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An update of weed control in the Australian cotton industry

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Introduction

This is a preliminary paper, prepared in response to a request from the Cotton Research and Development Corporation for additional information on weed control in cotton, and builds on the survey of Charles (1991)

The information has been gleaned from 10 of the 52 cotton growers covered in the 1989 survey (Charles 1991), and will be supplemented with information from members of the cotton consultants association as this becomes available. Additional information has been acquired from re-analysing the 1989 data (Charles 1991).

Due to the small survey sample, the accuracy of this report is limited but gives an indication of the industry trends. These trends will be confirmed by the complete report, to be finalised by spring.

Materials and methods

The herbicide usage data from the 1989 survey (Charles 1991) has been re-analysed, including some data not in the original survey. The data from each property in the 1993 survey has been directly compared with this earlier data, and trends established. Questions in the 1993 survey covered herbicide related cotton establishment problems, the current weed control practices, and the general changes that have occurred in these practices in the last 5 and/or 10 years.

Results and discussion

Herbicide use in the industry

The total use of herbicides by the Australian cotton industry as estimated from the 1991 survey is shown in Table 1. This data was derived from 52 growers in NSW, covering 67 600 ha, and representing 29% of the Australian cotton area. The values in Table 1 assume that NSW is representative of the cotton industry, and are based on irrigated cotton data. This may have caused an over estimate of herbicide use, as inputs are generally lower on non-irrigated cotton, the bulk of which occurs in Queensland. Only one non-irrigated property was included in the 1989 NSW survey.

Table 1. Herbicide usage by the Australian cotton industry, based on the results of Charles (1991), using a base of 230 300 ha for the 1989/90 cotton season (ABARE 1991).

Herbicide	Concentration (g ai L^{-1})	% of properties	Number of applications	Rate (L/ha)	Use ('000 L)
Diuron	500	81	1.4	2.7	634
Trifluralin	400	75	0.9	2.8	521
Cotoran	500	63	1.2	2.7	241
Cotogard	250 & 250[1]	48	1.0	3.2	143
Stomp	330	37	0.8	3.0	128
Gesagard	500	15	0.8	2.4	90
MSMA	500	17	0.2	3.7	26
Dual	720	15	0.8	2.3	12
Roundup	450	85	1.0	0.8	241
2,4-D amine	500	35	0.9	1.1	180
2,4-D ester	800	13	1.1	0.6	22

Note[1]. Cotogard contains a mixture of 250 g L^{-1} fluometuron and 250 g L^{-1} prometryn.

However, the herbicide usage pattern is not uniform between the cotton areas. The Macintyre generally had a lower than average herbicide usage pattern, although heavy rates of Cotoran are used to control competition from *Sesbania cannabina*. The heavy use of Cotoran in the Macquarie valley was related to heavy infestations of *Datura* spp. in this area.

Table 2. Herbicide usage in the main river valleys in the 1989/90 season.

Herbicide	(Litres used per ha of cotton grown)			
	Major river valley			
	Macintyre	Gwydir	Namoi	Macquarie
Diuron	1.2	3.1	2.5	2.8
Cotoran	2.0	1.0	1.0	3.7
Trifluralin	1.5	2.5	2.0	2.9
Stomp	0.8	0.2	0.9	0.3
Gesagard	0.3	1.1	0.2	0.7
Roundup	0.2	1.3	1.1	0.7
2,4-D Amine	0.1	0.7	1.1	1.2

Trifluralin and diuron usage were relatively uniform across the valleys. Stomp use appears to be related to the use of permanent beds and minimum tillage rather than a specific weed problem. The heavier use of Gesagard in the Gwydir valley was related to problems with *Ipomoea* spp. control. The 2,4-D amine and Roundup usage can be related to winter rainfall patterns, with more common use in the southern areas to control winter weeds.

Changes in weed control practices

The 1993 survey data was derived from 10 of the growers from the 1989 survey, covering 41 000 ha, representing 17% of the Australian cotton area. These results indicate that there have been major changes in the pattern of herbicide use over the last 4 years, with a general increase in the reliance on herbicides for weed control.

Table 3. Herbicide usage by the total Australian cotton industry, based on the 1993 survey of 10 growers, using an estimated area of 240 000 ha.

Herbicide	Number of applications	Rate (L/ha)	Herbicide usage '000 L	Herbicide usage % change[1]
Diuron (500 g ai / L)	1.4	2.3	722	-2
Trifluralin	1.0	3.0	647	-2
Cotogard	1.3	2.9	546	336
Cotoran	1.5	2.7	230	-20
Stomp	0.6	2.4	105	76
Gesagard	0.7	1.8	51	-57
MSMA (500 g ai / L)	0.1	2.8	10	-74
Dual	0.3	3.0	30	125
Roundup (450 g ai / L)	0.9	0.9	97	-54
2,4-D amine	1.0	1.4	74	-65
2,4-D ester	0.7	0.6	9	-46

Note[1]. The % change has been indexed to remove differences due to the area of cotton sown in 1993. A negative number indicates a reduction in the % use.

Between 1989 and 1992, there has been a 336% in Cotogard use. This can partly be related to a corresponding reduction in the use of Cotoran and Gesagard, but mostly to an increased use of Cotogard to control problem weeds, in particular *Sesbania cannabina*, and to reduce the need for chipping.

The use of trifluralin and diuron is stable, but there has been an increase in the use of Dual and Stomp, caused by the increased use of minimum tillage and permanent beds, reducing the opportunities for soil incorporated herbicides.

The use of Roundup, 2,4-D amine and 2,4-D ester probably reflects the prevailing seasonal conditions rather than a change in herbicide practices, with the observed reduction in herbicide use reflecting the drier autumn and winter in 1992 compared to 1989, with 164 mm of rain falling between April and August 1992 at Myall Vale, compared to 465 mm in the same period in 1989. The drier conditions of 1992 reduced the germination and growth of weeds, and allowed more effective weed control by cultivation, reducing the need for fallow weed control with these herbicides.

Most properties have reported a reduction in their chipping bills over this period, dropping from an average of $63 ha^{-1} in 1989, to $41 ha^{-1} in 1993. This was related to the increased use of Cotogard during this period, and generally improved hygiene on these properties, allowing the targeting of herbicides towards specific weed problems.

Herbicide induced plant establishment problems

Most properties reported occasional herbicide induced plant establishment problems due to wet conditions after planting, resulting in the herbicide being washed into the seed zone. Four of the 10 growers reported problems from diuron in the 1992/93 season, affecting 4 400 ha, or 11% of the survey area. However, the only other reported case of diuron damage occurred in the 81/82 season, indicating that although the problem can be severe, when averaged over the last 10 years it has only affected 1% of the cotton area. Two of the 4 growers also reported that the conditions which led to the cotton damage also increased the general efficacy of the herbicides, reducing the need for post-emergence herbicides and chipping. They considered that occasional establishment problems were inevitable with diuron, and that these were an acceptable risk. There were also reports of damage from Cotoran and Cotogard in the 92/93 season, Cotoran in the 91/92 season and Gesagard in the 88/89 season, although these only affected relatively small areas.

Conclusions

As the Australian cotton industry progresses in the development of minimum tillage and permanent bed management systems, there will be greater reliance on herbicides which do not require soil incorporation. This trend will be increased by the need to

reduce the reliance on chippers, brought about by constantly increasing wages, concerns for human health and difficulties in obtaining labour.

The trend towards increased reliance on herbicides will inevitably lead to increasing cotton establishment problems as herbicide rates are pushed towards maximum levels. However, the introduction of new herbicides, with greater cotton safety margins should quickly overcome this problem.

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A grower survey of weeds and herbicide use in the New South Wales cotton industry

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Summary. In 1989, 52 cotton growers from the 7 major cotton areas of New South Wales were surveyed regarding their weed-control costs, major weed problems and herbicide use. This paper presents and discusses the major results from this survey.

On average, weed control costs the cotton grower $A187/ha annually, the major components being $76/ha for cotton herbicides and $67/ha for hand chipping. The major cotton weeds are *Xanthium occidentale*, *X. spinosum*, *Cyperus* spp., *Physalis* spp. and *Ipomoea lonchophylla*. Although these weeds affect a large proportion of the cotton-growing area, their incidence is generally stable or declining under the current management systems. However, *Cyperus* spp., which presently affect 15% of the cotton area, are escaping the weed management practices and rapidly becoming the major weed problem in many fields. *Diplachne fusca* is a major weed on irrigation channels and is not controlled by the registered herbicides. Trifluralin, diuron and fluometuron herbicides are used in cotton by over 60% of cotton growers. Glyphosate is used by 59% of growers in fallows prior to cotton, and atrazine, diuron and glyphosate are used on irrigation channels by over 60% of growers.

Generally, cotton growers are dissatisfied with the high cost of weed control and the ineffectiveness of control of some problem weeds such as *Cyperus* spp.

Introduction

Seedling cotton is relatively uncompetitive, and uncontrolled weeds can result in no harvestable cotton (Keeley *et al.* 1986). Weeds reduce cotton yield directly by competing for light, nutrients and water, and they reduce cotton quality by lint contamination. Weeds may also interfere with water flow through channels and fields, reducing irrigation efficiency and increasing waterlogging, and may reduce harvest efficiency. Weeds harbour insect pests and cotton disease pathogens.

The effect of weed competition on cotton yield has not been closely examined in Australia, although results are published by researchers elsewhere. Snipes *et al.* (1987) found that *Xanthium strumarium* that emerged with cotton and was removed after only 2 weeks still reduced cotton yield. Buchanan and Burns (1970) found that weeds which emerged with cotton caused yield reductions if not controlled within 4–6 weeks, but weeds emerging after more than 8 weeks did not reduce yields. They reported up to 90% yield reductions where weeds emerged 2 weeks after cotton and were not controlled, and 85% where weeds were not controlled until 11 weeks after cotton emergence. *Ipomoea hederacea*, at only 1 plant per 2 m of cotton and planted at the same time as cotton or 4 weeks later, resulted in no harvestable cotton and an 11% yield reduction when planted at 8 weeks (Keeley *et al.* 1986).

In New South Wales, cotton growers are concerned by the inefficiencies of the current weed management strategies, the high cost of weed control, and the high cost and limited availability of hand chipping.

This paper reports the results of a grower survey of weed problems, weed-control costs, and herbicide use patterns, to identify the major short comings of the weed-control system. This information will be used to design a research program for problem weeds in Australian cotton.

Materials and methods

Survey area and data collection technique

The survey covered 52 properties in the New South Wales cotton-growing region, which was divided into 7 geographical areas based on the river valleys (see Table 1). With the assistance of District Agronomists, properties where cotton is a major farm enterprise were selected from within each valley, to give a representative geographical distribution. Only data from the Macintyre, Gwydir, Namoi and Macquarie Valleys are discussed individually.

A survey was sent to each grower, followed by an interview. Cotton growers were asked for information on their weed control in the 1988–89 season, and for information on previous seasons if 1988–89 was atypical.

Survey details and methods of analysis

The cost of weed control. Growers estimated how much they spent on weed control each year in cotton, in fallows,

and on roads and channels, expressing these per ha of cotton grown. Estimates were further divided into cultivation, herbicides and hand chipping cost components.

Where growers did not know some components, these were estimated at $A7/ha for pre-sowing cultivation for weed control; $5.70/ha for each post-sowing, inter-row cultivation; $10/ha for grading channels; $1/ha for contact herbicide applications; $7/ha for pre-sowing, soil-incorporated herbicides; $2.40/ha for post-sowing, incorporated herbicides where incorporation included an inter-row cultivation pass; and $5/ha for channel spraying, assuming channels occupied 4% of the cotton area. It was assumed that all herbicides were ground-applied. These values were average estimates from properties where this information was available. The cost of herbicides was determined from the retail herbicide price, the herbicide rate applied, application frequency and application band width.

Data from all properties were pooled and averaged, and standard errors of the means were calculated. No allowances were made for differences in property size.

Major cotton weeds. Growers ranked, in order of importance, up to 10 weeds that were the biggest problems in their cotton. They recorded the percentage of cotton affected by each weed and whether the weed problem was increasing or decreasing.

The weed importance data were tabulated, with each nominated weed receiving a value from 10 (for the most important), down to the last mentioned which would, for example, be rated 6 if 5 weeds were nominated. Weeds not nominated received 0 values. The percentage of properties affected by each weed was calculated from the proportion of properties that nominated each weed. The percentage of the area affected was averaged for all properties, including zero values where a weed was not nominated. The trend in weed incidence was ranked as 10 (a rapid increase), 0 (no change) or −10 (a rapid decrease); smaller changes were given intermediate values.

The data were pooled and averaged, and standard errors of the means were calculated.

Cotton herbicides. Growers defined their standard herbicide program, from the treatment of fallows prior to cotton, through the pre-sowing and post-sowing herbicide programs, to applications at and after defoliation. The program was defined in terms of the herbicide used, and the rate and time of application. If a herbicide was banded, the band width was given. Where a herbicide was routinely used on only part of a property, this proportion was estimated.

From these data, the percentage of properties using each herbicide was calculated, and for those properties using a herbicide, the average number of applications and rate of application were determined. The percentage of banded applications was also estimated.

The data were pooled and averaged.

Effectiveness of weed control. Growers rated their overall weed management practices from adequate (10) to inadequate (−10), or 0 if undecided. These values were pooled and averaged, and standard errors of the means were calculated. Values for the 4 main river valleys were compared.

Weeds and weed control on irrigation channels. These data were collected and analysed using the same methods as for the in-cotton data.

Table 1. Area of cotton and number of properties surveyed, and average duration of cotton growing on these properties

River valley	No. of properties	Years of cotton	Area (ha)
Macintyre	10	9	7949
Gil Gil Creek[A]	9	6	8403
Gwydir	9	8	17558[B]
Namoi	9	13	10002
Mooki	3	4	1478
Darling	2	16	7866
Macquarie	10	8	14331
Survey total	52	9[C]	67587

[A] The Gil Gil Creek system is in the Gwydir Valley.
[B] Two properties comprised the majority of this area.
[C] Average for the valleys.

Results and discussion

The properties surveyed covered 67 600 ha, representing 48% of the N.S.W. cotton area and involving 52 of the 329 cotton growers registered in N.S.W. The area surveyed in each of the river valleys is shown in Table 1.

The N.S.W. cotton area has expanded 4-fold over the last 10 years (Australian Bureau of Statistics 1978–1989). On average, the properties surveyed had been growing cotton for 9 years (Table 1), although many fields were developed more recently.

Cost of weed control

The annual cost of weed control averaged $187 per ha of cotton grown (Table 2), a total of approximately

Table 2. Variable costs ($A/ha) (mean ± s.e.) for weed control in cotton

	Cultivation	Herbicides	Chipping	Total
Cotton crop	19 ± 1	76 ± 4	67 ± 7	161
Fallow	4 ± 1	3 ± 1	—	7
Roads and channels	11 ± 1	6 ± 1	—	17

$26 million for N.S.W. The major components of this were $76/ha for herbicides in cotton and $67/ha for hand chipping in cotton. This agrees well with $165/ha, estimated by Patrick *et al.* (1990) as 12% of the total variable costs of $1400/ha for cotton growing. McMillan (1987) estimated the weed-control cost in 1984–85 at $130/ha, with $62 for herbicides, $58 for chipping and $10 for cultivation, again similar to the current estimate and indicating only a small increase in costs over time.

Although the weed-control cost is not a large proportion of the total variable costs, weed control can be very expensive in individual fields. In particularly bad fields, hand chipping alone may exceed $300/ha. The highest chipping cost recorded was $180/ha (averaged over the property), and the lowest $12/ha. On 2 properties, chipping had largely been replaced by spot spraying and shielded applications of glyphosate.

Major cotton weeds

Cotton growers identified 34 weed genera as problems in cotton, although 6 were only mentioned once. Twelve genera were important on at least 15% of the properties surveyed and are listed in Table 3.

In most cases, the important weeds affect a large proportion of the cotton area but are being controlled by the present weed management practices and have a stable or declining incidence; *Xanthium occidentale*, noted as the worst weed, affects 44% of the cotton area but is a diminishing problem, with a trend of –3.6 (Table 3). *Cyperus* spp. are the major exceptions, noted as the second worst of the weeds. They affect only 15% of the cotton area but are rapidly spreading in many fields, with a trend of 7.6. Similarly, *Sesbania cannabina*, *Haloragis glauca* and *Polymeria longifolia*, not recorded as problems by Felton (1979), are now major problems on some properties and could become industry-wide problems. This is in spite of the $187/ha spent on weed control, representing $26 million/year over the N.S.W. cotton industry, and is a major concern to cotton growers.

Of the weeds listed in Table 3, *X. occidentale*, *X. spinosum* and *Datura* spp. are large plants that compete strongly with cotton, contaminate lint and physically obstruct harvest. *Cyperus* spp., *H. glauca* and *P. longifolia* are extremely competitive plants with rhizomatous root systems, and they are difficult to control with cotton herbicides and cultivation. *Physalis* spp. and *Tribulus* spp. interfere with cultivation and harvesting and *Tribulus* spp. can also injure operators.

Generally, these are weeds of pastures and are native or naturalised in this region. *Xanthium occidentale*, *X. spinosum* and *Datura* spp. are hard-seeded and are a long-term problem. *Cyperus* spp. produces rhizomes and is resistant to cultivation, as are *H. glauca* and *P. longifolia*. With the exception of *Cyperus* spp., all of these weeds are susceptible to 2,4-D, which cannot be used in cotton.

In a survey of wheat management for northern N.S.W., Martin *et al.* (1988) found a similar spectrum of problem summer weeds, although *Cyperus* spp. were not recorded as a problem and *X. occidentale* was a lesser problem than in cotton. These differences can be expected for a non-irrigated, winter crop. Reporting the problem weeds of soybeans, Felton (1979) produced a similar list to Table 3, with the major difference being

Table 3. The weeds that growers identified as important problems in cotton

Weed importance (mean ± s.e.) was ranked from 10 to 1, where 10 means that all growers consider the weed to be the most important

For trend in incidence (mean ± s.e.), 10 is rapid increase, 0 is stable incidence and –10 is rapid decrease

Weed species	Percentage of properties affected	Weed importance	Percentage of area affected	Trend in incidence
Xanthium occidentale	87	6.6 ± 0.5	44 ± 6	–3.6 ± 1.1
Cyperus spp.	79	5.3 ± 0.5	15 ± 3	7.1 ± 0.8
Xanthium spinosum	60	4.7 ± 0.6	34 ± 6	–1.5 ± 1.0
Physalis spp.	46	3.2 ± 0.6	18 ± 4	–1.7 ± 1.2
Ipomoea lonchophylla	42	3.1 ± 0.6	20 ± 4	–1.8 ± 0.9
Hibiscus trionum	40	2.9 ± 0.6	22 ± 5	–2.9 ± 1.2
Datura spp.	38	2.6 ± 0.5	14 ± 4	–3.3 ± 1.0
Tribulus spp.	37	2.5 ± 0.5	16 ± 4	–2.5 ± 1.0
Haloragis glauca	37	1.8 ± 0.4	4 ± 2	4.2 ± 0.9
Polymeria longifolia	23	1.5 ± 0.4	3 ± 2	3.3 ± 1.3
Sesbania cannabina	25	1.4 ± 0.4	4 ± 2	6.3 ± 1.1
Echinochloa crus-galli	21	1.1 ± 0.3	10 ± 4	–3.3 ± 1.3
Salvia reflexa	17	1.1 ± 0.4	5 ± 1	–2.5 ± 1.4

Table 4. Herbicides used in cotton fields

	Percentage of properties	Average applications	Rate (L/ha)	Percentage banding[A]
Diuron	78	1.51	2.3	51
Fluometuron	63	1.15	2.5	74
Trifluralin	63	0.98	2.8	0
Cotogard[B]	49	0.93	3.2	80
MSMA	30	0.20	2.9	13
Pendimethalin	27	1.14	3.4	62
Prometryn	20	0.52	2.6	40
Metolachlor	12	0.80	2.1	100
Glyphosate	59	1.06	0.45	0
2,4-D amine	27	0.79	1.3	0
2,4-D ester	16	0.59	0.83	0

[A] Herbicide band widths varied from 0.2 to 0.67 m, with most being 0.4–0.5 m.
[B] Cotogard contains 250 g/L fluometuron and 250 g/L prometryn.

the inclusion of *Sorghum halepense*, which was a major problem weed but is now virtually eliminated from most cotton fields.

Herbicides used in cotton

The need for a pre-sowing, knock-down herbicide depended on prevailing weather conditions and the rotation practices used. Glyphosate was generally used to kill fallow weeds with minimum tillage and permanent beds, or where prolonged wet weather prevented cultivation. 2,4-D amine or ester was used at any time from defoliation through to sowing, although this practice was not popular due to the risk of damage to cotton. Glyphosate was used to spot-spray weeds in cotton, or with shielded or directed sprayers, although this was not widely practiced.

For pre-emergence grass control, 63% of growers used trifluralin (Table 4), although this herbicide requires soil incorporation and is less appropriate for late back-to-back, and minimum tillage fields, where metolachlor or pendimethalin are often substituted.

Diuron and fluometuron were used pre-sowing, at sowing, post-emergence, or a combination of these. In some situations, post-emergence fluometuron was replaced by prometryn or Cotogard, depending on the weed spectrum. Most herbicides were banded and only applied to the cotton row, to reduce the overall herbicide cost. MSMA was generally used for spot-spraying *Cyperus* spp. or *Xanthium* spp. in the crop.

Effectiveness of management systems for cotton weeds

Overall, cotton growers considered their current weed management practices unsatisfactory, although the degree of dissatisfaction varied (Table 5) and was strongest in the Macintyre and Namoi Valleys. The data show no obvious

Table 5. Effectiveness of in-cotton weed-control practices, and the breakdown of weed-control costs ($A/ha) in cotton for the main river valleys

Values are means ± s.e.
Growers replies were graded from 10 (satisfactory control) to –10 (unsatisfactory control)

River valley	Effectiveness	Chipping bill	Herbicide bill	Weed control bill
Macintyre	–6.0 ± 0.2	44 ± 10	66 ± 5	163 ± 14
Gwydir	1.1 ± 0.2	59 ± 12	73 ± 6	207 ± 14
Namoi	–5.6 ± 0.3	91 ± 18	78 ± 8	177 ± 26
Macquarie	–1.0 ± 0.3	54 ± 12	100 ± 8	209 ± 17
Overall	–0.9 ± 0.1			

reason for this variation. The weed-control costs are highest in the Gwydir and Macquarie Valleys, and the major weed problems are also at least as bad in these valleys (Table 6).

The high input of herbicides in the Macquarie Valley can be related to the high weed incidence in this region, particularly the incidence of burrs (the Macquarie had the highest incidence of 7 of the 13 major weeds), but the herbicide input appears to be resulting in relatively good weed control. Conversely, the problems in the Macintyre Valley can be related to the relatively low inputs of both herbicides and chipping in this region. The dissatisfaction in the Namoi Valley may be related to an imbalance between chipping and herbicides apparent from this survey.

Weeds of irrigation channels and storage dams

River banks, water storages and irrigation channels are sources of weed infestation. Weeds in channels restrict water flow, although weeds on storage structures may be desirable to protect and stabilise dam walls. The weed seed load in irrigation water may be quite small (up to 120 seeds/ha; Dastgheib 1989) but can be important in introducing new weed species.

In addition to the 34 genera identified as weeds in cotton, 11 new genera were identified as weeds of

Table 6. Percentage of properties adversely affected by the 8 most important weeds within each of the four major river valleys

Weed species	Macintyre	Gwydir	Namoi	Macquarie
Xanthium occidentale	41	41	9	49
Cyperus spp.	11	20	10	24
Xanthium spinosum	14	25	8	72
Physalis spp.	39	21	4	15
Hibiscus trionum	32	23	28	4
Ipomoea lanchophylla	23	42	11	4
Datura spp.	37	7	14	3
Tribulus spp.	0	28	26	8

Table 7. Weeds occurring in irrigation channels

Weed importance was ranked (mean ± s.e.) from 10 to 1, where 10 means that all growers consider the weed to be the most important

Species	Properties affected (%)	Importance
Diplachne fusca	54	4.6 ± 0.4
Cyperus spp.	34	2.4 ± 0.3
Cynodon dactylon	34	2.3 ± 0.3
Echinochloa crus-galli	24	2.2 ± 0.3
Xanthium occidentale	26	2.1 ± 0.3
Digitaria spp.	18	1.7 ± 0.3
Persicaria spp.	14	1.0 ± 0.2
Tribulus spp.	18	0.8 ± 0.2
Typha spp.	10	0.7 ± 0.2

irrigation channels, although only 3 of these 11 were important on at least 15% of properties. These important weeds are listed in Table 7.

Diplachne fusca is the major weed of irrigation channels and is difficult to control, but it is not a problem in cotton. It is a large plant which obstructs channels and it is not controlled by heavy rates of diuron, atrazine or glyphosate. It can be mechanically controlled, which may mean removal by hand, but this is expensive and time consuming. *Cyperus* spp. are not as important a problem on channels as in cotton, due to their prostrate habit, but are very difficult to control with either herbicides or cultivation. *Cynodon daetylon* is also difficult to manage with either herbicides or cultivation but may be beneficial for erosion control.

Weed management on irrigation channels

Growers reported a wide range of management practices for channel weeds, from heavy applications of residual herbicides and regular mechanical cultivation to maintain weed-free channels, to occasional applications of knock-down herbicide.

The more common herbicide programs involved heavy rates of atrazine, diuron and chlorsulfuron, for long-term weed control (Table 8), applied in combination after the last irrigation in autumn. Atrazine and chlorsulfuron are not normally used on head ditches.

Glyphosate and dicamba were used to remove weeds escaping the residual herbicides and were applied at any time. Only 4% of growers relied solely on knock-down herbicides.

Table 8. Herbicides used for weed control on irrigation channels, and percentage of properties using herbicides

	Properties using herbicides	Average no. applications	Application rate (per ha)
Atrazine	76	1.21	9.0 L
Glyphosate	73	1.91	1.9 L
Diuron	67	1.30	10.5 L
Chlorsulfuron	33	0.96	30.0 g
Pendimethalin	12	0.96	3.6 L
Dicamba	10	2.42	0.8 L

Table 9. Growers' opinions of the effectiveness of their channel weed-control practices

Growers replies were graded (mean ± s.e.) from 10 (satisfactory control) to −10 (unsatisfactory control)

Major river valley	Effectiveness
Macintyre	0.0 ± 3.3
Gwydir	5.5 ± 2.0
Namoi	−4.4 ± 2.9
Macquarie	4.0 ± 3.1
Overall	3.4 ± 1.3

Effectiveness of management systems for channel weeds

Channel weed management was more of a problem on properties that routinely use dryland rotation crops, as this effectively increases the area of channels relative to the cotton area, and some channels are not used for several seasons.

Overall, cotton growers considered that their channel weed management practices were effective, with the Namoi Valley the only region giving an unsatisfactory average response (Table 9).

Cotton weed management systems

This survey highlights the need to define the effects of weeds on cotton production and to understand the effects of management on weed populations. Weed control is based on large inputs of herbicides and hand chipping, which are in most cases reducing the incidence of problem weeds over time. Nevertheless *Cyperus* spp., *S. cannabina*, *H. glauca* and *P. longifolia* are escaping current weed management practices, reducing cotton yields, and decreasing production efficiency and profitability, and new weed problems may appear in the future. Based on the survey results, a series of experiments on *Cyperus* spp. has been commenced. These experiments will examine aspects of *Cyperus* ecology, and management systems for these weeds.

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