Cotton Research & Development Corporation

Rural Industries Research & Development Report

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Project Title: **WEED CONTROL IN COTTON**

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A final report prepared for the Rural Industries R & D Corporation

1. Non Technical Summary

a) Survey of weeds in cotton

A survey form asking the cost of weed control, the major weed problems and the herbicides used was sent to fifty two cotton growers from the seven major cotton areas of New South Wales. On average, weed control costs the cotton grower $187/ha annually. The major components of this cost are $76/ha for herbicides in cotton and $67/ha for hand chipping. The most important cotton weeds are noogoora burr, bathurst burr, nutgrass, Chinese lantern and peach vine. Although these weeds are problems on a large proportion of the cotton growing area, repeated use of herbicides, cultivation and chipping are reducing their importance. However, nutgrass, which is a major weed problem on 15% of the cotton area, is escaping the weed management practices currently used and is rapidly spreading in many fields. Brown beetle grass is an important 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 before cotton, and atrazine, diuron and glyphosate are used by over 60% of growers to control weeds on irrigation channels.

Generally cotton growers are dissatisfied with the high cost of weed control, and the ineffectiveness of control of problem weeds such as nutgrass. Growers recommended that research into nutgrass control should be given top priority.

b) Field Experiments

Aspects of nutgrass ecology and management have been examined. The principle nutgrass problem in cotton was identified as *Cyperus rotundus*, with *C. bifax* as a secondary problem.

C. rotundus reproduces asexually by underground nuts and in irrigated cotton, nuts can multiply at least 10-fold over the summer period. This rate can be reduced 80% by a directed application of glyphosate during the cotton crop, but was not altered by an application of MSMA (a commonly used herbicide). *C. bifax* has a much lower reproductive capacity, producing less than 2 nuts over summer, and the production of nuts was reduced 90% by glyphosate and 60% by MSMA, when used as directed applications in the cotton crop.

Although nutgrass (*C. rotundus*) competes strongly with cotton, it appears that cotton competes poorly with nutgrass, which was able to grow equally well in the cotton row or in the furrow. There was a strong relationship between cotton yield and nutgrass density, with high densities of nutgrass reducing cotton yield by up to 90%.

Similarly, noogoora burr competes strongly with cotton, and it was found that a single burr in 10 m of cotton could cause a 6% cotton yield reduction.

Caustic weed is a pest which is less obvious but nearly always present at high densities in cotton, although it is rarely controlled. It was found that even at high densities caustic weed causes little or no yield loss in cotton, and is easily controlled by some of the commonly used cotton herbicides.

A study on MSMA herbicide found that this chemical caused a reduction in cotton yield of up to 18% when used in the recommended manner. Also, the reduction in cotton yield was not altered by the time of day when the MSMA was applied, although applications during the warmer period (December) caused a much greater yield reduction than applications in November.

A preliminary look at the pre-emergent cotton herbicides found that none of them gave good weed control, and that regardless of any 'root pruning' effects, there was no difference between them in their effect on cotton yield.

3. Background

Weed control always features very highly in surveys of research priorities and field problems of cotton. M. Fay presented a survey of agronomists and consultants at the 1986 ACGRA Conference. This survey highlighted that weed control was the only major weed problem area which had no Government research effort. The weed control problem exists because of the high cost of control, and the severity of yield and quality penalties that occur with weeds. The environment of North-West NSW encourages weed problems, particularly when developing from dryland pasture to irrigated cropping. Extended wet periods encourage weed germination and hamper control, and flooding carries new seed into fields. With the rapid expansion of cotton into new areas and the shift to alternative methods of tillage, there are many weed problems in the industry where growers have difficulty in maintaining control.

Because the industry has had no weed research input from Government bodies, some producers and company representatives have developed strategies and experience in dealing with problem weeds. There is a need to collate this information and experience, so that it can be used to refine research project planning and also be extended to growers. However the main requirement of research is to undertake experiments which test application methods of chemicals against problem weeds such as burrs (bathurst, noogoora and datura), nutgrass and the take-alls.

4. Objectives

a) To conduct a grower survey of weeds, control practices and costs in the NSW cotton growing area, including rotation crops, fallows and channels. This information is to be collated and disseminated to the industry. The information will be used to prepare a case for the need for future weed research, and the direction of such research.

b) To instigate research into the control of broadleaf weeds, nutgrass and other problem weeds in cotton.

5. Introductory Technical Information

Weed control costs cotton growers about \$130 ha^{-1} for chemicals, cultivation and hand chipping, a total cost of over \$16 million to the NSW industry. There are many instances where costs are greater and/or management does not achieve full weed control so yield or quality is affected, resulting in substantial reductions in returns; there is no available estimate of this cost although American research data indicates that weed competition could easily account for a 20% yield reduction. Because of the expansion into new areas and the adoption of new tillage systems, there are many instances where new weed problems are being encountered.

6. Research Methodology

The survey of weeds in cotton was conducted during 1989 and analysed in 1990. A survey form was developed in consultation with researchers, consultants and cotton growers and was mailed to approximately 10 growers in each of the major NSW cotton growing areas; in all 52 growers were surveyed. The form was collected during a visit when weed control and other related matters were discussed. The information, which was largely subjective, was categorised and fed into spread sheets for statistical analysis, with means separated by standard errors. A paper presenting all the results was sent to the cooperating growers, and results were published in the Proceedings of the 1990 ACGRA Cotton Conference, The Australian Journal of Experimental Agriculture, and The Australian Cotton Grower.

A series of replicated complete block and split plot glass house and field experiments examined aspects of weed ecology and herbicide efficacy in cotton. Results were

7. Detailed Results & Discussion

a) A survey of weeds and weed control practices in the New South Wales cotton industry

The weed survey covered 52 of the 350 cotton growers registered in NSW, and 66100 ha, approximately 40% of the NSW cotton growing area. On average, these properties had been growing cotton for 9 years.

i) The cost of weed control

The average cost of growing cotton is presented in Table 1. Although the cost of weed control is not a large proportion of the total variable costs of cotton of \$1400 ha^{-1}, weed control costs can be very high on individual fields. In particularly bad fields, the hand chipping bill alone may exceed \$300 ha^{-1}. The highest chipping bill recorded was \$180 ha^{-1}, and the lowest \$12 ha^{-1}.

Table 1. The variable costs for weed control in cotton.

Inputs		\$/ha
In cotton	Cultivation	19
	Herbicides	76
	Chipping	67
In fallow	Cultivation	4
	Herbicides	3
On roads &	Cultivation	11
channels	Herbicides	6
	Total	\$187

The breakdown of weed control costs shows the reliance on herbicides and chipping for weed control in cotton. Chipping is used to remove weeds which escape the cultivation and herbicide strategies. These weeds are often in the cotton row and germinate from beneath the herbicide band. Weed problems will also be accentuated when seasonal conditions prevent the application or incorporation of herbicides (particularly pre-emergent) and delay inter-row cultivation and the application of post-emergent herbicides.

Accurate and timely applications of herbicides reduce the need for chipping, although the safety margin of the cotton herbicides is such that some chipping is always necessary.

ii) Cotton weeds

Cotton growers identified 34 weed genera as problems in cotton, although 6 were only mentioned by single growers. Fifteen genera were important in at least 4 of the 6 regions surveyed and are listed in Table 2. Of the remaining weeds, none were considered important on more than 7 of the 52 properties surveyed.

Of the 10 weeds listed in Table 2, noogoora burr, bathurst burr and datura are large plants that contaminate lint and physically obstruct harvest. Nutgrass, haloragis takeall and polymeria takeall are extremely competitive plants, with rhizomatous root systems, and are difficult to control. Chinese lantern and yellow vine interfere with cultivation and harvesting.

Generally these weeds are weeds of pastures and are native or naturalised in this region. Noogoora burr, bathurst burr and datura are hard-seeded and are a long term problem. Nutgrass produces nuts and is resistant to cultivation.

iv) Weeds of channels

River banks, water storages and irrigation channels are a potential source of weed infestation. Importantly, weeds may also restrict water flow, silting up channels and causing long term problems, although weeds on storage dams may protect and stabilise the walls of these structures.

Table 4. The problem weeds of irrigation channels listed in order of importance[1].

Weed	% of properties	Importance[1]
Brown beetle grass	54	4.6
Nutgrass	34	2.4
Couch	34	2.3
Barnyard grass	24	2.2
Noogoora burr	26	2.1
Summer grass	18	1.7
Smart weed	14	1.0
Yellow vine	18	0.8
Cumbungi	10	0.7

[1] A score of 10 would mean every grower considered the weed to be the most important.

In addition to the 34 genera identified as weeds in cotton, a further 11 were identified is weeds of irrigation channels, although only 3 of these are important weeds. The 9 weeds identified as important in at least 4 of the 6 regions are listed in Table 4; 5 of these 9 weeds were also major weed in cotton (Table 2).

Most weeds of channels were also important in cotton. Brown beetle grass is the major weed problem on channels, as it is a large plant which obstructs channels, produces large quantities of seed and is resistant to the currently registered herbicides. Nutgrass is not as important a problem on channels as in cotton, due to its prostrate habit, but is very difficult to control with either herbicides or cultivation. Couch is also very difficult to control with herbicides or cultivation, but on some properties is considered beneficial on storage dams. Smart weed and cumbungi are common weeds of water ways but were not important problems on most of the properties surveyed.

v) Channel herbicides

A wide range of channel weed control management strategies exist, ranging from heavy applications of residual herbicides and mechanical cultivation to maintain weed free channels, to occasional applications of knock-down herbicide to manage the weed population. Consequently the weed spectrum which emerges as a problem on channels reflects the weed control program. Where knock-down herbicides are used, a wide spectrum of short lived annual weeds, and perennial weeds become problems, whereas regular applications of residual herbicides selects out the small number of weeds resistant to the herbicides used.

Table 5. The irrigation channel herbicides.

Herbicide	% use	Average no	Rate (ha^{-1})
Atrazine	76	1.20	9.0 l
Glyphosate	72	1.91	1.9 l
Diuron	68	1.28	10.5 l
Chlorsulfuron	34	0.96	30 g
Pendimethalin	12	0.96	6.4 l
Dicamba	10	2.42	0.8 l

Heavy rates of atrazine, diuron, and chlorsulfuron are applied for long term residual weed control (Table 5), and are generally used in combination. Commonly a different herbicide combination will be used on tail drains and head ditches, where the herbicide could contaminate the cotton.

b) Field experiments

i) Nutgrass

Nutgrass identification

Nutgrass is a world wide problem in irrigated, summer cropping. Several nutgrass types occur in the cotton area, but their identification is uncertain, although there appear to be differences in the degree of competition in cotton and their response to control treatments.

Nutgrass types were collected from the Macquarie, Namoi and Gwydir valleys. Plants were grown in a glass house for 18 months, and identified as *Cyperus rotundus*, *C. bifax*, *C. victoriensis*., *C. difformis*, *C. alterniflorus* and *C. eragrostis*.

C. rotundus and *C. bifax* are common in cotton fields, and are serious weeds. *C. victoriensis* is very common along road sides, but has not been seen in fields. *C. difformis* has not been seen in the field, but seedlings have germinated from field soil samples. *C. alterniflorus* was found on a channel bank, and *C. eragrostis* occurs in some drains.

Efficacy of glyphosate and 2,4-D for *Cyperus rotundus* control

The efficacy of glyphosate and 2,4-D herbicides was assessed on *C. rotundus* in a fully randomised experiment with 8 treatments and 3 replicates. Herbicides were applied in summer and autumn and the treatment effects were assessed by soil sampling in the following spring.

Even in a site that appeared uniform, the nut density in the field is highly variable. Although there has been a difference in nut density between seasons, to date the treatments have had no significant effect.

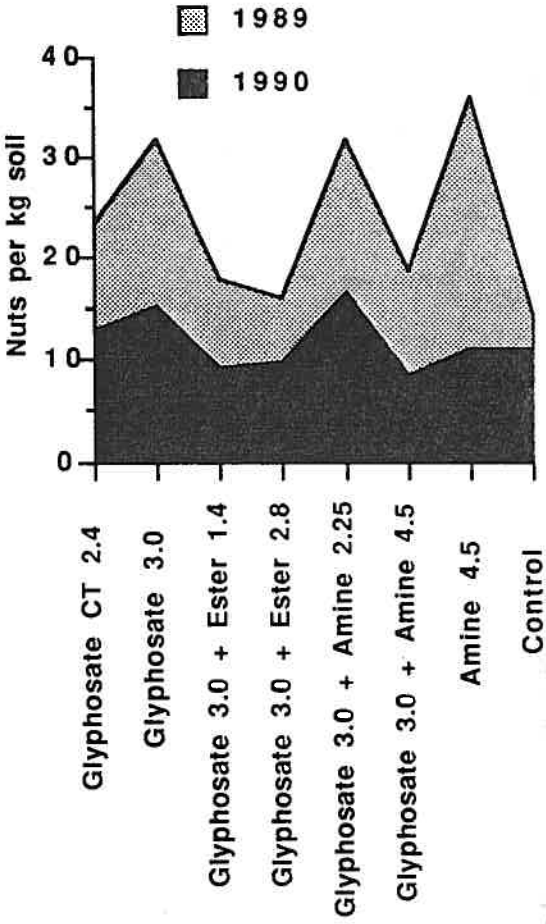

Figure 1. The average nut count in spring 1989 and 1990, from a 0 - 15 cm soil core.

The reproductive potential of translocated *Cyperus rotundus* and *C. bifax* nuts in cotton

The rapid spread of *C. rotundus* in many cotton fields can probably be attributed to frequent cultivation, and particularly inter-row cultivation during the cotton season. To assess this problem, an experiment was established to examine the fate of nuts sown into cotton and removed at known intervals. The experiment was a complete factorial using 2 species (nuts of *C.rotundus* and *C. bifax*), 3 sowing times (the start of November, December and January), 4 recovery periods (after 2, 4, 8

population per planted nut was lower from the higher nut density, although the absolute shoot density was much higher. The directed application of glyphosate reduced the shoot density by 70 to 90%. MSMA had no effect on the shoot density of *C. rotundus*, but caused a 47 to 57% reduction in the shoots of *C. bifax*.

The effect of herbicides and inter-row cultivation on *Cyperus rotundus* control in cotton

Long term field experiments were established in the Macquarie and Namoi valleys to assess the effect of herbicides and cultivation on the management of *C. rotundus* in cotton. Soil samples were taken prior to the initiation of the experiment to map the *C. rotundus* population, and at 12 monthly intervals to assess the progress of treatments. Cotton yield was also measured to determine the effect of the treatments. The experiment was a randomised complete block with 16 treatments and 4 replicate.

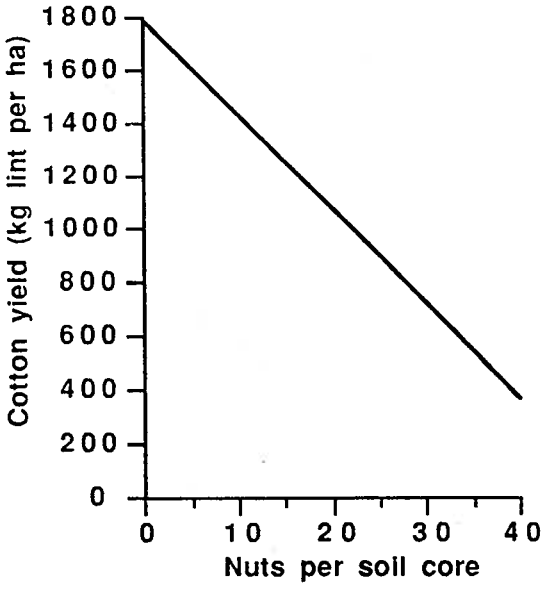

Figure 2. The relationship between cotton yield and nut density.

The treatments had no effect on cotton yield, but there was a highly significant relationship between cotton yield and the nutgrass density as determined by soil sampling.

The effect of herbicides and cultivation on *Cyperus rotundus* control in a cotton fallow

Long term field experiments were established in the Gwydir and Namoi valleys to assess the effect of herbicides and cultivation on the management of *C. rotundus* in a fallow prior to cotton. Soil samples were taken prior to the initiation of the experiment to map the *C. rotundus* population, and at 12 monthly intervals to assess the progress of treatments. The fallow will be maintained for two seasons and the *C. rotundus* competition in the following cotton crop measured to determine the effect of the treatments. The experiment is a randomised complete block with 16 treatments and 4 replicate.

ii) Appraisal of noogoora burr and datura area of influence on cotton

The area of influence of two large weed species, datura noogoora burr, was assessed by hand picking individual cotton plants within 4 m of the weed, which occurred in the cotton row.

Statistical analysis showed significant reductions in cotton yield for up to 1 m away from the weed. This means that in the field, a single noogoora burr results in a 32% reduction in cotton lint yield on average for the metre either side of the weed, which equates to a 6.4% yield reduction from a single burr in 10 m of cotton row.

Even though the site was irrigated, the herbicide response was not nearly as good as expected, apparently because the caustic weed were stressed. Diuron at 3.0 and 2.5 L gave good control (85% kill), but the non-diuron treatments were not better than the control.

Appraisal of caustic weed competition in cotton

The effect of caustic weed competition on cotton yield was assessed by a randomised complete block experiment with 6 densities and 6 replicates. Caustic weed was thinned by chipping to densities of 0, 4, 10, 20, 30 and 40 plants m^{-1} and the weight of seed cotton was recorded.

The cotton yield averaged 2825 kg ha^{-1}, with no significant effect of caustic weed density on cotton yield.

iv) The effect of MSMA on cotton

The effect of temperature and repeated applications on the efficacy of MSMA on cotton

MSMA (monosodium methanearsonate) is applied in November, December and January to control nutgrass, noogoora and bathurst burrs in cotton. The label advises that MSMA should be applied to actively growing weeds, under dry, hot conditions when air temperatures are above 21°C, but there is no data on the extent of cotton yield suppression attributable to MSMA. A randomised factorial experiment was established using 3 application temperature ranges (<20, 21-24, >26°C), 8 application times (from mid-November to late December), and 4 replicates.

Over all, spraying at the two higher temperatures reduced cotton yield by 8%. There was no yield reduction from a late November spray, a 13% yield reduction from an early December spray by itself, an 11% reduction from a late December spray alone, and an 18% reduction from spraying twice, early December and late December.

In situations of sever weed competition, the yield reduction caused by MSMA will be less than that of the competing weed species. However, this herbicide should be considered only as a last resort, and spot application should be used where ever possible.

The effect of time of day and repeated applications on the efficacy of MSMA on cotton

A factorial experiment was established using 3 application times (6 am, 10 am and 3 pm), on each of two occasions, with treatments on neither, either or both of these times and with four replicates

There was no effect of time of day on the results. Spraying in mid-December alone resulted in a 22% yield reduction, and in late-December alone caused a 23% reduction. Spraying on both occasions resulted in a 32% cotton yield reduction.

The results clearly show that there is no effect of spraying at an particular time within a day. This conclusion seems reasonable, as there is a delay between MSMA application and the onset of visible spray symptoms. It will be the average temperature for the 2 or 3 days following application which effect MSMA's efficacy, not the temperature at the moment of application, although applications in the evening, followed by a cold night, may decrease herbicide efficacy.

Table 14. The treatment effects on caustic weed density (plants m^{-2})

Herbicide	Rate		
	Nil	Normal	High
fluometuron	8.0^{Aa}	10.3^{Aa}	13.2^{Aa}
metolachlor	7.8^{Aa}	9.4^{Aa}	5.8^{Ab}
pendimethalin	8.2^{Aa}	0.9^{Bb}	0.3^{Bc}

Values in the same column, followed by the same upper case, superscript letter, and values in the same row with the same lower case super script letter are not significantly different, as separated by the Duncan's multiple range test.

There was no herbicide effect on cotton yield, which averaged 1044 kg ha^{-1} of cotton.

The retention of wheat stubble did not reduce the seedling establishment problem, and so the work will not be continued.

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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,

$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 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 dactylon* 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.

Acknowledgments

I thank Dr G. A. Constable for his assistance at all points throughout the survey and the growers who contributed their time and experience. I also gratefully acknowledge the Cotton Research Council, who funded this survey and the many growers and consultants who recognised the need for weed research in cotton.

WEEDS, A COSTLY SQUATTER?

Graham Charles, Research Agronomist (Weeds in Cotton),
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Introduction

Over the past 20 years, the Australian cotton industry has become increasingly sophisticated, until it is now a world leader. However, despite the research push in pest management, plant breeding, nutritional and soil problems, the humble weed has been a largely overlooked, but costly squatter. Weed control costs the industry about $30 million each year; the cost of reduced yields, lint contamination, increased pest and disease problems, enforced rotations, and reduced cultivation, irrigation and harvesting efficiency would far exceed this. Weeds result in the inefficient use of resources in an otherwise efficient industry.

In late 1988 a research program was commenced at Narrabri Research Station looking at weeds in cotton, jointly funded by NSW Agriculture & Fisheries and the Cotton Research Council. This project is focusing on defining the weed problems in cotton, the factors contributing to these problems and the practices available to overcome them. It has initially involved a survey of weeds and weed control practices, and the development of a weeds research program.

This article presents some of the results of the weed survey, which was conducted in 1989, covering 67 600 ha, representing 48% of the NSW cotton area, and involving 52 growers. The survey used a set format, but involved an interview where a wide range of issues were discussed.

<u>History for weeds!</u>

The cost of weed control

The first, and probably most difficult section of the survey related to the cost of weed control and the components of this cost (Table 1). There was a wide range in costs between properties, varying from $101 to $357 ha^{-1}, and averaging $187 ha^{-1}. The hand chipping cost was particularly variable, ranging from $180 (on 2 separate properties), to $12 ha^{-1}. On a couple of properties, hand chipping had largely been replaced by spot spraying and shielded applications of Glyphosate.

The current weed control strategies rely heavily on herbicides and hand chipping. Accurate and timely applications of herbicides reduce the need for chipping, but because of the marginal safety of cotton herbicides, chipping is

major exception, noted as the second worst weed. It affects only 15% of the cotton area, but is rapidly spreading in fields (trend of 7.6). Similarly, Sesbania, Haloragis Take All and Polymeria Take All are major problems on some properties, and could become industry problems.

Table 2. The problem weeds identified by farmers.

Important weed	% of Properties	Importance[1]	% of Area	Trend[2]
Noogoora burr	87	6.6	44	-3.6
Nutgrass	79	5.3	15	7.1
Bathurst burr	60	4.7	34	-1.5
Chinese lantern	46	3.2	18	-1.7
Peach vine	42	3.1	20	-1.8
Bladder ketmia	40	2.9	22	-2.9
Thornapple	38	2.6	14	-3.3
Yellow vine	37	2.5	16	-2.5
Haloragis take all	37	1.8	4	4.2
Polymeria take all	23	1.5	3	3.3
Sesbania	25	1.4	4	6.3
Barnyard grass	21	1.1	10	-3.3
Mint weed	17	1.1	5	-2.5

Note[1]. Weeds were listed in order of their importance. A score of 10 means every grower considers the weed to be the most important.

Note[2]. The trend in weed incidence. A score of 10 means the incidence is increasing, 0 the weed is stable, and -10 the incidence is diminishing.

Weeds, a growing problem!!!

Are you satisfied with your weed management strategies?

This was the obvious question to ask cotton growers. On the basis of the results listed in Table 2, the answer should be no, and this was the overall response of growers (Table 3).

This view was particularly strong in the Macintyre and Namoi Valleys. However, the data shows no obvious reason for the variation in opinion between the valleys. Although the Macintyre and Namoi valleys were the least satisfied with

Many factors influence herbicide efficacy including temperature, humidity, rainfall, soil moisture, soil nutrition, soil type, weed growth and development stage, physiological stress, accurate weed identification and herbicide application.

Table 4. Areas where cotton growers feel there is an absence of, or a need for further weed research in cotton.

Areas requiring a research input	% of growers
Nutgrass	37
Herbicide application technology	32
The development of new herbicides	28
Field evaluation of the existing herbicides	26
The development of herbicide resistant cotton	21
Strategies for channel weed control	13
Evaluation of weed herbicide resistance	13
Weed ecology	10
Cultivation technology	10
The long term effect of residual herbicides	8
The development of lower cost systems	7
Strategies for fallow weed control	4
The importance of weed seeds in irrigation water	4

The development of new herbicides and herbicide resistant cotton is impossible in this program, but there is a large need for cooperative work with the organisations involved, to integrate new and existing technology into effective weed management strategies, and to develop new strategies for the use of techniques such as minimum tillage and permanent beds, and the introduction of herbicide resistant varieties.

The need for further field evaluation of the current herbicides arises from a number of sources, including problems with weed identification, herbicide application and timing, and many other factors which influence the plant, including the other inputs into the weed management system, such as cultivation, irrigation and the other herbicides. There is a great need to look at these interactions and develop integrated weed management systems.

American data on the quantity of weed seed in irrigation water suggests that this is not an important source of weed infestation, and is far less important than good cultural practices in the cotton field.

Can you identify nutgrass?

By Graham Charles, Research Agronomist, NSW Agriculture & Fisheries, Narrabri

WHAT ACTUALLY IS NUTGRASS?

It is a serious weed of cotton, identified as an important weed on 79% of NSW cotton properties, affecting 15% of the cotton area, and becoming an increasingly important problem on most of these properties.

However, nutgrass is actually not a grass. it is a member of the sedge family Cyperaceae, genus Cyperus. Also, it is not a single species. Cunningham et al. (1981) list 23 Cyperus species in Western New south Wales, of which I have observed three species commonly occurring in the cotton growing areas. These three, collectively referred to as nutgrass, are C. rotundus, C. bifax and C. victoriensis. I've also seen isolated plants of C. difformis and C. alterniflorus.

C. rotundus, commonly known as purple nutgrass or purple nutsedge, is considered the world's worst weed and is important in 92 countries (Holm et al. 1977), including the U.S. As far as I am aware, no where in the world has a successful control system for C. rotundus been developed, although some herbicides and management strategies give some success. C. esculentus, the other important Cyperus weed problem in the U.S., is not currently a problem in the cotton areas.

"Of course I can", you reply indignantly, "it's....well.. it's.... it's nutgrass! It's green, it's a grass, it's a weed, and it's getting worse! Of course I know what it is."

C. bifax and C. victoriensis are native to Australia and have not been widely studied. Reports by cotton growers indicate that C. bifax can be controlled with glyphosate herbicide, while C. victoriensis which is widely distributed on roadways throughout the north, does not seem to be a problem in cotton.

IDENTIFICATION

These three nutgrass species appear quite similar at first glance, and can develop similar habits in some situations, but in most cases, identification is relatively easy.

In general terms, C. rotundus has the shortest stature, at around 10-15cm tall. It has dark green leaves, dark purple inflorescence and grows in dense clumps. It spreads very rapidly from underground tubers.

C. bifax is a taller plant at around 50-70cm. The leaves are paler green and the inflorescence, which may initially be brown in colour, turns orange with age. Plants occur in loose clumps.

C. victoriensis is very tall, around 100-120cm, and may have few leaves. It may have no inflorescence, or a small inflorescence with only a few spikelets.

These plants are: C. bifax (left), C. Rotundus (two middle plants) and C. victoriensis (right). The C. victoriensis plant has had a section of stem removed.

DISTINGUISHING FEATURES

The stems of C. rotundus and C. bifax are triangular throughout their length, whereas the C. victoriensis stem, which may be triangular at the top, is circular for most of its length.

C. rotundus is characterised by purple colouration at the stem base. This can be seen by stripping the outer leaves from the stem near the nut. The outer leaves of C. bifax may be a bit red, but the stem is yellow or white below this. The C. rotundus stem is distinctly purple and this colour remains true through successive layers.

THE FUTURE

In my position as Research Agronomist (Weeds in cotton), jointly funded by the Cotton Research Council and NSW Agriculture & Fisheries, I am commencing a research program on nutgrass control. This work involves experiments in back-to-back cotton and in fallow followed by cotton, and will use a field site in each of the Macquarie and Gwydir Valleys, and two sites in the Namoi. The experiments will examine the long-term effects of different nutgrass management systems, integrating fallow, cultivation and multiple uses and combinations of herbicides. The initial experiments will run over the next two to three seasons and will be supplemented by a number of subsidiary experiments.

ACKNOWLEDGEMENTS

I particularly thank Mrs. Karen Wilson, from the National Herbarium for her help in identifying these plants.

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The cost of unwanted weeds to the cotton industry

By Graham Charles, Research Agronomist, NSW Agriculture & Fisheries, Narrabri

Over the past 20 years, the Australian cotton industry has become increasingly sophisticated, until it is now a world leader, with high yields and the efficient use of resources.

However, despite the enormous research inputs into pest management, plant breeding, nutrition and soil problems, the humble weed has been a largely overlooked but costly squatter, drinking water and nutrients, and repaying with reduced yields, lint contamination and many other problems. Weed control alone directly costs the industry about $30 million each year.

TABLE 1
The breakdown of variable costs for weed control in cotton ($/ha)

	Inputs	Variable cost	Totals
In cotton	Cultivation	19	
	Herbicides	76	
	Chipping	67	161
In fallow	Cultivation	4	
	Herbicides	3	7
On roads and channels	Cultivation	11	
	Herbicides	6	17
	TOTAL		$187

TABLE 2
The problem weeds identified by farmers

Important weed	% of properties	Importance[1]	% of area[2]	Trend[3]
Noogoora burr	87	6.6	44	-3.6
Nutgrass	79	5.3	15	7.1
Bathurst burr	60	4.7	34	-1.5
Chinese lantern	46	3.2	18	-1.7
Peach vine	42	3.1	20	-1.8
Bladder ketmia	40	2.9	22	-2.9
Thornapple	38	2.6	14	-3.3
Yellow vine	37	2.5	16	-2.5
Haloragis take all	37	1.8	4	4.2
Polymeria take all	23	1.5	3	3.3
Sesbania	25	1.4	4	6.3
Barnyard grass	21	1.1	10	-3.3
Mint weed	17	1.1	5	-2.5

NOTE 1: WEEDS WERE LISTED IN ORDER OF THEIR IMPORTANCE. A SCORE OF 10 MEANS EVERY GROWER CONSIDERS THE WEED TO BE THE MOST IMPORTANT.
NOTE 2: THE PERCENTAGE OF THE AREA AFFECTED BY EACH WEED, OVER PROPERTIES.
NOTE 3: THE TREND IN WEED INCIDENCE. A SCORE OF 10 MEANS THE WEED INCIDENCE IS INCREASING RAPIDLY, 0 THAT THE INCIDENCE IS STABLE, AND -10 THAT THE WEED IS BEING CONTROLLED.

The cost of reduced yields, lint contamination, increased pest and disease problems, enforced rotations, and reduced efficiency of cultivation, irrigation and harvesting would far exceed this. Weeds result in the inefficient use of resources in an otherwise efficient industry.

By 1986 it was obvious that weed control needed a research push and a program was initiated with NSW Agriculture & Fisheries, funded jointly by the Cotton Research Council. This program, based at Narrabri, is focusing on defining the weed problems in cotton, the factors contributing to these problems and the practices available to overcome them. This has initially involved a survey of weeds and weed control practices, and the development of a research program.

This article presents some of the results of the weed survey, which was conducted in the NSW cotton industry in 1989, covering 67,600 hectares, representing 48 per cent of the NSW cotton area, and involving 52 growers. The survey used a set format, but involved an interview where a wide range of issues were discussed.

THE COST OF WEED CONTROL

The first, and probably most difficult section of the survey related to the cost of weed control and the components of this cost. There was a wide range between properties in their weed control cost, varying from $101 to $357/ha, and averaging $187/ha. The cost of hand chipping was particularly variable, with the highest cost at $180 (on two separate properties), and the lowest $12/ha. On a couple of properties, hand chipping had largely been replaced by spot spraying and shielded applications of Glyphosate.

The current weed control strategies rely heavily on the input of herbicides and hand chipping. These practices compliment each other from a management viewpoint, but regression analyses showed no relationship between the quantity of herbicide used

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present strategies (trend of -3.6 for noogoora). Nutgrass is the major exception, noted as the second worst weed. It affects only 15 per cent of the cotton area, but is rapidly spreading in fields (trend of 7.6). Similarly, Sesbania, Haloragis Take All and Polymeria Take All are major problems on some properties, and could become industry problems.

TABLE 4
Farmers' opinions of the effectiveness of their cotton weed control strategies and the break-down of the weed control costs

River valley	Strategy[1]	Chipping bill ($/ha)	Herbicide bill ($/ha)	Total weed ($/ha)
Macintyre	-6.0	44	66	163
Gwydir	1.1	59	73	207
Namoi	-5.6	91	78	177
Macquarie	-1.0	54	100	209
Over all	-0.9	67	75	186

NOTE 1: GROWERS REPLIES WERE GRADED FROM 10 IF THEIR CONTROL WAS SATISFACTORY, TO -10 IF IT WAS NOT.

The herbicides used in cotton

The third section of the survey related to the herbicide practices in cotton, attempting to define the standard practices used in the industry. The herbicide use pattern varies between products and properties, although most growers use the same pre-emergent herbicides on all fields. Post-emergent herbicide selection is related to weed pressures, although in practice similar treatments are generally used property wide.

Based on their experiences with herbicides, cotton growers differed widely in their opinion of the efficacy of individual herbicides on specific weeds. Inconsistencies are probably caused by interactions with soil types, climatic conditions, weed age and stress, application rates and application technology.

For pre-emergent grass control, most growers use Trifluralin (63 per cent), although this is less appropriate for late back-to-back, and minimum till fields, where Metolachlor or Pendimethalin are often substituted (Table 3).

Diuron and Fluometuron may be replaced by Prometryn or Cotogard, depending on the weed spectrum, but in some conditions these herbicides can damage cotton before emergence, and are most frequently used post-emergent. Most herbicides are banded and only applied to the cotton row, to reduce the overall herbicide cost.

Comparison of the average herbicide rates being used in the industry (Table 3) and the recommended rates shows that while the maximum recommended rates of the safer herbicides (such as Trifluralin) are being used, the rates of the herbicides to which cotton is more sensitive (such as Fluometuron) are well below the maximum recommended.

Are you satisfied with your weed management strategies?

This was the obvious question to ask cotton growers. On the basis of the results listed in Table 2, showing the very large proportion of the cotton area affected by the major weeds, and the increasing problem that some weeds are becoming, it seems that the answer should be no, and this was the overall response given by growers (Table 4).

This view, that the current weed management strategies are not adequate, was particularly strong in the Macintyre and Namoi Valleys. How-

The channel weeds we have and don't want!

By Graham Charles, Research Agronomist (weeds in cotton), NSW Agriculture & Fisheries, Agricultural Research Station, Narrabri

In late 1988 a research program was commenced at Narrabri Research Station looking at weeds in cotton, jointly funded by NSW Agriculture & Fisheries and the Cotton Research Council. This project is focusing on defining the weed problems in cotton, the factors contributing to these problems and the practices available to overcome them. It has initially involved a survey of weeds and weed control practices, and the development of a weeds research program.

This article presents some of the results of the weed survey, which was conducted in 1989, covering 67,600 hectares, representing 48 per cent of the NSW cotton area, and involving 52 growers. The first part of the survey, discussing the cost of weed control, and the weeds and herbicides used in cotton, was presented in the previous article.

THE WEEDS OF IRRIGATION CHANNELS AND STORAGE DAMS

In addition to the 34 genera identified as weeds in cotton and discussed in the previous article, a further 11 genera were identified as weeds of irrigation channels, although only three of these are major weeds, important on more than 15 per cent of the properties surveyed (see Table 1).

Brown beetle grass is the major weed problem on irrigation channels and is proving extremely difficult to control, but it is not a problem in cotton. It is a large plant which obstructs channels, is resistant to Diuron and Atrazine, and is burnt off by Glyphosate, but not killed. Some control can be achieved by mechanical removal, which in some situations will mean hand removal, but this is expensive and time consuming.

Nutgrass is not as important a problem on channels as it is cotton, due to its prostrate habit, but it is very difficult to control with either herbicides or cultivation. Couch is also very difficult to control with herbicides and cultivation, but may be beneficial for erosion control.

WEED CONTROL ON IRRIGATION CHANNELS

A wide range of channel weed control management strategies exist, ranging from annual applications of residual herbicides and regular mechanical cultivation to maintain weed free channels, to occasional applications of knock-down herbicide. Where knock-down herbicides are used, a wide spectrum of short lived annual weeds and perennial weeds become problems, whereas residual herbicides select out the small number of resistant weeds.

Mechanical cultivation is often used to maintain the shape and structure of channel banks, and has the added advantage of giving some weed control. However, on head ditches, where syphons run through the banks, cultivation is limited and weed control becomes more difficult.

The importance of maintaining weed free channels is difficult to assess. Weeds reduce water flow and increase silting problems in channels, but they can be beneficial in erosion control, and they may be difficult and expensive to control. Weeds such as couch are generally encouraged on supply dams for erosion control. However, any weed seeds produced on dams and in channels may end up in cotton fields.

Heavy rates of Atrazine, Diuron, and Chlorsulfuron are being applied for residual weed control (Table 2), and are applied used in combination after the last irrigation in early autumn. Atrazine

TABLE 1
The major problem weeds of irrigation channels

Important weed	% of properties	Importance[1]
Brown beetle grass	54	4.6
Nutgrass	34	2.4
Couch	34	2.3
Barnyard grass	26	2.2
Noogoora burr	26	2.1
Summer grass	18	1.7
Yellow vine	18	0.8

NOTE 1: WEEDS WERE RANKED IN ORDER OF THEIR IMPORTANCE. A SCORE OF 10 WOULD MEAN EVERY GROWER CONSIDERED THE WEED TO BE THE MOST IMPORTANT.

TABLE 2
The commonly used irrigation channel herbicides

Herbicide	% of properties	Average applications[1]	Rate (/ha)
Atrazine	76	1.21	9.0L
Glyphosate	73	1.91	1.9L
Diuron	67	1.30	10.5L
Chlorsulfuron	33	0.96	30.0g
Pendimethalin	12	0.96	3.6L
Dicamba	10	2.42	0.8L

NOTE 1: THE NUMBER OF APPLICATIONS BY THE GROWERS USING EACH HERBICIDE.

of herbicide resistant varieties.

The need for further field evaluation of the herbicides currently being used in the cotton industry arises from a number of sources, including environmental differences such as soil type, temperature and soil moisture, incorrect weed identification, and problems with herbicide application and timing. There is a great need to develop integrated weed management systems which are able to make use of the many interacting factors.

American data on the quantity of weed seed in irrigation water suggests that this is not an important source of weed infestation, and is far less important than good cultural practices in the cotton field.

Of the research priorities in Table 5, all require some input from a comprehensive weed research program, although there are limits to the number of topics that can be examined at any one time. Some research into the herbicide sensitivity of the Take All weeds has already been carried out, but there is a need to further examine these species, which are natives and largely confined to the Northern NSW irrigation areas. On the basis of the survey information, it has been determined that research into the nutgrass problem will be the top priority of this research program.

TABLE 5
The top priorities for weed research identified by cotton growers

Top research priorities	% of growers
Nutgrass	29
The development of new herbicides	16
The development of herbicide resistant cotton	11
Developing new management systems	11
Research on Take All weeds	10
The ecology of problem weeds	7
Other areas	8
No research required	6

CONCLUSIONS

Channel weeds are very obvious, but are a comparatively small problem.

There is an obvious need for a well directed weeds research program into long-term weed problems. Weeds are a major cost to the industry and there is a need to look at integrated management approaches, incorporating herbicides, cultivation, rotations and other cultural practices.

The current weeds program at Narrabri can be a vital component of the research push that is needed to evaluate our long-term problems.

Weeds, too costly to ignore!

Here today, worse tomorrow!

REFERENCE

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APPENDIX
A list of the common names used in Table 1, and their corresponding botanical names

Common name	Botanical name
Barnyard grass	*Echinochloa crus-galli*
Brown beetle grass	*Diplachne fusca*
Couch	*Cynodon dactylon*
Noogoora burr	*Xanthium occidentale*
Nutgrass	*Cyperus sp.*
Summer grass	*Digitaria sp.*
Yellow vine	*Tribulus terrestris*