earlier in the season can be very effective when conditions are favourable.

Low soil moisture

Nutgrass has a shallow, fibrous root system that makes it very prone to moisture stress in the cotton system. Experience has shown that nutgrass is most susceptible to glyphosate when the weed is rapidly growing, immediately after irrigation or rainfall. Ideally, glyphosate should be applied to the nutgrass as soon as possible after irrigation or rainfall.

The exception to this is that glyphosate can be very effective when applied to moisture stressed nutgrass, provided that rain or irrigation occurs within hours of the application. Applying glyphosate to nutgrass immediately before irrigation can be a practical way to overcome the difficulty of wet tail ditches etc.

Cultivation

One of the practical difficulties of controlling nutgrass with glyphosate can be the need to delay inter-row cultivation to allow nutgrass to grow sufficiently to be sprayed.

Nutgrass should be allowed to grow for at least four weeks between cultivation and spraying. Cultivation should then be delayed for at least one week after spraying and two weeks if possible. Cultivating within a week of spraying can reduce spray efficacy, as shown in Table 12.

Table 12. Reduction in Roundup CT efficacy from simulated, post-spraying cultivation. Nutgrass plants were sprayed 6 weeks after first shoot emergence of plants growing in pots.

Herbicide rate (L/ha)	Post-spraying cultivation	% Kill	Leaves per plant
-	-	0	125
2.4	-	75	0.3
2.4	2 days	25	7
2.4	4 days	50	3
2.4	8 days	25	14

Glyphosate rate

Most glyphosate labels recommend a split application of herbicide at **1 L active** per ha per application. This rate has generally been adequate to control nutgrass in most situations, with the second application greatly improving the final result.

A range of other glyphosate rates has been used on nutgrass over the years with varying success. Half the recommended rate has been adequate to control nutgrass under ideal conditions, as shown in Tables 13 and 16, but has often lead to spray failures (also shown in Table 13). A higher rate (such as 2 L active/ha) will give better control in some situations, but is not generally needed and may not be cost-effective. Increasing the rate beyond 1 L active/ha will not generally overcome limitations such as the plant being stressed by cool temperatures or lack of soil moisture, but will greatly increase the risk of damage to the crop when applied as an inter-crop spray.

Water quality

One of the desirable characteristics of glyphosate is its ability to be rapidly adsorbed to soil particles and inactivated. This makes glyphosate ideal as a knockdown herbicide prior to planting or even between planting and crop emergence. Glyphosate can also be inactivated by metals and ions in the spray solution, and is very sensitive to zinc, which is present on galvanized surfaces.

These qualities make glyphosate very sensitive to water quality. Glyphosate efficacy can be reduced by dirty water, by hard water, by alkaline water and by metal ions. To avoid problems with water quality, it is important to use the best quality water available and to ensure that glyphosate remains in the spray tank for as short a time as possible.

Under most circumstances, however, water quality should not be a major factor reducing the efficacy of glyphosate on nutgrass, provided the spray mixture is not allowed to sit for an extended period.

Table 13. Herbicide efficacy of two rates of Roundup CT on nutgrass applied 3 or 6 weeks after first shoot emergence of plants grown in pots. The herbicide was applied in 100 L water/ha with 0.4% Turbo P (non-ionic surfactant) added. The spray mix was allowed to sit for 24 hours before spraying. Water quality is shown in Table 14.

Age	Rate (L/ha)	Source	% Kill
3 weeks	1.2 L	Distilled	82
		Bore A	98
		Bore B	76
		River	100
		Channel	58
	2.4 L	Distilled	88
		Bore A	99
		Bore B	77
		River	94
		Channel	100
6 weeks	1.2 L	Distilled	37
		Bore A	5
		Bore B	0
		River	1
		Channel	0
	2.4 L	Distilled	78
		Bore A	42
		Bore B	93
		River	0
		Channel	81

Table 14. Water quality of the sources used in Table 13. The channel water was allowed to sit in storage for an extended period before use.

Source	pH	Conductivity (dS/m)	Hardness (Ca + Mg)	Chloride (mg/L)
Distilled	6.65	0	0	10
Bore A	6.62	0.36	164	15
Bore B	8.18	0.57	157	48
River	9.48	2.59	98	370
Channel	9.21	0.18	67	25

A comparison of glyphosate efficacy using a range of water sources where the mixture was allowed to sit for 24 hours (Table 13) showed that poor water quality could have a large effect on herbicide efficacy, but that the effects were not consistent. Results from a second experiment where the spray was used 3 hours after mixing showed no reduction in efficacy due to water quality.

In both experiments, herbicide rate and nutgrass age had as much impact on herbicide efficacy as did water quality.

Water rate

Most glyphosate labels recommend a maximum water rate at or below 100 L/ha. Common farm use is in the range of 40 to 60 L/ha, well below the maximum recommended rate.

Lower water rates improve spraying efficiency by increasing the area that can be covered by each tank load, but may also reduce the coverage of droplets on the target plant. Coverage and spray penetration into the plant canopy can be improved by using higher nozzle pressure, but this leads to the production of more small spray droplets and more spray drift. Higher water volumes and lower nozzle pressures are desirable when using an in-crop shielded application of glyphosate to reduce spray drift and thereby reduce damage to the crop.

Additives

A large range of wetters, surfactants and other additives is available for use with glyphosate and other herbicides. These additives can improve herbicide efficacy in some situations, but generally are not required with glyphosate. Some additives may have an inconsistent or negative affect in some situations, as shown in Table 15.

The addition of Prep® (ethephon) to glyphosate for example, may improve control in some situations, but Prep is antagonistic to glyphosate, causing the chemicals to come out of solution and may reduce glyphosate efficacy.

Table 15. The effect of some spray additives on glyphosate efficacy on nutgrass, sprayed 8 weeks after first shoot emergence.

	Treatment	% Kill	Leaves per plant
1	Untreated	0	234
2	Roundup 3 L	0	231
3	Roundup 3 L + 3% Agral 600	100	0
4	Roundup 3 L + Herbex 3 L	75	1
5	Roundup 3 L + Prep 0.3 L	0	50

Both percentage kill and leaves per plant data are shown in this and some other tables. Leaves per plant gives an indication of the suppression of plants that survived the treatment. A comparison of treatments 1 and 2, in Table 15 shows that the Roundup application (without additive) not only failed to kill the nutgrass, it failed to even suppress the weed. Treatment 5 (Roundup + Prep) also failed to kill the nutgrass, but did suppress the weed, causing a 79% reduction in leaf number.

Additives are often used to overcome poor application conditions, poor water quality, or antagonism from other tank-mixed herbicides. Generally, these additions do not fully overcome

the problems. No additive will make stressed nutgrass plants receptive to glyphosate.

However, experience in the field has shown that the addition of a non-ionic surfactant at 0.2% will often improve glyphosate efficacy, as shown with Agral 600 in Table 15. Data in Table 16 shows an improvement when using a non-ionic surfactant with low glyphosate rates, but no improvement when using the recommended rate of glyphosate.

Table 16. Nutgrass leaf production and % kill from three rates of Roundup CT with 4 rates of added non-ionic surfactant (Turbo-P).

Roundup CT rate	Surfactant rate (%)	% Kill	Leaves per plant
-	-	0	110
0.6	-	0	133
	0.2	25	80
	0.5	25	43
	1.0	25	75
1.2	-	25	61
	0.2	100	0
	0.5	100	0
	1.0	100	0
2.4	-	100	0
	0.2	100	0
	0.5	100	0
	1.0	100	0

Additives should not be used with over-the-top glyphosate applications to Roundup Ready[®] cotton, except as directed on the product label. The use of other additives could affect the activity of glyphosate and cause damage to the Roundup Ready cotton.

Tank-mixing

Glyphosate can be tank-mixed with a range of other herbicides. However, tank-mixing with some of the more commonly used cotton herbicides is likely to reduce glyphosate efficacy to some extent, as many of these herbicides contain some clay that will inactivate the glyphosate. The amount of reduction of glyphosate efficacy will depend on water volume and quality, the amount of clay in the tank-mixed herbicide, and the length of time the mixture stands in the spray tank.

Tank mixing with clay-based products should be avoided if possible. Ammonium sulfate should be added when tank-mixing with a clay-based product is necessary and higher glyphosate rates should be considered. Always ensure that these mixtures remain in the spray-tank for as short a time as possible.

Re-spraying interval

Glyphosate is frequently used to control other weeds at a lighter rate than the 1 L active/ha used for nutgrass. Ideally, nutgrass patches should be sprayed with a heavier rate at the same time by using a boom spray fitted with a second boom line with larger nozzles or by slowing the tractor to increase spray rate. The additional boom line is likely to give the better result of these two options as it is far easier for the operator to switch on or off an additional boom than to be constantly changing tractor speed.

Table 17. Effect of timing of a 1.4 L/ha (0.63 L active/ha) application of Roundup CT after a 1 L/ha (0.45 L active) application on nutgrass 3 or 6 weeks of age.

Nutgrass age	Initial spray rate	Time to re-spraying with 1.4 L	% Kill	Leaves per plant
3 weeks	-	-	0	108
	1 L	-	50	49
		at spraying	100	0
		1 week after	75	7
		2 weeks after	100	0
		3 weeks after	75	1
		4 weeks after	25	71
6 weeks	-	-	0	166
	1 L	-	0	32
		at spraying	25	1
		1 week after	25	52
		2 weeks after	50	1
		3 weeks after	0	4
		4 weeks after	0	24

However, if the two applications can't occur on the same day, the second application should be delayed for around two weeks, as shown in Table 17.

Herbicide efficacy is reduced when the two sprays are too close together due to the stress on the plant caused by the first spray. Glyphosate applied to a plant with the second spray is unlikely to be readily translocated or to be very effective, as the plant is already stressed and damaged by the first spray. However, if the sprays are too far apart, the affect of the first spray is lost.

For best control, nutgrass should be resprayed approximately four weeks after green shoots emerge.

Herbicide combinations

The best control of nutgrass has been achieved using multiple applications of glyphosate on a field that previously received Zoliar. However, this can be a very expensive option, as unless the nutgrass patches are well defined, the Zoliar must be applied to most or all of the field. GPS mapping of the nutgrass patches may be used to greatly reduce this cost.

An alternative strategy for lighter infestations of nutgrass that has been successfully used by some growers is to apply a tank mix of Zoliar and Semptra as a spot application in December, with a follow-up application of glyphosate in January. Both applications must be made through a shielded sprayer. The combination of Zoliar and Semptra is very expensive on a per hectare basis, but the applications can be very cost-effective when applied through a weed-activated sprayer so that the herbicide is only applied to the weed infestation.

Spraying equipment

In-crop applications of glyphosate must be applied so as to avoid contact with the crop foliage. The only exception to this is Roundup Ready cotton, which can be sprayed over-the-top with Roundup up to the fourth true leaf, in compliance with the product label.

Glyphosate can be applied in-crop as a directed spray or through a shielded sprayer. A range of equipment is available, at a range of prices, ranging from basic rubber or steel shields against the crop, to completely enclosed sprayers. The primary differences between these extremes of design is their ability to be safely operated in windy conditions, their ability to be adjusted to meet a range of requirements and crop size, and their ability to be used in a range of crop sizes without causing excessive physical damage to the crop.

It is essential when using any spray equipment to ensure that the equipment is properly set up and is used only under appropriate conditions. Generally, the more open the equipment design is, the more sensitive it is to windy conditions. Any air movement into the shield area will cause air movement back out of the shield area. This air is likely to carry fine spray droplets that may then be deposited onto the crop. Shields that have open fronts and tops are most prone to this movement, but some air movement is inevitable in even the best designed shields.

Nevertheless, even an open shield design can be used safely in the crop provided that it is used at low tractor speeds and low wind conditions, and with correctly set up and operated spray nozzles. Fine mesh such as shade cloth can be used to enclose the shields, greatly reducing air movement within the shield area and reducing the risk of crop damage from spray drift.

A range of nozzle designs is available, including low drift nozzles. Low nozzle pressure (pressures towards the bottom end of the recommended range for the nozzle) and high water volumes (allowing the use of larger nozzles) will also help reduce the production of fine spray droplets.

Once a shielded sprayer has been set up, it is important that it is regularly checked to ensure that nozzles are operating correctly, and that the operator is aware of the operating conditions. Operating a sprayer in windy conditions will inevitably lead to crop damage.

Crop competition

Although nutgrass can compete very strongly with cotton, nutgrass does not itself tolerate strong competition. Nutgrass has a fibrous, relatively shallow root system. This enables it to compete strongly early in the cotton season and to respond quickly after rain and irrigation, but it does not compete well with irrigated cotton later in the cotton season when soil moisture in the surface soil layers is limiting.



A section of a cotton crop severely infested with nutgrass. No harvestable cotton was present in this portion of the field.

Nutgrass is also relatively intolerant of shading and has a greatly reduced growth rate when shaded by a taller crop.

One of the keys to growing cotton and other crops in a field that is infested with nutgrass is to ensure that the crop establishes as quickly as possible and is able to shade-out the nutgrass. There are a number of management practices that can influence crop competitiveness, including:

- stubble management
- soil conditions
- crop species and variety selection
- sowing date, rate and depth
- seed dressings
- fertilizer type, rate and placement
- irrigation management (pre- and post planting)
- herbicides - residuals and knock-down pre-emergence and post-planting
- cultivations
- weed control (of nutgrass and other weeds)

These practices should be optimised to maximise crop competitiveness. The result of not optimising these factors can be that the crop does not establish vigorously on nutgrass infested areas and competes poorly, allowing the nutgrass to establish and spread. This worst-case scenario can result in a crop failure with no harvestable crop.

One of the most common problems with establishing rotation crops is inadequate soil moisture and nutrition in the nutgrass infested areas. The main part of a field may have good moisture and nutrition following a cotton crop, but both these inputs are likely to be lacking on nutgrass infested areas, as the weed has already used these resources during the cotton season. Consequently, crop establishment is comparatively poor on the nutgrass infested areas. Irrigation at planting and inclusion of a starter fertilizer with the crop can make a large difference to the crop's competitiveness and its impact on nutgrass.

Developing an IWM program for nutgrass

Nutgrass is a perennial weed that will not be controlled with any single treatment. Successful nutgrass management is built on using as many management tools as possible, at every available opportunity, over a number of years.

No one management program is suitable for every field and every season. The management tools can be successfully used in a variety of ways, depending on the extent of the problem and available resources.

The type of nutgrass program required for any individual field will depend on the extent of the problem and the management resources available.

Results from field experiments conducted over a number of seasons and a number of sites are shown in Tables 18 to 21. These results allow comparison of some treatments and treatment combinations.

Of the contact herbicides, multiple glyphosate applications have given the most reliable nutgrass control over a number of sites and seasons. However, glyphosate is only effective on actively growing nutgrass. The combination of glyphosate (applied on actively growing nutgrass) and cultivation (on moisture stressed nutgrass) can be used very effectively (Table 18).

The best results in cotton were achieved using a combination of Roundup and Zoliar (Table 19), with Zoliar incorporated pre-planting and two in-crop shielded applications of Roundup applied each season. This treatment (Treatment 8) resulted in an 88% decrease in the nutgrass population over two seasons, compared to a 5-fold increase in the nutgrass population where no treatment was imposed (Treatment 1).

The Roundup and Zoliar combination also resulted in the best cotton yield, 117% (3 bales/ha) higher than the untreated comparison (Treatment 1). This yield increase of 3 bales would have more than paid for the cost of treating the nutgrass. In addition, use of this treatment would result in a field starting the next season with a lower density of nutgrass than was initially present, potentially resulting in even better yields than were recorded over these two seasons.

Results using a range of herbicides and herbicide combinations on an initially much lighter nutgrass population were similar (Table 20), with the best nutgrass control (an 87% reduction in tuber density) from three in-crop Roundup applications (Treatment 4) and the best yield (a 47%, 1.7 bales/ha increase) from 2 in-crop applications (Treatment 3). The slight reduction in yield associated with the third Roundup application was probably caused by crop damage from the additional herbicide application, as the herbicide



WEEDpak

section **H3**

was applied through a poorly designed shield which allowed some herbicide drift to the crop.

The improvements in crop yields after treatment would probably have been even better if better designed equipment and/or Roundup Ready cotton had been used. Generally, any damage to the cotton from the herbicide application is more than compensated for by the associated reduction in weed competition resulting from the reduction in the nutgrass population. Nevertheless, it is essential to only apply glyphosate through a well designed and properly set-up shielded sprayer, operating in appropriate conditions. This is equally true whether using conventional or Roundup Ready cotton varieties.

Results from a more extensive comparison of Roundup and Zoliar combinations are shown in Table 21. In this experiment, the best nutgrass control was achieved using a single Roundup application in early December (Treatment 4), which resulted in a 97% decrease in the nutgrass density.

However, results from a single Roundup application were highly variable (compare Treatments 2 to 7). This variability reflects the normal variability of results often achieved with glyphosate and was caused by a number of factors including the condition of the nutgrass at the time of spraying. On some occasions, the nutgrass was highly stressed at spraying, resulting in a poor kill. Growers should be able to achieve much better results by targeting conditions that are more suitable for glyphosate when nutgrass is actively growing.

Table 18. Changes in nutgrass density in a fallow with treatments over 2 seasons. The area initially had an average nutgrass infestation of 334 tubers/m².

Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²
Untreated	-	-	3879
Cultivation	-	8	1114
MSMA	2.8	2	2895
MSMA	2.8	4	789
Roundup CT	2.4	2	668
Roundup CT	2.4	4	346
Roundup CT	4.8	4	150
Roundup CT	2.4	8	47
Cultivation + Roundup CT	2.4	4 + 4	118

Table 19. Changes in cotton lint yield and nutgrass density with in-crop and residual herbicide treatments over 2 seasons. The area initially had an average nutgrass infestation of 1348 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			7194	582
2	Roundup CT	2.4	1	3728	547
3	Roundup CT	2.4	2	797	856
4	Roundup CT	2.4	3	611	891
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	741	987
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	1194	873
7	Zoliar + Roundup CT	3 + 2.4	1 + 1	786	660
8	Zoliar + Roundup CT	3 + 2.4	1 + 2	160	1262

Table 20. Changes in cotton lint yield and nutgrass density with in-crop treatments over 2 seasons. The initial nutgrass infestation averaged 338 tubers/m².

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1097	819
2	MSMA	1.8	2	577	871
3	Roundup CT	2.4	2	223	1206
4	Roundup CT	2.4	3	43	1173
5	MSMA + Roundup CT	1.8 + 2.4	1 + 1	385	930
6	MSMA + Roundup CT	1.8 + 2.4	2 + 1	231	1126
7	MSMA + Roundup CT	1.8 + 2.4	1 + 2	108	1018
8	Sempra	0.14	1	552	944
9	Sempra	0.07	1 + 1	367	1047
10	MSMA + Sempra	1.8 + 0.07	1 + 2	386	1061
11	MSMA + Sempra + Roundup CT	1.8 + 0.14 + 2.4	1 + 1 + 1	278	992
12	MSMA + Roundup CT + Sempra	1.8 + 2.4 + 0.14	1 + 1 + 1	278	1143

Table 21. Changes in nutgrass density with in-crop treatments over 2 seasons and cotton lint yield in the first season. The initial nutgrass infestation averaged 456 tubers/m². The Zoliar was applied over-the-top of the cotton after crop emergence and the Roundup CTXtra was applied as a directed spray.

	Treatment	Rate (L or Kg /ha)	Applications	Tubers/m ²	Lint yield (kg/ha)
1	Untreated			1213	1467
2	Roundup CTXtra	2	early Nov	615	1588
3	Roundup CTXtra	2	late Nov	210	1661
4	Roundup CTXtra	2	early Dec	39	1486
5	Roundup CTXtra	2	late Dec	685	1532
6	Roundup CTXtra	2	early Jan	1076	1674
7	Roundup CTXtra	2	late Jan	410	1493
8	Roundup CTXtra	2 + 2	early Nov + late Dec	328	1371
9	Roundup CTXtra	2 + 2	late Nov + early Jan	667	1543
10	Roundup CTXtra	2 + 2	early Dec + late Jan	173	1532
11	Zoliar	4	Oct	434	1564
12	Zoliar + Roundup CTXtra	4 + 2	Oct + early Jan	152	1600
13	Zoliar + Roundup CTXtra	4 + 2 + 2	Oct + early Dec + early Jan	226	1573

A management program for heavy infestations

Cotton yields are reduced by nutgrass competition on a field heavily infested with nutgrass.

Consequently, it is important to try to reduce the weed infestation as quickly as possible to improve crop yields. To do this, it is necessary to use a range of treatments in combination, using as many treatments as practical each season. Examples of intensive management plans for conventional and Roundup Ready cotton are shown in Tables 22 and 23. It may not be practical or appropriate to use all of these treatments each season, but it is important to use as many treatments as possible, until the nutgrass population is reduced to a more manageable level.

Table 22. A management plan for back-to-back conventional cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in green type. An additional glyphosate application could replace the deep ripping operation if the soil is wet and the nutgrass is actively growing.

Operations	Crop
September cultivation planting	Cotton
October	
November MSMA application inter-row cultivation	
December glyphosate application	
January glyphosate application lay-by herbicide	
February	
March glyphosate application at defoliation	
April picking slashing	
May deep ripping Zoliar application incorporation	
June listing	
July herbicide or cultivation	Fallow
August	

A management program for lighter infestations

A less intensive nutgrass management program can be used once the weed density on a field has been reduced to a level where the nutgrass is not reducing cotton yield. This program needs to be responsive, allowing for additional treatments should they become necessary, and must include regular field inspection. Failure to adequately treat nutgrass can result in a field becoming rapidly reinfested.

Such a management program would probably not include broadcast applications of Zoliar but may include a spot application of Zoliar to nutgrass patches. The main component of the management program should be in-crop shielded applications of glyphosate, with at least one application each season. Ideally, a second application will be allowed for in case the first application is not effective.

Table 23. A management plan for back-to-back Roundup Ready cotton in a heavy nutgrass infestation. Treatments directly used for nutgrass control are shown in green type. An additional glyphosate application could replace the deep ripping operation if the soil is wet and the nutgrass is actively growing.

Operations	Crop
September cultivation planting	Cotton
October	
November Roundup application inter-row cultivation	
December Roundup application	
January Roundup application lay-by herbicide	
February	
March Roundup application at defoliation	
April picking slashing	
May deep ripping Zoliar application incorporation	
June listing	
July herbicide or cultivation	Fallow
August	

Summary

Eight different nutgrass species are commonly found in or around cotton fields. These species are quite different in their ability to spread from seed or rhizomes, and consequently require specific management strategies. Positive identification of the problem species is essential as the first step in a management program.

A range of management tools is available to manage these weeds. These tools include residual and contact herbicides, cultivation, and crop competition. There are also some management practices that can exacerbate a nutgrass problem and should be avoided whenever possible.

Management of nutgrass needs a long-term approach, as these weeds will not be eliminated by any single management option. A successful management program will include all the management tools, used in combination as opportunity arises.

Glyphosate and Zoliar® herbicides have given the most effective control of nutgrass over time. Glyphosate should ideally be applied in-crop twice each season. It must be applied through a well constructed, properly set up shielded sprayer, operating under favourable conditions, when applied in conventional cotton. Roundup Ready Herbicide can be applied with much greater safety in Roundup Ready cotton varieties.

Zoliar is a residual herbicide that must be applied in consecutive seasons to be fully effective. It has a long plant-back period to most rotation crops.

Farm machinery can be a major contributor to spreading nutgrass around a farm. Attention to machinery hygiene can be pivotal in a successful management program.

Case studies of grower experiences with nutgrass

Nutgrass on Kilmarnock

John Watson

I remember nutgrass starting to be noticeable on channels in 1975; it was endemic in the dryland cropping paddocks and grazing country. The local pharmacist and then chemical supplier gave me a few mLs of something in a small plastic bottle. It was to be the answer to our potential problem and think it was probably Roundup! I was overseas for three years and by 1978 there were now small patches in some of the fields. Despite all our efforts it got progressively worse.

Many chemical products were tried, all of which gave variable and inconsistent results. Zoliar was effective if thoroughly incorporated on the flat before hilling up. It's extended use lead to problems in rotation crops. Cotton grown in a field with a relatively low population of nutgrass at planting could see it so thick after three months that yield would be affected if no action was or had been taken.

Graham Charles commenced trial work in the 1990's on our worst block, which, at the time, was on the leased property "Nandewar". He tested a number of products over three years and the best results indicated multiple applications of one or more chemicals. Overall, the trials showed that a cost effective result could be obtained from an early application of Zoliar and single in crop spray of Roundup using shielded sprayers.

The nutgrass control program is now largely based on control in the fallow phase, Roundup or chisel ploughing dry soil; rotations, cereal every second or third year; and in crop shielded spraying. It can sometimes be advantageous to do a broadacre application of Roundup after planting but before crop emergence. The result is quite variable, probably because of low temperatures especially here in the upper Namoi.

Roundup Ready® cotton will allow an over the top application after emergence and should therefore give better control as temperatures should be higher. Other than this obvious advantage, we will use much the same practices with Roundup Ready cotton, but will be looking to alternate some of the non-crop sprays with other chemistry to delay the onset of resistance of weeds to Roundup.

Case studies of grower experiences with nutgrass

Nutgrass Control at Norwood

Peter Glennie and Kylie May

Nutgrass has always been present on “Norwood”. Years of flood inundation (prior to development), grazing and cultivation led to the gradual spread of the weed around the farm.

Early control methods consisted of cultivation and herbicides such as MSMA and glyphosate - all to varying degrees of success. The late 80's saw the introduction of Zoliar, which was incorporated into the control program. The worst areas were attacked first. The cost of Zoliar prohibited full field sprays in all but the worst fields, so various methods of spot spraying were tried, including manually turning small tractor mounted booms on and off, a spray boom on the back of a slasher at picking time and spraying with a quad. Zoliar was applied both at planting and picking and it was discovered that it wasn't until about the third year into the Zoliar program, that the nutgrass really started to respond to the applications. The patches were still there, but they were getting smaller and thinner.

The early 90's saw little or no irrigation water from Copeton and not much more rain. Water was conserved in the soil by preparing the hills early then leaving them to sit until planting time. Although this was a good drought strategy, the reduced disturbance saw nutgrass areas increase again.

A very dry winter in 1994 resulted in no winter crops being planted. This left an opportunity to grow a green manure crop the following summer. A lablab/forage sorghum mix was planted in December and left to grow for three months before being rolled and ploughed back into the ground. The following summer saw a marked reduction in the amount of nutgrass in those fields, probably due to a combination of the competition from the lablab/forage sorghum, and the extra cultivations needed to work the high amount of dry matter back into the soil. This result has been repeated in other years with lucerne and again this season with another lablab/forage sorghum mix that was planted last summer. Although this did reduce the amount of nutgrass in the field, other methods of control are necessary to keep the patches from increasing.

Zoliar still forms part of the nutgrass control program on “Norwood”, although it is now mostly applied with a GTS sprayer, which has allowed more accurate targeting of the weed. Other methods of control are continually being trialled, both for better control and to hopefully reduce the amount of Zoliar in the soil, which limits rotation crop choice. Increased seed bed preparation, particularly deep cultivation, is having an affect, although more work still needs to be done.

This season (2001/02), saw the first commercial use of Roundup Ready cotton and herbicide. The herbicide had a dramatic effect on nutgrass patches, at a time of the season, when control is most important. It has allowed the cotton to out compete the nutgrass, without the need for extra cultivations. The wet November possibly helped contribute to the good result, by keeping the nutgrass fresh and more receptive to the Roundup Ready herbicide. It will be interesting to see if the result can be repeated over the next few seasons - here's hoping it will.

Currently we are trialling a more aggressive approach with the use of a large ripper with a wire cable connecting all the tynes. This cable is situated at the back of the tyne and is pulled by a D9N bulldozer, about 1 foot into the ground. The thought is that it will cut off the nuts from below and dry out the nuts above. So far the results are promising.

Case studies of grower experiences with nutgrass

Nutgrass control on Auscott Narrabri

David Wood

Nutgrass has been a problem on Auscott for a long time, but the issue came to a bottleneck over the last couple of years. Some fields were becoming so heavily infested that it was no longer economical to continue growing cotton.

The increase in the nutgrass populations was due to number of factors,

1. Succession of wet winters
2. Lack of effective in crop control options
3. Reduced tillage at depth

The run of wet winters reduced opportunities to use tillage as a control method, and resulted in operations for seedbed preparation being undertaken in less than ideal conditions. This made it very difficult to uproot and expose the tubers to desiccation as the nuts remained in moisture. Consequently, this simply spread the nutgrass from head ditch to tail drain.

In the past Zoliar was used as a broad acre spray across heavy infestations, however, its use was limited because of the restrictions that it imposed on future rotation crops. Due to the rotation issue Roundup was than used as an in crop control through shields. This also provided challenges with drift onto susceptible plants. MSMA was then used because of the greater crop safety, though unfortunately its success was variable. Semptra was also tried but was relatively ineffective. Together they gave reasonable control to continue cotton production, but were unable to stop the population from steadily increasing.

The situation took a turn for the better with the onset of Roundup Ready cotton. The Roundup Ready technology provided the opportunity to attack the nutgrass in the plant line early season, allowing the cotton to grow away and out compete the weed. The results from the Roundup spray are still sometimes variable, however, the successive applications achieve good brown off of the shoots more regularly, which is then followed by cultivation. In some cases it was taking the nutgrass 3-4 weeks to come back.

Zoliar is still an important part of the program on Auscott. Fields with light infestations are spot sprayed with a row weeder to prevent patches from spreading. It is also now sprayed through all rotobuck and tail drains in an attempt to stop cultivators from dragging the nuts down the field.

In combination with the chemical approach, rotation and tillage play an important role. The use of deep rooted crops, such as lucerne or safflower, dry out the soil profile and allow for deep ripping to expose nuts to desiccation. The advantage of lucerne over other crops is that if rains just prior to tillage, then it can be left to continue growing and draw the moisture out again, which is something that safflower or wheat cannot do if they have reached maturity.

At the end of the cotton season a Roundup spray at 2-3L/ha straight after harvest has shown signs of significantly reducing nutgrass populations in the following year. We are not sure if it will work each year, however, the results are encouraging.

