COTTON RESEARCH &
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NSW AGRICULTURE

Weed Control in Cotton

Final Report

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Summary

Abstract

Nutgrass control was examined in field and glasshouse studies. A nutgrass control strategy was developed based on Zoliar and in-crop Roundup, and in-fallow, cultivation in dry conditions and Roundup in wet conditions. Many unresolved aspects of nutgrass ecology and control remain.

Future research should focus on developing weed management packages and identifying weaknesses and solutions for current and future weed management systems.

Introduction

In 1989 cotton growers identified nutgrass control as the area of highest research priority. Purple nutgrass (*Cyperus rotundus*) is the weed species most seriously affecting cotton production, although another 7 *Cyperus* species occur in the cotton area.

This project commenced in 1992 to continue the work on nutgrass ecology and control in cotton begun in project 60C.

Objectives

- *to examine the ecology of nutgrass and new and alternative nutgrass control combinations and techniques, to develop an effective, integrated nutgrass control strategy.*
- *to establish cotton plant-back periods for the commonly used rotation crop herbicides* .

Results

Aspects of nutgrass (*C. rotundus*) control have been examined in the field, glass house and laboratory.

Experiments in bare fallow at Glencoe and Norwood showed that repeated Roundup applications virtually eradicated nutgrass, with the level of control closely related to the number of treatments. Roundup applied monthly from October to May gave a 98% reduction in the nutgrass population compared to untreated plots.

In-crop experiments showed that nutgrass can be controlled with herbicides in cotton. A nutgrass control strategy based on in-crop, shielded applications of Roundup was successful in reducing the nutgrass population and the adoption of this strategy will improve with the introduction of Roundup Ready cotton (transgenic, Roundup tolerant cotton) in the near future.

Laboratory experiments found that *C. rotundus* produced large amounts of viable seed, potentially with thousands of seeds per seed-head. This seed is very hard, but storage for 12 months and treatment with potassium nitrate gave 17% germination.

Glasshouse experiments examining nutgrass control with Roundup show that nutgrass age per se has little effect on efficacy although flowering plants are generally less susceptible to Roundup than vegetative plants.

Information on herbicide plant-back periods was published in 1993 in 'The Australian Cottongrower'.

Conclusions

An effective nutgrass control strategy of Zoliar and in-crop Roundup applied through shielded sprayers, and in-fallow, of cultivation in dry conditions and Roundup in wet conditions was developed. Nevertheless, many aspects of nutgrass ecology such as seed production and its importance in infestations, tuber dormancy, the depth of shoot emergence, and herbicide translocation are still not well understood and require further work.

Future weed control research should focus on developing weed management packages and identifying weaknesses and solutions for current and future weed management systems.

Communication of Results

Every opportunity was taken to disseminate information on weed control in cotton, fallows and rotation crops through phone calls, visits, field days, seminars and conferences.

Introduction

Research into weed control in cotton began in late 1988 with the appointment of Mr Charles, as Research Agronomist (Weeds) with NSW Agriculture. The project was initially CRDC funded and was established to examine the broad topic of weed control in cotton and the need or otherwise for research into weed control. The main emphasis of the project was a survey of 52 cotton growers, collectively from the Macintyre, Gwydir, Namoi and Macquarie valleys. The survey collated grower information on problem weeds, herbicide use patterns, cultivation, cropping rotations and research priorities. The survey established that in 1989, weed control cost cotton growers on average $187/ha for chemicals, cultivation and hand chipping. There were however, many instances where costs were greater than $187/ha, and/or these inputs did not achieve the required levels of weed control, resulting in reducing cotton yield and quality, and substantially reduced grower returns. Weed control was costing the industry in excess of $26 million per year, and the cost of lost production due to lint contamination, competition from weeds and associated problems was even greater.

While many research needs were identified by cotton growers, the area of highest priority identified at this time was the control of nutgrass in cotton. The need for this research was highlighted by the survey data showing that nutgrass was a serious weed on 79% of properties and the major weed problem on 15% of the cotton area. Of the weeds growers identified, only 3 others were becoming more severe with time. These weeds were: haloragis takeall, polymeria takeall and sesbania, affecting 4, 3 and 4% respectively of the cotton growing area and 37, 23 and 25% of the properties surveyed. Consequently, research into nutgrass control was commenced by Mr Charles in 1990.

In 1991, Mr Charles identified purple nutgrass (*Cyperus rotundus*) as the nutgrass species most seriously affecting cotton production. *C. rotundus* has been described as the world's worst weed and costs the Australian cotton industry at least $13 million per year to control. It is a serious problem in many countries and many crops, particularly in irrigated, summer cropping. There are another 7 *Cyperus* species, however, which occur in the cotton area and cause some problems. The most commonly occurring of these, *C. bifax* (Down's nutgrass), is easily miss-identified as *C. rotundus*, and these 2 species have often been confused.

With this background, this project commenced in 1992 to continue the work being undertaken on nutgrass ecology and control.

Objectives

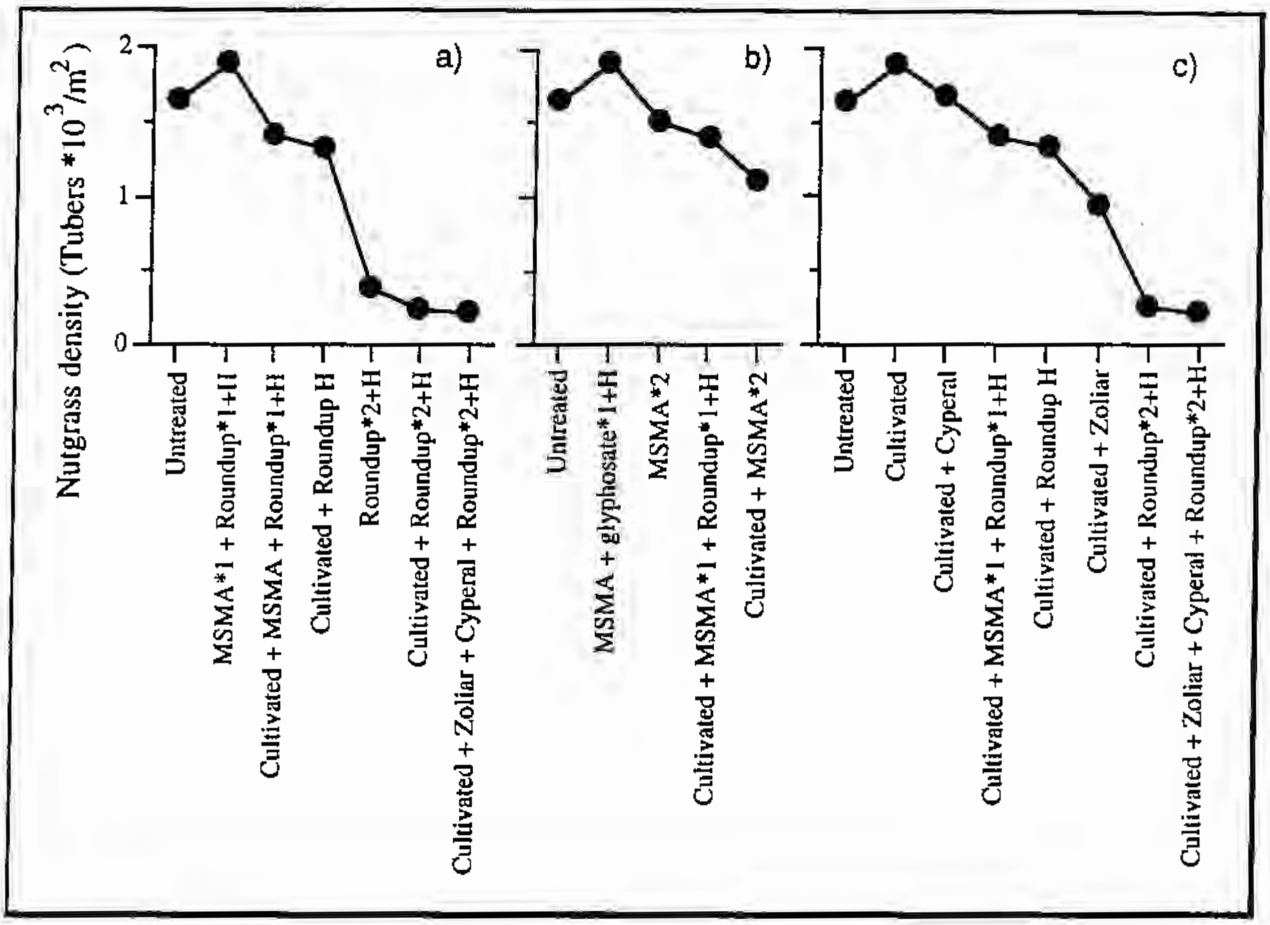
- *to examine the ecology of nutgrass and the nutgrass / cotton interaction.*
- *to evaluate the agronomic and economic efficiency of nutgrass control techniques.*
- *to examine new and alternative nutgrass control combinations and techniques, and develop an effective, integrated nutgrass control strategy.*
- *to establish cotton plant-back periods for the commonly used rotation crop herbicides and evaluate the effect of long-term use of cotton herbicides on cotton production.*

Results & Discussion

A number of aspects of nutgrass (*C. rotundus*) control were examined over the term of this project, with experiments in the field, glass house and laboratory.

The first step in the project was the completion, analysis and publication of nutgrass control information from project, DAN 60C. This information is being published and a copy of the paper is included in the Appendix. The research occurred at 'Norwood', Moree; 'Glencoe', Glencoe and; 'Wilona', Auscott Warren. The Wilona data is summarised below.

Figure 1. Nutgrass tuber density in spring 1993 following 2 years of in-crop treatments at Wilona. Roundup and Sempra applications were through a curtained sprayer. 'Roundup H' indicates a Roundup application after harvest.



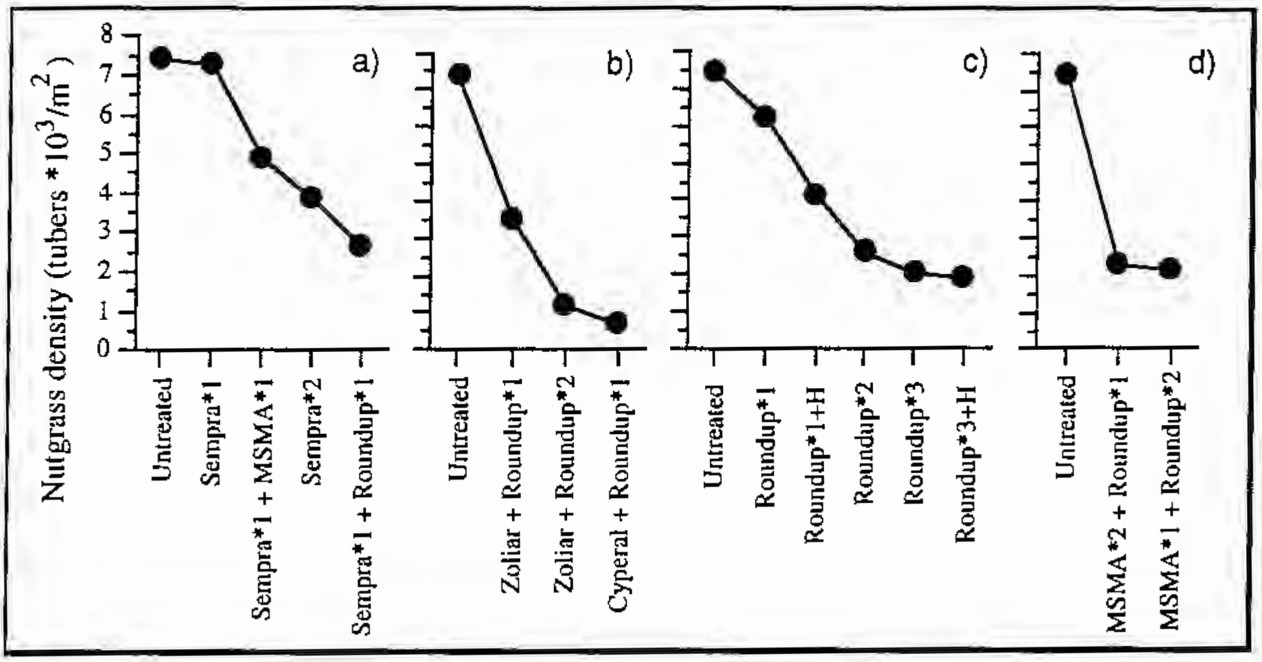
By spring 1993 at Wilona, there were huge differences between untreated plots and some treatments, with an 87% reduction in nutgrass population from the best treatment, which was a combination of inter-row cultivation, Zoliar, Cyperal and Roundup compared to untreated plots (Figure 1c); the Roundup was applied through a curtained sprayer. The more conventional treatment of MSMA and inter-row cultivation reduced nutgrass density by 32% compared to untreated plots, but had 5 times as many tubers as the best treatment (Figure 1b). Inter-row cultivation had little impact on the nutgrass population, although it appeared to enhance some treatments.

At Norwood and Glencoe, repeated Roundup applications virtually eradicated nutgrass from a fallow; the level of control was closely related to the number of treatments. The most intensive treatment of Roundup applied monthly from October to May, showed a 98% reduction in the nutgrass population compared to untreated plots.

Based on these results, nutgrass control in cotton was examined at Norwood and Wilona in 1992/93 and 1993/94, and at 'Togo' (Myall Vale) in 1994/95. This work focused on developing the successful nutgrass control treatments used at Wilona, although emphasis moved from Cyperal to Sempra, as the former herbicide will not become commercially available, whereas the later should be registered in the near future.

The Norwood site was in fallow in 1994/95, but work will continue there in 1995/96. The Wilona data is again summarised below.

Figure 2. Nutgrass tuber density in spring 1995 following 2 years of in-crop treatments at Wilona. Roundup and Sempra applications were through a curtained sprayer. 'Roundup H' indicates a Roundup application after harvest.



Nutgrass density on untreated plots rose to very high levels by the end of the experiment, but much smaller populations were present on the Cyperal + Roundup*1 and Zoliar + Roundup*2 treatments, which had 91 and 84% reductions in nutgrass population respectively, compared to the untreated plots (Figure 2b). As at Norwood, nutgrass control was improved with successive Roundup treatments (Figure 2c), with best results from Roundup*3+H, giving a 75% reduction in nutgrass population compared with untreated plots. The results for Sempra were relatively poor, with 48% reduction in the nutgrass population from Sempra*2 (Figure 2 a). The MSMA*2 + Roundup*1 treatment was very good, giving similar control to the MSMA*1 + Roundup*2 treatment (Figure 2d); the MSMA*2 + Roundup*1 treatment has the advantage of improved crop safety.

Three new experiments were conducted at Norwood. Experiment 1 examined in-crop treatments of Roundup, MSMA, Zoliar and Sempra. The best nutgrass control was achieved with Roundup*3+H, Zoliar + Roundup*3, and Zoliar + MSMA*3, respectively giving 88, 85 or 88% reductions in nutgrass density.

Experiment 2 examined the range of available herbicides which according to the literature and/or local experience had shown efficacy on nutgrass in cotton or a rotation crop; 20 different herbicides were examined in 36 treatments. The greatest reduction in nutgrass population was achieved with Cyperal (83% reduction) in one experiment, and in a second experiment, with Roundup (93% reduction), Frontier (92% reduction) and atrazine (90% reduction compared to untreated plots). The Roundup + Prep combination gave a similar level of control to Roundup alone (92% compared to 93% reduction), while atrazine + Roundup gave better control than atrazine alone (94% compared to 90%). Visually the Roundup + Cotoran combination looked very promising and gave a 75% nutgrass population reduction.

Experiment 3 further examined the Roundup + Cotoran combination, as well as Sempra by itself and in combination with Roundup. Of these treatments, the greatest nutgrass population reduction (67% compared to untreated plots) came from 3 applications of Sempra at 70 g/ha per application.

These experiments are continuing, but it is clear that nutgrass can be controlled with shielded applications of Roundup. However, this strategy has not been well accepted by growers, who are concerned by the potential for damage to cotton from Roundup drift. This problem will be overcome in the near future by the use of Roundup Ready cotton (transgenic, Roundup tolerant cotton) and the strategy will then receive much wider acceptance. Up-take of the strategy has also been slowed by the prevailing dry weather conditions, which have not favoured nutgrass growth but have favoured nutgrass control by cultivation in a bare fallow. Currently the work is concentrating on examining Roundup/MSMA, Roundup/Zoliar and MSMA/Zoliar combinations to give better nutgrass control, with improved crop safety. Work with Sempra is also continuing.

Numerous glasshouse studies have examined the biology and ecology of nutgrass (*C. rotundus* and *C. bifax*). These experiments centred around nutgrass seed production and seed viability, and the effect of nutgrass age on glyphosate efficacy.

Contrary to most published information, *C. rotundus* produces large amounts of viable seed in Australia, potentially with thousands of seeds per seed-head. This seed is very hard, but storage for 12 months and treatment with potassium nitrate gave up to 17% germination. Further work is assessing seed production and the conditions for germination. Given the high nitrate levels found in cotton fields after nitrogen application, it seems likely that nutgrass will germinate in some situations.

Work in Israel in the 1930's showed that nutgrass tubers are easily killed by desiccation if all roots are severed by cultivation in a dry soil. However, experience in Australia has shown that nutgrass control by cultivation over summer is of limited value, with gains made in some situations, but also the potential to spread the weed into previously uninfested parts of a field. The effectiveness of cultivation is influenced by the distribution of nutgrass tubers down the soil profile. Anecdotal evidence from Peter Glennie suggests there are many tubers at depths below the practical plow zone. Nutgrass tuber depth was assessed by 3 experiments at Norwood and Glencoe. At Norwood, 20 soil cores to 1 m depth were taken from a heavily infested nutgrass plot which had not been disturbed for 2 seasons. At Glencoe, 200 cores were taken from each of 2 fields which had just come out of cotton. One field had received light cultivation, while the other had been deep ripped to 40 cm prior to cotton.

	Percentage of tubers found in each soil layer.		
Soil layer	Undisturbed	Light cultivation	Deep ripped
0 to 10 cm	71	54	46
10 to 20 cm	22	34	40
20 to 30 cm	6	8	11
30 to 40 cm	1	4	3

Table 1. Nutgrass tuber distribution for 3 soil profiles. No tubers were found below 40 cm.

Soil cores revealed that most nutgrass tubers (approximately 90%) occur in the top 20 cm of the soil profile (Table 1). Although cultivation and deep ripping altered the tuber distribution, the effect was largely to increase the proportion of tubers in the 10 to 20 cm soil layer, and no tubers were found below 40 cm. This was surprising given that cultivation and ripping operations occurred prior to listering, but indicates that most nutgrass tubers should be susceptible to cultivation in a dry soil. These results suggest the apparent ineffectiveness of this treatment in Australia is related to the high water holding capacity of the heavy clay soils and the tendency for nutgrass roots to be pushed aside rather than being severed by cultivation tynes. There may be benefit from examining the choice of cultivation tyne designs and configurations for nutgrass cultivation in a fallow.

One frustrating aspect of nutgrass control in the field has been that Roundup gives very good control of nutgrass on some occasions, but is relatively ineffective on other occasions. It has been suggested that this relates to the age of the nutgrass plant and the time of year, with best control occurring when Roundup is applied to flowering plants in autumn. Field results have not always supported this observation however, so the effect of nutgrass age on glyphosate efficacy was examined in glasshouse experiments. The results of these have been very confusing, with no readily apparent explanation for differences with time. Although nutgrass is supposed to be photoperiod sensitive, flowering in autumn under reducing day-length, nutgrass appears to flower all year long.

In the first glasshouse experiment where Roundup was applied to nutgrass plants 1 to 9 weeks after first shoot emergence, very young nutgrass (sprayed 1 to 4 weeks after shoot emergence) was less affected by Roundup, as was older nutgrass (sprayed 9 weeks after first shoot emergence). In a second experiment where Roundup was applied to nutgrass plants 1 to 17 weeks after first shoot emergence, the younger plants (sprayed 1 to 11 weeks after shoot emergence) were killed by Roundup, and the older, flowering nutgrass were more tolerant of Roundup. A third experiment again found that older plants were more tolerant of Roundup. The results of later experiments have been equally confusing, although a number of conclusions can be drawn. It is clear that nutgrass age per se has little effect on Roundup efficacy, although flowering plants are generally less susceptible to Roundup. Also, generally speaking, Roundup treatments which kill the nutgrass plant also kill the tubers. It seems apparent that humidity has a large effect on Roundup efficacy by affecting leaf uptake of the herbicide and work is planned to examine additives to overcome uptake problems. Soil moisture also affects Roundup efficacy.

An extensive survey of the literature and consultation with colleagues yielded the necessary information on herbicide plant-back periods without the need for additional field experiments. This saved an enormous amount of work, as any field results are necessarily site and year specific. The information indicated a group of 9 commonly used herbicides, the use of which is likely to cause problems to cotton, and a further group of 12 herbicides which could cause problems, particularly in dry conditions. This information was published in 1993 in 'The Australian Cottongrower'.

Conclusions

The nutgrass control research has produced excellent results, with Roundup, Roundup + Zoliar and MSMA + Zoliar treatments giving large reductions in nutgrass tuber density when compared to untreated plots or compared to plots treated with the more conventional MSMA and inter-row cultivation. A nutgrass management strategy based on Zoliar and in-crop Roundup applied through shielded sprayers, and in-fallow, of cultivation in dry conditions and Roundup in wet conditions has been effective, although the success of the strategy has been limited by concerns regarding crop safety with in-crop Roundup. Nevertheless, many aspects of nutgrass ecology such as seed production and its importance in infestations, tuber dormancy, the depth of shoot emergence, and herbicide translocation are still not well understood. Future work will develop the control strategy and examine more of the important aspects of nutgrass. Transgenic, Roundup tolerant cotton will be an important tool for nutgrass control.

The cotton industry has changed over the years of this research and weed control research should reflect these changes. The tendency towards permanent beds, minimum tillage and reduced reliance on chipping are all factors which influence the success of weed control. While nutgrass remains an important weed for many cotton growers, future work should concentrate more on the problems emerging as the industry develops. The successful integration of transgenic, herbicide resistant cotton varieties into the cotton industry will be of major importance for the future. Work should focus on developing weed management packages, and identifying weaknesses and solutions for current and future weed management systems.

Communication of Results

Every opportunity was taken to disseminate information on weed control in cotton, in fallows and in rotation crops. Opportunities occurred through phone calls, visits, field days, seminars and conferences.

Below is a list of relevant publications covering the 3 years of the project. Copies of these publications are attached in the appendix.

Charles G. W. (1995). Nutgrass (*Cyperus rotundus L.*) control in cotton (*Gossypium hirsutum* L.). *Australian Journal of Experimental Agriculture.* (in press).

Charles G. W., Constable G. A. & Kennedy I. R. (1995). Current and future weed control practices in cotton: the potential use of transgenic herbicide resistance. In "The role of herbicide-resistant crops and pastures in Australian agriculture", Workshop proceedings, Barton, Canberra, March 15 - 16.

Charles, G. W. (1994). Successful nutgrass control in cotton. In "The Fabric of Success", Proceedings of the Seventh Australian Cotton Conference, Broadbeach, Queensland, p: 289 - 294.

Charles, G. W. (1994). Nutgrass in Australian Cotton. World Cotton Research Conference-1, Brisbane, Australia. p: 179.

Charles G. W. (1994). Keys to nutgrass control in cotton. *The Australian Cottongrower* **15, (6):** 73 - 74.

Charles, G. W. (1993). An update of weed control in the Australian cotton industry. A report to the Cotton Research and Development Corporation, pp. 11.

Charles, G. W. (1993). Rotation crop herbicides: the pitfalls for cotton. *The Australian Cottongrower* **14, (4):** 44 - 46.

A list of major meetings and field days attended by Mr Charles is given below.

- CRC for Sustainable Cotton Production Annual Review, June 6 1995.
- Transgenic Crops Workshop, Canberra, March 15 - 16 1995.
- Macquarie Cotton Field Day, Warren, 14 March 1995.
- Namoi Cotton Field Day, ACRI, March 2 1995.
- Joint CRC/CRDC Workshop/Review on Weed Research in Cotton, ACRI December 20 1994.
- Seventh Australian Cotton Conference, Broadbeach, August 9 - 12 1994.
- CRC Annual Program Review, 1 June 1994.
- CRC Rotation Experiments Annual Review, 31 May 1994.
- National Farm Chemical User Training Program, Narrabri, March 25 & 30 1994.
- NSW Agriculture, Weeds Sub-Program Planning Meeting, 24 May 1994.

- Walgett Cotton Field Day, Walgett, February 24 1994.
- International Cotton Research Conference, Brisbane, February 13 - 17 1994.
- Evaluation of Macquarie Nutgrass Control Program, Warren, November 5 1993.
- CRDC Soils and Farming Systems Coordination Meeting, Narrabri, December 9 & 10, 1993
- Market-Focussed Planning Workshop, Dubbo, June 23 - 25 1993.
- Cotton 2001: Vision for the Future, Narrabri March 15 - 16 1993.
- Macquarie Valley Cotton Field Day, Warren, March 11 1993.
- Gwydir Valley Cotton Field Day, Moree, March 5 1993.
- Namoi Cotton Field Day, Narrabri, March 3 1993.
- Evaluation of Macquarie Nutgrass Control Program, Warren, November 27 1992.
- 6th Australian Cotton Conference, Broadbeach, August 12 - 14 1992.

Nutgrass (*Cyperus rotundus* L.) control in cotton (*Gossypium hirsutum* L.).

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Running Header - *Nutgrass control in cotton*

Summary

The effects on cotton lint yield and nutgrass tuber density of 12 treatment combinations were examined. Treatments included pre-plant norflurazon and benfuresate, in-crop cultivation, glyphosate and MSMA, and post-harvest glyphosate. The effects on tuber density of a further 14 treatment combinations of cultivation, MSMA, glyphosate and norflurazon were examined in fallow.

Under a traditional nutgrass control program of in-cotton cultivation and MSMA, nutgrass tuber density increased from 216 tubers/m^2 (0 to 0.15 m soil core) in 1990, to 1112 in 1992, with an average cotton yield of 1239 kg lint/ha. This result compared well with the untreated control, where the tuber density increased to 1641 tubers/m^2 in 1992, with an average yield of 959 kg lint/ha. By comparison, the best treatment was a combination of norflurazon, benfuserate, glyphosate and cultivation, resulting in a tuber density of 220 tubers/m^2 in 1992 and an average lint yield of 1217 kg/ha.

Repeated applications of glyphosate in fallow effectively controlled nutgrass, with incremental improvements in control from additional glyphosate applications. Monthly glyphosate applications reduced the tuber density from 334 in 1990, to 47 tubers/m^2 in 1992 at one site, and from 334 in 1990, to 50 tubers/m^2 in 1992, on a second site.

Overall, the results showed the traditional nutgrass control techniques were unsatisfactory, but repeated glyphosate applications gave effective nutgrass control both in cotton and in fallow.

Introduction

The family *Cyperacea* includes about 220 weed species, of which *Cyperus rotundus* L., is the most serious, affecting 52 crops in 90 countries (Bendixen and Nandihalli 1987). *C. rotundus* is a highly competitive, perennial weed (Horowitz 1992). It spreads rapidly from rhizomes, which produce large numbers of underground tubers. These tubers may remain dormant in the soil for prolonged periods, avoiding most control methods.

Cyperus spp. compete strongly with cotton. In 1991, *Cyperus* spp. infested 905 000 ha (16%) of the United States cotton area (Byrd 1992), and reduced cotton lint yields by 25 400 t (112 000 bales). Chernicky and Watkins (1992) concluded that *C. rotundus* reduced cotton yields and quality, and could not be eradicated with existing technology. Patterson *et al.* (1980) found that *C. esculentus* reduced cotton yields by up to 61%, with a linear decrease in yield with increasing *C. esculentus* density.

Charles (1991) identified *Cyperus* spp. as the second most important weeds of Australian cotton production, adversely affecting 79% of New South Wales cotton properties and 15% of the cotton area (21 000 ha). The *Cyperus* spp. problem was increasing with time, in spite of an average of $187/ha spent annually on weed control in cotton.

Australian cotton growers generally consider the current *Cyperus* spp. control strategies of multiple, in-crop, inter-row cultivation passes and directed applications of MSMA, are not cost-effective, although most growers report instances of successful control. In the USA, Keeley and Thullen (1971) and Zandstra *et al.* (1974) observed effective control of *C. rotundus* with MSMA, but Australian cotton growers report mixed results. Some Australian growers also use glyphosate to control *Cyperus* spp., but with mixed results.

Charles (1992) observed 6 *Cyperus* species in the New South Wales cotton area, but reported that only *C. rotundus* and *C. bifax* C. B. Clarke. were problems in cotton. Charles (1994) identified *C. rotundus* as the major problem in Australian cotton, being far more difficult to control than *C. bifax*.

As well as in-crop cultivation, MSMA and glyphosate, 2 herbicides (norflurazon and benfuserate), were being developed by chemical companies for use in nutgrass control in Australia. Based on advice and grower experience, the most likely treatments and combinations were examined and compared with the cotton industry standard of MSMA and cultivation, to determine the efficacy of these nutgrass control options. Nutgrass tuber density and cotton lint yield were used to monitor the success of these strategies. Various combinations and strategies of cultivation, MSMA, glyphosate and norflurazon were also examined in fallow, using a range of application times, application rates and repeated applications. Nutgrass tuber density was used to determine the success of these strategies.

Materials and methods

Nutgrass control in cotton.

Experiment 1, was at Wilona, Warren (lat. 31° 48' S, long. 147° 59' E), on an alluvial soil, pH 6.7 (1:5 water) at the soil surface, to 7.4 at 0.7 m (McKenzie 1992). The field was developed in 1978 and had subsequently grown 7 cotton crops. The field was pulled into 1 m beds in February 1990, and 120 kg N/ha was applied as anhydrous ammonia. The beds were maintained with minimal disturbance, and a further 151 kg N/ha was applied in July 1991. Twelve treatments (Table 1), were randomly allocated into 2 blocks of 7 plots, with 5 replicates and 3 untreated plots per replicate. Plots were 20 m long and 4 m (4 rows) wide.

Herbicides were applied at 100 L/ha and 200 kPa nozzle pressure, using a 4 m wide, hand held boom. Norflurazon and benfuresate were incorporated with a Lilliston® cultivator. In-crop herbicides were applied using 2 directed nozzles per row, positioned to spray the inter-crop area. In 1991, the first in-crop herbicide was applied through a tractor mounted, curtained sprayer, using the same nozzle configuration. A sled cultivator with 0.46 m sweeps was used for in-crop cultivation.

Nutgrass tuber density was recorded annually in spring (25 Sept 1990, 15 Oct 1991 and 28 Oct 1992) from 14 soil cores per plot, taken from the top of the centre row, at 1 m intervals. Cores were 70 mm diameter by 150 mm deep, and tubers were counted after washing. Tuber density was estimated as tubers/m^2 and adjusted for differences in soil core length.

Cotton cv. Siokra 1-4 and cv. Siokra S324 were planted at 20 kg/ha on 1 Oct 1990 and 9 Oct 1991, respectively. The central two rows of each plot were picked with a single row, plot picker and the yield of seed cotton recorded. Sub-samples were ginned in a single saw gin, and ginning percentage and lint yield recorded.

Climatic conditions and irrigation events are presented in Figure 1.

Nutgrass tuber density data were analysed using the poisson model in GENSTAT 5. Two dimensional trends were removed as row and column effects and the spring 1990 tuber density was used as a covariate ($\log_e$) in the analysis. Standard errors are presented. Cotton ginning percentage and lint yield data were analysed using the REML model. The maximum estimated standard error of the differences is presented. Statistical significance was determined at the 5% level.

Nutgrass control in fallow.

Experiment 2 was at Norwood, Moree (lat. 29^0 26' S, long. 149^0 47' E), on a grey cracking clay, pH 7.3 (1:5 water). The field had grown 18 cotton crops before the experiment, and was redeveloped in 1977. The field was pulled into 1 m beds for cotton production in September 1990, and 200 kg N/ha was applied as anhydrous ammonia. Beds were maintained with minimal disturbance.

Eleven treatments (Table 2), were randomly allocated into two blocks of 6 plots, with 4 replicates and 2 untreated plots per replicate. Plots were 20 m long and 4 m (4 rows) wide. Cultivation treatments used a sled cultivator with 0.53 m sweeps, and hills were knocked down and reformed on each occasion.

Nutgrass tuber density was recorded annually in spring (17 Oct 1990, 4 Sept 1991 and 11 Sept 1992), as for Experiment 1.

Nutgrass shoot density was visually assessed and ranked as 0 (no shoots) to 10 (100% of ground covered by shoots) on 17 Oct 1990 and 11 May 1992.

Climatic conditions and irrigation events are shown in Figure 2.

A second site was established at Glencoe (lat. 30° 08' S, long. 149° 28' E), on a grey cracking clay, pH 7.3 (1:5 water). This experiment included 2 additional herbicide treatments (Table 3), with 4 replicates. The site received no irrigation, but otherwise was treated the same as the Norwood site.

The nutgrass tuber density data were analysed using the Poisson model, and the visual assessment was analysed using REML as described for Experiment 1.

Nutgrass competition in cotton.

Experiment 3, situated at the Australian Cotton Research Institute, Narrabri (lat. 30° 13' S, long. 149° 36'), was on a brown clay, pH 6.9 at the surface, to 8.5 at 0.7 m (McGarry *et al.* 1989).

Soil cores were taken from the hill at 1 m intervals along 10 m lengths of 2 rows, to determine nutgrass tuber density, as for Experiment 1. These transects covered the nutgrass population from zero density to maximum and back to zero density within each row. Cotton was hand-picked and each plants position and lint production recorded.

The effect of nutgrass density (tubers/m^2) on cotton lint yield (measured as lint yield reduction %) was estimated by regression analysis. A range of functions were evaluated and the data were best described by a linear function.

Results

Nutgrass control in cotton.

Experiment 1. Rainfall during the 1990/91 and 1991/92 cotton seasons at Wilona was 215 and 388 mm, respectively.

(Insert figure 1 here)

There were on average 216 tubers/m^2 at the start of the experiment at Wilona. Tuber density increased on most treatments, rising to 476 and 1188 tubers/m^2 on average in 1991 and 1992, respectively. The tuber density on Untreated plots, rose to 579 and 1641 tubers/m^2, while the density on the Cultivation + MSMA treatment, which is the industry standard, rose to 562 and 1112 tubers/m^2 after the first and second seasons, respectively. The lowest tuber densities occurred on the Cultivation + norflurazon + benfuresate + glyphosate and Cultivation + glyphosate (Treatment 7) treatments, with 220 and 241 tubers/m^2, respectively in 1992.

(Insert table 1 here)

There were no significant treatment effects on cotton ginning percentages, which averaged 44.0 and 42.7% in the 1990/91 and 1991/92 seasons.

There were significant treatment effects on cotton lint yield (Table 1), which averaged 1132 and 1017 kg/ha in 1990/91 and 1991/92, respectively; the year by treatment interaction was not significant. The Untreated plots averaged 959 kg lint/ha, 21% less than the best treatment of Cultivation + norflurazon + benfuresate + glyphosate of 1217 kg lint/ha. The Cultivation + MSMA treatment averaged 1239 kg lint/ha.

Nutgrass control in fallow.

Experiment 2. Rainfall during the 1990/91 and 1991/92 cotton seasons at Norwood was 410 mm and 687 mm, respectively.

(Insert figure 2 here)

There were on average 334 tubers/m^2 at the start of the experiment, multiplying to 3851 and 2879 tubers after the first and second seasons on the Untreated plots (Table 2). In spring 1991, the most intensive glyphosate treatment (Treatment 9) had the lowest tuber density of 867 tubers/m^2, although this was still a 160% increase on the initial tuber density. By spring 1992, the tuber density had fallen on all treatments, with the lowest tuber density of 47 tubers/m^2 on the intensive glyphosate treatment (Treatment 9).

(Insert table 2 here)

Visual assessment of the nutgrass shoot density in May 1992 (Table 2) showed the same trends as the tuber density data, with the lowest visual scores on the Glyphosate and Cultivation + glyphosate treatments (Treatments 8, 9 and 10).

Experiment 2, Glencoe. There were on average 334 tubers/m^2 at the start of the experiment, rising to 864 and 1826 tubers/m^2 after the first and second seasons on the untreated plots (Table 3). By spring 1992 there were more tubers on the Untreated plots than on any other treatment. There was a significant year by treatment interaction, with tuber density falling on most plots from 1991 to 1992, but tuber density rising on the Untreated, MSMA (Treatment 3) and Norflurazon treatments. The tuber density was generally lowest on the glyphosate and cultivation treatments (Treatments 2, 6, 7, 8, 9, and 10).

(Insert table 3 here)

Nutgrass competition in cotton.

Experiment 3. There was a strong linear relationship (R^2=0.87) between cotton lint yield reduction and nutgrass tuber density (Figure 3). The maximum observed cotton lint yield reductions of 91 and 92% occurred at nutgrass tuber densities of 3399 and 2260 tubers/m^2, respectively.

(Insert figure 3 here)

Discussion

Over the range of treatments used in Experiments 1 and 2, glyphosate applications gave the most consistent and effective nutgrass control. Repeated glyphosate applications reduced the nutgrass tuber density in fallow by 86 and 85% (Norwood and Glencoe experiments, respectively), with no live nutgrass plants remaining at the end of the experiment. However, some viable tubers remained and could rapidly reinfest this treatment under suitable conditions. Zandstra *et al.* (1974) emphasised the importance to reinfestation from viable nutgrass tubers remaining in the soil. They reported effective control of nutgrass after repeated glyphosate applications, but saw the residual population increase 5-fold over 6 weeks. Toth and Smith (1979) reported a 153-fold increase from a single tuber over one season. Given this reproductive potential, it will be essential to maintain a control program over a number of seasons to achieve effective and long-term nutgrass control.

In cotton, repeated glyphosate applications controlled the nutgrass population to a level similar to the starting population. Importantly, this nutgrass control was achieved without a significant lint yield penalty. Zandstra *et al.* (1974), and Doll and Piedrahita (1982) similarly showed that glyphosate controlled nutgrass, but since cotton is sensitive to glyphosate, its use in cotton is limited by application technology. In Experiment 1, glyphosate was applied through drop nozzles, arranged to minimise spray drift. The treatments receiving glyphosate had amongst the highest lint yields, but nevertheless, some spray drift occurred, and in 1990/91, cotton in the glyphosate treatments was visibly stunted. A curtained sprayer was used for the first glyphosate application in 1991/92, and no stunting was apparent. If glyphosate is to be routinely used in cotton, it will be necessary to use specialised spraying equipment, or glyphosate-resistant cotton varieties. It has been the risk of glyphosate damage to cotton which has limited the adoption of this strategy to date.

MSMA and inter-row cultivation have traditionally been the main components of nutgrass management in cotton. In experiment 1, directed MSMA and cultivation resulted in the highest cotton yield, but failed to control the nutgrass tuber density, which increased 415% over the experiment. MSMA applications did reduce the nutgrass density in fallow, although the effect was much smaller than the glyphosate effect. These results contrast with Keeley and Thullen (1971), who reported effective control of nutgrass with MSMA, and Zandstra *et al.* (1974), who reported similar levels of control between MSMA and glyphosate. However, Chernicky and Watkins (1992) found MSMA did not result in long-term nutgrass control, but gave a short-term reduction in nutgrass height and shoot number (less than 15 days in 1990), allowing cotton to compete more effectively. In the current work, MSMA had no effect in cotton, and a much lesser effect than glyphosate in fallow, but MSMA has the advantage that it is much less toxic to cotton than glyphosate. The combination of early in-crop MSMA, followed by glyphosate later in the season, may achieve acceptable nutgrass control levels in cotton, with improved crop safety compared to a strategy based solely on glyphosate.

Repeated cultivation controlled nutgrass in Treatment 2 at Glencoe (Experiment 2), but this result was not consistent with the other experiments. Smith and Mayton (1942) reported that cultivation controlled nutgrass, as tubers are susceptible to desiccation and are predominantly distributed near the soil surface (Toth and Smith 1979). Smith and Fick (1937) observed that tubers exposed to the soil surface in summer are rapidly killed by desiccation and high temperatures. Nevertheless, in-crop cultivation, when soil moisture levels are relatively high, is unlikely to be effective and will spread the weed (Chernicky and Watkins 1992).

However, cultivation may enhance herbicide effectiveness. Cultivation can break nutgrass chains, removing apical dominance between tubers, and encouraging tuber sprouting (Zandstra and Nishimoto 1977), leaving more tubers susceptible to later treatments. In-crop cultivation can also remove old growth and allow better herbicide penetration into the nutgrass canopy. Glyphosate efficacy may also be enhanced by cultivation through the promotion of regrowth and new growth which should give better herbicide translocation (Suwunnamek and Parker 1975).

Nutgrass was controlled by norflurazon in cotton but not in fallow. Vencil (pers. comm.) found that although norflurazon initially gave good control of nutgrass, the level of control declined to be unacceptable 10 weeks after planting. The current work indicates that norflurazon might be most effectively used in combination with glyphosate. Norflurazon is active at high soil moisture levels and is suited to use in irrigated cotton. Its efficacy in fallow was probably limited by the dry fallow conditions.

Nutgrass competes strongly with cotton under the Australian production system, with 91 and 92% cotton lint yield reductions observed at nutgrass densities of 3399 and 2260 tuber/m^2, respectively (Experiment 3). The relationship from this data (Figure 3), shows a lint yield reduction of 0.023% for each successive tuber/m^2. Based on the average Australian cotton yields for the 1990/91 and 1991/92 seasons of 1685 kg/ha (Anon 1994), this corresponds to a yield reduction of 0.39 kg lint for each successive nutgrass

Bendixen, L. E., and Nandihalli, U. B. (1987). Worldwide distribution of purple and yellow nutsedge (*Cyperus rotundus* and *C. esculentus*). *Weed Technology* 1, 61 - 65.

Byrd, J. D. (1992). Report of the 1991 Cotton Weed Loss Committee. *Proceedings of the Beltwide Cotton Conferences* **3**, 1296 - 1297.

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. (1992). Nutgrass, a problem weed: a review of the literature. *Proceedings of the Australian Cotton Conference* **6**, 191 - 196.

Charles, G. W. (1994). Nutgrass in Australian cotton. *Proceedings of the First World Cotton Research Conference*, Brisbane, 110.

Chernicky, J. P., and Watkins, S. (1992). Controlling purple nutsedge (*Cyperus rotundus*) in pima cotton (*Gossypium barbedense*). *Proceedings of the Beltwide Cotton Conferences* **3**, 1301 - 1302.

Doll, J. D., and Piedrahita, W. (1982). Effect of glyphosate on the sprouting of *Cyperus rotundus* L. tubers. *Weed Research* **22**, 123 - 128.

Hauser, E. W. (1962). Development of purple nutsedge under field conditions. *Weeds* **10**, 315 - 321.

Horowitz, M. (1992). Mechanisms of establishment and spreading of *Cyperus rotundus* - the worst weed of warm regions. *Proceedings of the First International Weed Control Congress*, Melbourne, 94 - 97.

Keeley, P. E., and Thullen, R. J. (1971). Control of nutsedge with organic arsenical herbicides. *Weed Science* **19**, 601 - 606.

McGarry, D., Ward, W. T., and McBratney, A. B. (1989). Soil studies in the Lower Namoi Valley: methods and data. 1, The Edgeroi data set. CSIRO Division of Soils **2**.

McKenzie, N. J. (1992). Soils of the Lower Macquarie Valley, New South Wales. CSIRO Division of Soils, Divisional Report No. 117. pp 73.

Patterson, M. G., Buchanan, G. A., Street, J. E., and Crowley, R. H. (1980). Yellow nutsedge (*Cyperus esculentus*) competition with cotton (*Gossypium hirsutum*). *Weed Science* **28**, 327 - 329.

Smith, E. V., and Fick, G. L. (1937). Nutgrass eradication studies: I. Relation of the life history of nutgrass *Cyperus rotundus* L. to possible methods of control. *Journal of the American Society of Agronomy* **29**, 1007 - 1013.

Smith, E. V., and Mayton, E. L. (1942). Nut grass eradication studies. III. The control of nutgrass, *Cyperus rotundus* L., on several soil types by tillage. *Journal of the American Society of Agronomy* **34**, 151 - 159.

Suwunnamek, U. and Parker, C. (1975). Control of *Cyperus rotundus* with glyphosate: the influence of ammonium sulphate and other additives. *Weed Research* **15**, 13 - 19.

Toth, J. and Smith, L. W. (1979). *Cyperus rotundus* control with glyphosate. *Proceedings of the 7th Asian-Pacific Weed Science Society Conference*, 67 - 69.

Zandstra, B. H., and Nishimoto, R. K. (1977). Movement and activity of glyphosate in purple nutsedge. *Weed Science* **25**, 268 - 274.

Zandstra, B. H., Teo, C. K., and Nishimoto, R. K. (1974). Response of purple nutsedge to repeated applications of glyphosate. *Weed Science* **22**, 230 - 232.

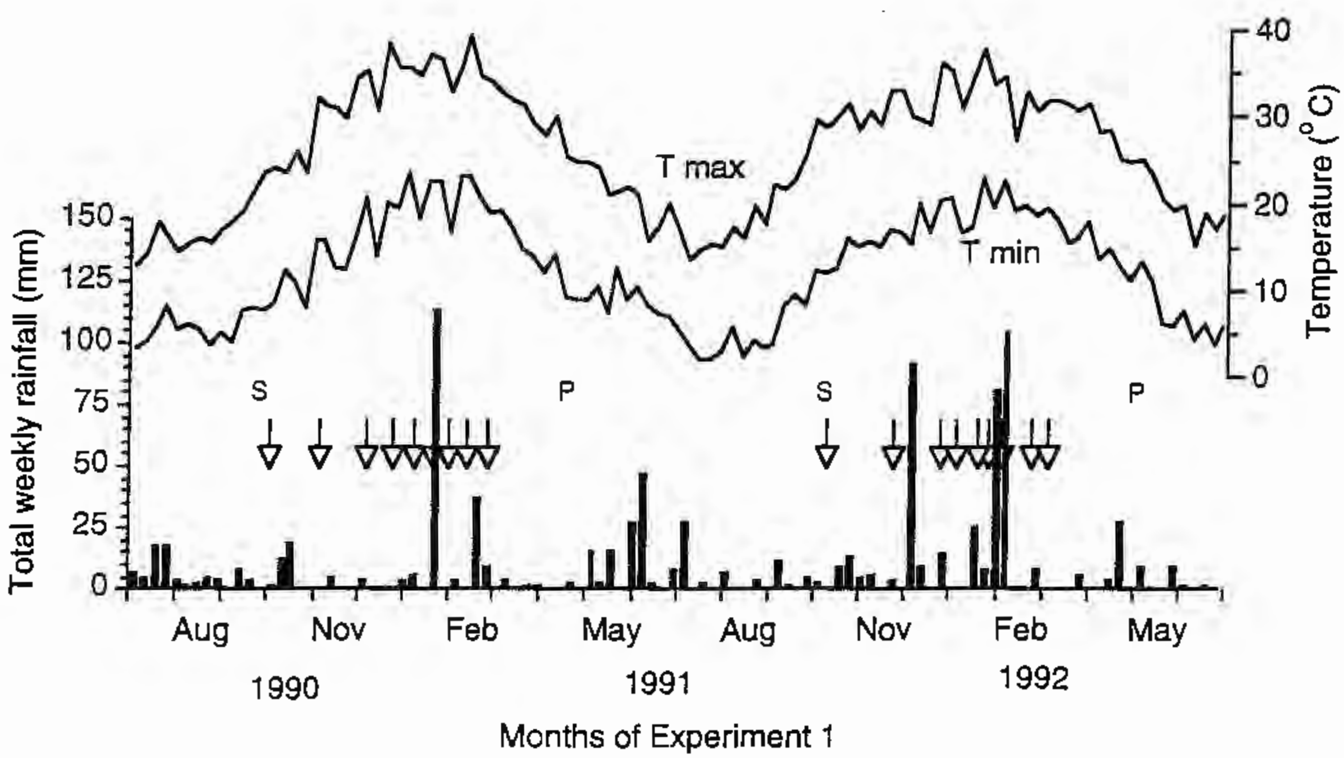

Figure 1. Climatic data for Experiment 1, at Wilona. Data are total weekly rainfall, and average weekly maximum (T max) and minimum (T min) temperatures. Arrows indicate irrigation events. "S" indicates sowing and "P" picking of the cotton.

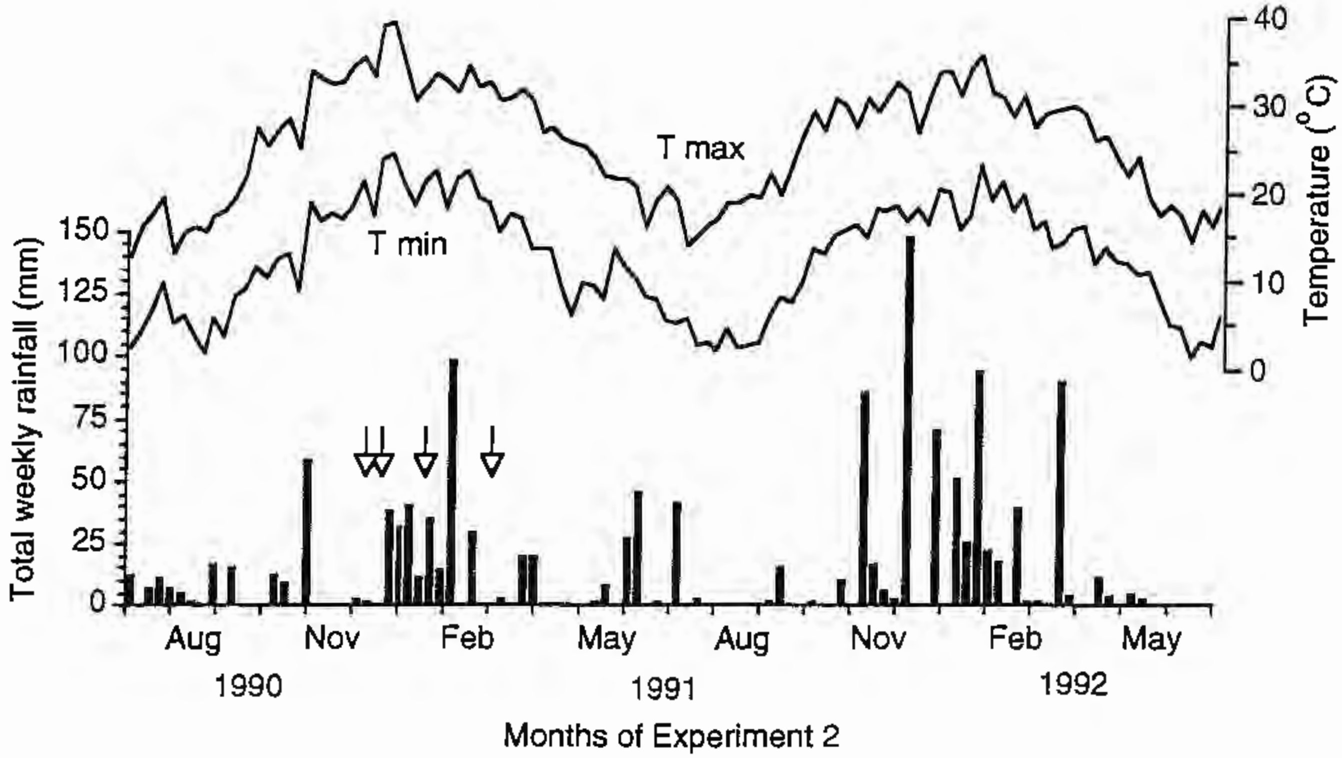

Figure 2. Climatic data for Experiment 2 at Norwood. Data are total weekly rainfall, and average weekly maximum (T max) and minimum (T min) temperatures. Arrows indicate irrigation events; the site was not irrigated in 1992.

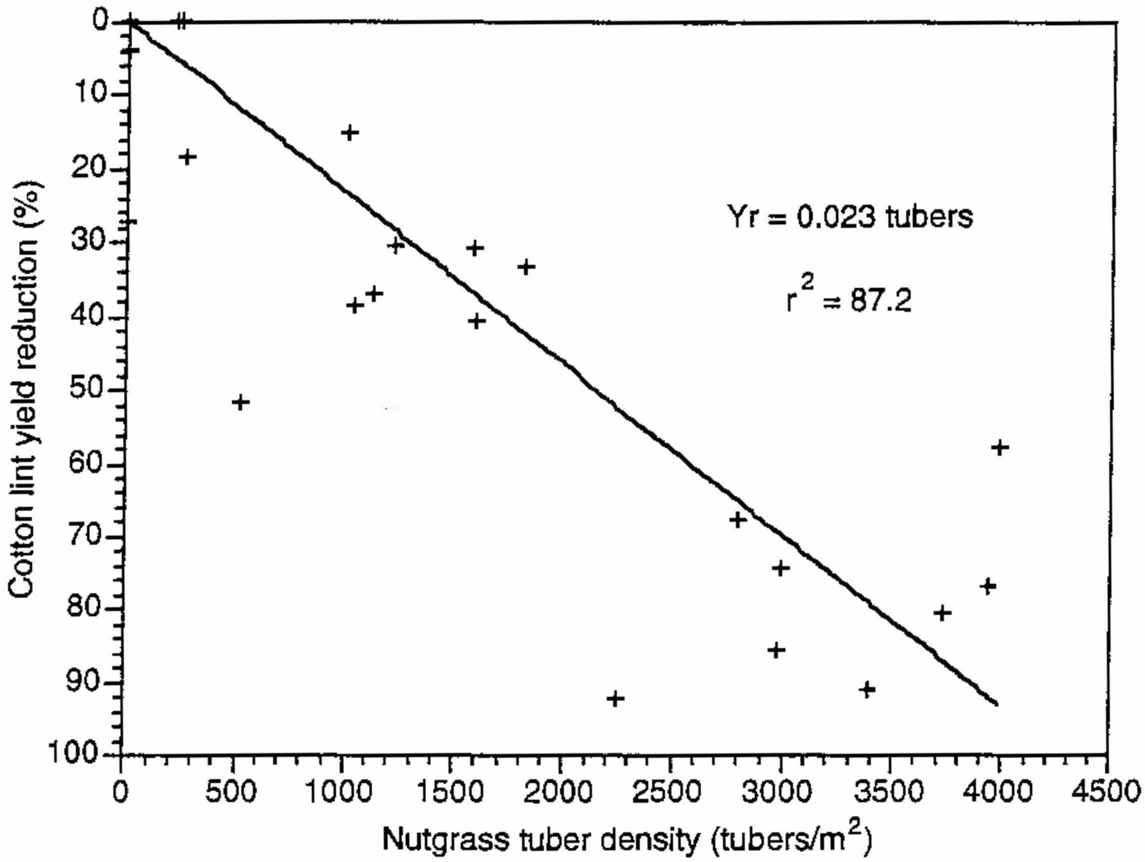

Figure 3. The relationship between cotton lint yield reduction (Yr) and the nutgrass tuber density (tubers) in Experiment 3 at Narrabri.

Table 1. Nutgrass tuber density (tubers/m^2) and cotton lint yield (kg lint/ha) for the 1990/91 and 1991/92 seasons in Experiment 1, at Wilona. The spring 1990 tuber density averaged 216 ±40 tubers/m^2. The year by treatment interaction was significant for tuber density but not for lint yield. Nutgrass tuber density treatment means are followed by standard errors in brackets. The maximum stantard error is presented for lint yield.

Weed control treatments		Time of cultivation	Herbicide rate kg a.i./ha	Time of application	Nutgrass tubers/m^2 Spring 1991	Nutgrass tubers/m^2 Spring 1992	Lint yield (Av. 1991/92)
1	Untreated	-	-	-	579 (62)	1641 (112)	959
2	Cultivated	Nov & Dec	-	-	677 (102)	1895 (179)	1094
3	MSMA	-	1.8	Dec & Jan	356 (98)	1510 (217)	919
4	Cultivation + MSMA	Nov & Dec	1.8	Dec & Jan	562 (91)	1112 (134)	1239
5	Glyphosate	-	1.1	Dec, Jan & May	305 (87)	384 (98)	1155
6	Cultivation + glyphosate	Nov & Dec	1.1	May	574 (112)	1330 (188)	927
7	Cultivation + glyphosate	Nov & Dec	1.1	Dec, Jan & May	122 (65)	241 (92)	1150
8	MSMA + glyphosate	-	1.8 + 1.1	(Dec & Jan) + May	858 (138)	1901 (219)	1034
9	Cultivation + MSMA + glyphosate	Nov & Dec	1.8 + 1.1	(Dec & Jan) + May	323 (113)	1404 (255)	1215
10	Cultivation + norflurazon	Nov & Dec	4.0	Sept	489 (117)	943 (172)	1014
11	Cultivation + benfuresate	Nov & Dec	1.8	Sept	643 (131)	1676 (230)	1090
12	Cultivation + norflurazon + benfuresate + glyphosate	Nov & Dec	4.0 + 1.8 + 1.1	Sept + Sept + (Dec, Jan & May)	222 (54)	220 (54)	1217
				Average	476	1188	1092
						Max. s.e.d.	182

Table 2. Nutgrass tuber density (tubers/m^2) in spring 1991 and spring 1992, and visual assessment, from Experiment 2 at Norwood. The spring 1990 tuber density averaged 334 ±77 tubers/m^2. The year by treatments interaction was significant for tuber density. Nutgrass shoot density was visually assessed at the end of the experiment. Plots were ranked from 0 (no nutgrass) to 10 (100% nutgrass), using estimated percentage ground cover. Nutgrass tuber density treatment means are followed by standard errors in brackets. The maximum stantard error is presented for the visual assessment.

Weed control treatments		Herbicide rate kg a.i./ha	Time of treatment	Tuber density Spring 1991		Tuber density Spring 1992		Shoot density
1	Untreated	-	-	3851	(412)	2879	(348)	9.9
2	Cultivated	-	monthly Oct to May	3578	(361)	1114	(188)	5.9
3	MSMA	2.2	Nov & Jan	5053	(843)	2895	(602)	10.0
4	MSMA	2.2	Nov, Dec, Jan & Feb	2164	(228)	789	(132)	9.8
5	MSMA	4.4	Nov, Jan, Mch & May	3086	(338)	1390	(214)	10.0
6	Glyphosate	1.1	Jan & Apl	1928	(285)	668	(163)	3.0
7	Glyphosate	1.1	Oct, Dec, Feb & Apl	1625	(205)	346	(92)	2.4
8	Glyphosate	2.2	Oct, Dec, Feb & Apl	1190	(160)	150	(52)	0.1
9	Glyphosate	1.1	monthly Oct to May	867	(149)	47	(33)	0.0
10	Cultivation + glyphosate	1.1	(Oct, Dec, Feb & Apl) + Nov, Jan, Mch & May	1170	(167)	118	(50)	0.2
11	MSMA + glyphosate	2.2 + 1.1	(Nov & Dec) + (Feb & Apl)	2062	(232)	510	(110)	1.6
			Average	2416		991		4.8
						Max. s.e.d.		0.9

Table 3. Nutgrass tuber density (tubers/m^2) in spring 1991 and 1992, from Experiment 2 at Glencoe. The spring 1990 tuber density averaged 334 ± 146 tubers/m^2. The year by treatments interaction was significant.

Weed control treatments		Herbicide rate kg a.i./ha	Time of treatment	Tuber density	
				Spring 1991	Spring 1992
1	Untreated	-	-	864 (156)	1826 (292)
2	Cultivated	-	monthly Oct to May	145 (78)	6 (13)
3	MSMA	2.2	Nov & Jan	127 (32)	322 (68)
4	MSMA	2.2	Nov, Dec, Jan & Feb	982 (339)	192 (119)
5	MSMA	4.4	Nov, Jan, Mch & May	1850 (680)	532 (251)
6	Glyphosate	1.1	Jan & Apl	444 (196)	105 (83)
7	Glyphosate	1.1	Oct, Dec, Feb & Apl	32 (15)	17 (11)
8	Glyphosate	2.2	Oct, Dec, Feb & Apl	269 (115)	76 (58)
9	Glyphosate	1.1	monthly Oct to May	893 (286)	50 (54)
10	Cultivation + glyphosate	1.1	(Oct, Dec, Feb & Apl) + (Nov, Jan, Mch & May)	481 (187)	49 (50)
11	MSMA + glyphosate	2.2 + 1.1	(Nov & Dec) + (Feb & Apl)	493 (109)	182 (47)
12	Norflurazon	4.0	Apl	627 (215)	1157 (328)
13	Glyphosate + norflurazon	1.1 + 4.0	(monthly Oct to May) + Apl	390 (267)	340 (246)
			Average	584	373

CURRENT AND FUTURE WEED CONTROL PRACTICES IN COTTON: THE POTENTIAL USE OF TRANSGENIC HERBICIDE RESISTANCE

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ABSTRACT

Research is currently under way on the development of at least four separate genes for herbicide tolerance/resistance in cotton. In one case, the technology is within a year of commercialisation in the USA. Even with regulatory approval, herbicide resistant cotton is at least three years away from release in Australia.

The current weed management practices in Australian cotton involve multiple applications of herbicides ($75/ha and $10/ha application), hand chipping ($67/ha) and cultivation ($34/ha). These practices aim for weed-free fields, at minimum cost. The industry is reducing reliance on chippers due to high cost, limited availability and health concerns.

New technology imminent in the cotton industry (pre-transgenic) includes the introduction of new herbicides and new application technology which have the potential to improve weed control and will further reduce reliance on cultivation and chippers.

Our analyses of future scenarios indicate there is potential to reduce the amount of broad-spectrum residual herbicides, by using cotton resistant to specific non-residual herbicides. There is no evidence for the potential escape of genes from cotton into weeds or other crops and it is unlikely the technology will encourage irresponsible herbicide use. Research is needed to assess the potential for weeds to develop resistance to the herbicides used with transgenic cotton. Chemical and cultural management strategies will be required to develop integrated weed management systems to minimise the chance of weeds developing resistance to herbicides and to manage the build-up of herbicide tolerant weeds.

INTRODUCTION

There are at least two potential advantages of a transgenic, herbicide resistant cotton plant. Of direct interest is better/easier/cheaper control of weeds, as the herbicide can be applied directly to the weed with minimal chance of affecting the crop. The second advantage is to reduce the use of prophylactic residual herbicides. This reduction may have direct and indirect benefits to the environment.

The most commonly raised concerns regarding the use of herbicide resistant crops are: (a) the gene might escape into other plants, particularly weeds, creating greater problems; (b) with continued use of a particular herbicide, weeds may develop resistance to that chemical and become an even greater problem; (c) heavy reliance on a single herbicide will select out a new weed spectrum tolerant to the herbicide; and (d) the technology might encourage irresponsible use of herbicides, increasing the negative side effects of chemical use.

It is the aim of this paper to review current and future weed management in cotton in Australia and impartially discuss the potential advantages and difficulties with the use of transgenic herbicide resistant cotton.

THE CURRENT INDUSTRY SITUATION

An Overview of the Cotton Industry

The Australian cotton industry is the most advanced in the world, with the highest average lint yield of the major cotton producing nations (1160 kg/ha in 1994) (Anon 1994). Initially it developed as an irrigated industry; non-irrigated cotton is becoming increasingly important, although it accounts for less than 10% of the cotton area. The irrigated and non-irrigated industries have many differences, including their approach to weed management, but can be expected to respond similarly in their approach to herbicide resistant cotton and for the purposes of this paper will be treated as one.

The cotton industry relies heavily on intensive management and pesticides, of which herbicides are a large component. The industry generally achieves high levels of weed control, with most producers aiming for weed-free fields. This is achieved by intensive herbicide use, inter-row cultivation, hand chipping and crop rotations. A typical farm program is outlined in Figure 1.

insert Figure 1 here

Weeds (Table 1) impact on cotton production in many ways. They compete directly for light, nutrients and water, thereby reducing cotton yields and delaying maturity. Weed competition for water is often the most harmful of these effects, as water is generally the most limiting input. In irrigated cotton, weeds reduce productivity by slowing the movement of water through channels and fields, delaying the timeliness of irrigation applications and increasing waterlogging, which may lead to soil compaction. Weeds at harvest contaminate cotton lint and reduce its quality and value. Many of the larger weeds, such as thornapple and noogoora burr, and twining weeds, such as peach vine and yellow vine, can also cause problems with blocking and breakages on harvesting equipment. Weeds are important hosts of pests (Fitt 1989; Wilson 1994) and diseases (Evans 1971; Cudney and others 1984; Hearn and Fitt 1992).

insert Table 1 here

The spectrum and density of weeds in cotton crops is related to geographic region, field history, soil type and management. Most cotton is grown on highly fertile flood plains with a large weed seed bank. Many of these seeds may remain dormant for long periods and cause long-term weed problems, regardless of the management imposed in any particular season. Continuing weed problems occur on low lying fields which are subject to flooding and on the 80% of farms which use river water for irrigation.

A grower survey in 1989 found that weed control cost the cotton industry $185/ha on average, of which $85/ha was spent on herbicides, $67/ha on chipping and $34/ha on cultivation (Charles 1991). Of the $85/ha for herbicides, herbicide application cost approximately $10/ha, although where possible, applications were combined with other operations, such as cultivation or planting. On an industry basis, this amounted to $20 million spent annually on herbicides and $48 million on weed control, which represented 12% of the variable costs of growing cotton in 1989. The major herbicides and quantities used in cotton are shown in Table 2.

insert Table 2 here

Weed Control Programs

Herbicide programs vary between fields and years, and are determined by management practices, soil type, rainfall, and weed species and density. Since 1989, there has been an increase in the use of broadleaf, fallow and channel herbicides (Table 2), associated with a reduction in chipping and cultivation. MSMA use has declined, and prometryn, glyphosate and dicamba use has greatly increased, with a corresponding reduction in cultivation for fallow weed control.

Generally, grasses are adequately controlled by one of the pre-emergent grass herbicides, whereas broadleaf weeds are frequently a serious problem. Of the 13 most important weeds of Australian cotton production (Table 1), 11 were broadleaf weeds (Charles 1991). Few of these weeds are reliably controlled by the currently available herbicides at rates which are selective in cotton, and many weeds emerge from below the herbicide treated layer.

The use of hand chipping is declining in the cotton industry, with a corresponding increase in the use of herbicides, particularly pre-planting broadleaf herbicides, and in-crop glyphosate through directed spot-spraying and shielded sprayers. This decline may lead to the emergence of herbicide resistant weeds. In contrast to the American cotton industry and other Australian cropping industries which are also heavily reliant on herbicides for weed control, there is as yet no evidence of herbicide resistance developing in the Australian cotton industry. One reason for this difference has probably been the heavy use of chipping and inter-row cultivation which remove any weeds not controlled by herbicides.

Pre-planting applications of diuron and fluometuron improve weed control, but movement of these herbicides into the cotton seed zone as a result of rainfall during cotton emergence can result in damage to or death of cotton seedlings. In the 1992/93 season, rainfall at planting caused herbicide related establishment problems on 13% of NSW cotton plantings, much of which required re-sowing. Nevertheless, growers consider this risk is acceptable given the improvement in weed control achieved from this practice.

The increasing use of permanent beds and minimum tillage to maintain soil structure and cotton yields, is causing further difficulties for weed control, particularly with perennial weeds and soil incorporated herbicides. Although trifluralin is relatively cheap and effective, the need for soil incorporation limits its application in minimum tillage systems, leading to its replacement by pendimathelin and metolachlor. Stubble trash is also a problem, and although the industry realises that it is undesirable to burn trash, this is currently the most efficient disposal method. Trash maintained on the surface of cotton beds cause difficulties for tillage operations and can absorb and inactivate herbicides, reducing their effectiveness.

Environmental Concerns

Cotton producers are very concerned with environmental issues including spray drift and the movement of pesticides into rivers and ground water. Currently the cotton industry relies heavily on residual herbicides which may lead to long-term environmental problems due to their long half-lives and their potential for movement in the environment. Herbicides differ markedly in water solubility, persistence and soil binding properties. Many herbicides are soluble in water and consequently prone to leaching if they are not firmly bound to soil. Binding to soil can occur either by adsorption on the surface of clay, such as with positively charged ions like paraquat, or by binding to organic matter, as occurs with lipophilic compounds such as trifluralin.

Atrazine is the only commonly found herbicide in ground water, partly because of its moderate solubility in water, but also because it is relatively persistent. In a 1993/94 study in the Namoi Valley (Cooper 1994), diuron and atrazine were found in river water, sometimes exceeding the recommended guidelines for drinking water. In this study, fluometuron, metolachlor and prometryn were also infrequent contaminants of surface water. In response to this report, atrazine use has been restricted in the cotton industry.

THE IMMEDIATE FUTURE FOR WEED MANAGEMENT IN COTTON

New Herbicides

There have been no new herbicides introduced to the cotton industry in the past decade. However, two new herbicides are likely to be registered in the next few years. These are pyrithiobac (Staple®), which has activity on some broadleaf weeds, and halosulfuron-methyl (Sempra®), primarily for nntgrass control.

Although nutgrass is a major weed problem in cotton, it adversely affects only about 15% of the cotton growing area (Charles 1991). Cotton is not tolerant of halosulfuron-methyl and this product will need to be applied through shielded-sprayers. This limitation will restrict the use of halosulfuron-methyl and its limited weed spectrum will have little impact on the overall weed control program.

By contrast, pyrithiobac is expected to have a marked impact on the cotton industry. It can be applied post-emergence, over the top of cotton; the first broadleaf herbicide to fill this niche. Pyrithiobac controls Noogoora and Bathurst burr, Chinese lantern, peach vine, thornapple, yellow vine and sesbania. It will probably have its biggest impact in the Central Queensland cotton growing area, where sesbania has been a major weed problem for many years.

With the wide-spread use of pyrithiobac and minimum tillage, it is likely that weed control systems will evolve along the lines of Table 3 (system F1), with an increase in the use of glyphosate, a reduction in fallow and inter-row cultivation and chipping, and substitution of pendimethalin for trifluralin and pyrithiobac for diuron. While these changes seem minor, pyrithiobac is one of the new generation of herbicides, effective at 75 g a.i./ha. If pyrithiobac captures 50% of the broadleaf herbicide market, the net effect will be a 135 000 kg a.i. (12%) reduction in the amount of herbicides used in the cotton industry.

insert Table 3 here

New Technology

The increased use of glyphosate by the cotton industry caused by a reduction in cultivation may be partly offset by the introduction of new technology, where the presence of a weed is detected by sensors which then activate spray nozzles (Felton and others 1992). This technology can have a big impact, particularly in fallow situations where there are low weed densities. A weed activated sprayer can control these weeds while only spraying a small proportion of the total area, with potential reductions in herbicide use of around 90%. Unfortunately this equipment is expensive and has had limited adoption. The price of glyphosate has been dropping and in many situations the saving in herbicide with the weed activated sprayer has not covered the additional costs of the equipment.

Further into the future, the development of computerised scanning equipment which can identify cotton plants will allow much greater accuracy for inter-row cultivation and may eventually replace large-scale chipping. Equipment currently in development will allow extremely accurate tracking through the field, enabling greater precision for inter-row cultivation, reducing the amount of plant damage and increasing the effective cultivation area. Future developments may enable identification of every cotton plant in the row and allow the removal of all other plants from between and within the plant row. This technology allows the development of a farm system with no chipping component (farm system F2), but it will be very expensive and cost may again limit its adoption.

TRANSGENIC HERBICIDE RESISTANT COTTON

We are currently aware of the development of herbicide resistance in cotton to four separate herbicides, although other resistance genes are likely to be developed in the future. These four herbicides are i) 2,4-D, ii) bromoxynil, iii) glyphosate, and iv) a sulfonylurea.

2,4-D Resistance

Resistance in cotton to 2,4-D was developed in Australia and the USA some years ago. The resistance gene was developed to protect cotton from 2,4-D damage from spray drift, rather than to encourage the use of 2,4-D in cotton. In Australia, spray drift from 2,4-D applications is primarily a problem in the mixed-cropping areas of the Darling Downs (Qld) and the Liverpool Plains (NSW).

Bromoxynil Resistance

Resistance in cotton to bromoxynil has been developed by Calgene and Rhone-Poulenc and could be commercially available in the US by 1995. In Australia, the resistance gene could be commercially available towards the end of this decade.

Cotton with the bromoxynil resistance gene (Bromotol™) has been grown experimentally in the US for several seasons and is giving yields at least equal to commercial varieties (Ward and others 1993). Cotton plants with the Bromotol™ gene are tolerant to bromoxynil at rates as high as 10 times the anticipated use rate is 1.7 kg a.i./ha (McLaughlin 1993). At 1.7 kg a.i./ha, bromoxynil controls a wide range of broadleaf weeds, but has no efficacy on grass weeds.

Bromoxynil is effective on small weeds but will not control large, well established plants. Of the weeds in Table 2, bromoxynil is only registered for control of *Salvia reflexa*, although it does control some species of *Ipomoea*, *Xanthium* and *Sesbania* (McLaughlin 1993) and *Datura stramonium* (Grey and others 1993).

US reports (McLaughlin 1993; Richburg and others 1993; Wilcut and others 1993), indicate that bromoxynil resistance will be a useful weed management tool, but that bromoxynil will aid rather than replace the existing residual herbicides. A likely bromoxynil scenario includes pre-planting trifluralin, post-planting fluometuron and two post-emergence bromoxynil applications, possibly one combined with an MSMA application (system FB, Table 4). Inter-row cultivation and some chipping will still be necessary to control grass weeds and some broadleaf weeds.

Glyphosate Resistance

Glyphosate resistance has been developed in cotton by Monsanto and could also be commercially available by the end of this decade. In Australia, the glyphosate resistance gene is currently being incorporated into material by cotton breeders with both DeltaPine and CSIRO.

No trial results are available for cotton with the glyphosate resistance gene, but Monsanto claims good expression of this gene has been achieved and cotton is not affected by over-the-top applications of 1.0 L a.i./ha glyphosate during early growth. Assuming good expression of glyphosate resistance and no adverse effects on cotton, a possible scenario for glyphosate resistant cotton includes pre-planting trifluralin and three post-emergence glyphosate applications. This system (FG, Table 4) requires no inter-row cultivation or chipping. However, with almost total reliance on non-residual herbicides, this system may break down when very wet or windy conditions prevent applications being made. Problems will occur with the development of a new weed spectrum including the few weeds not controlled by glyphosate, such as medics and clovers. These weeds may be adequately controlled by cropping rotations and 2,4-D applications in winter, or it may be necessary to occasionally use another herbicide.

The heavy reliance of system FG on glyphosate will increase the risk of cotton weeds developing resistance to glyphosate. However, even though glyphosate has been widely and repeatedly used for many years, to date there has been no report any where in the world of weeds developing resistance to glyphosate.

Sulfonylurea Resistance

DuPont has been developing transgenic cotton resistant to the sulfonylurea herbicides. This system has the major advantage that the sulfonylureas are phytotoxic at very low rates and should result in a large reduction in the total amount of herbicide used. No other information on this development is currently available.

FUTURE WEED MANAGEMENT SYSTEMS

A Comparison of the Systems

A generalised comparison of the likely farm systems is presented in Table 4. The current farm system (C) relies heavily on residual herbicides, chipping and cultivation. We anticipate a decline in chipping and cultivation in the near future with the introduction of pyrithiobac (system F1), with no additional cost to growers. Pyrithiobac use will result in big savings to growers who have large problems with sesbania, thornapple and the burrs, as these growers currently have chipping bills which run into hundreds of dollars per ha. Pyrithiobac will also be important to growers who have difficulty in obtaining chipping teams. Under the

Ward, R., Baldwin, G., Stanton, J., Panter, D. & Kiser, J. (1993) Yield potential of Bromotol™ cotton strains containing Buctril® resistance. Abstract only, *45th Cotton Improvement Conference, Proceedings Beltwide Cotton Conferences*, 2: 617.

Wilcut, J. W., Eastin, E. F. & Richburg, J. S. (1993) Buctril systems and efficacy for transgenic cotton in Georgia. Abstract only, *17th Cotton Weed Science Research Conference, Proceedings Beltwide Cotton Conferences*, 3: 1524.

Wilson, L. J. (1994) Habitats of twospotted spider mites (*Acri: tetranychidea*) during winter and spring in a cotton producing region in Australia. *Environmental Entomology* (in press).

Table 1. Major problem weeds of the Australian cotton industry as identified by Charles (1991).

WEED SPECIES	COMMON NAME
Xanthium occidentale	Noogoora burr
Cyperus spp.	nutgrass
Xanthium spinosum	Bathurst burr
Physalis spp.	Chinese lantern
Ipomoea lonchophylla	peach vine
Hibiscus trionum	bladder ketmia
Datura spp.	thornapple
Tribulus spp.	yellow vine
Haloragis glauca	takeall
Polymeria longifolia	takeall
Sesbania cannabina	sesbania
Echinochloa crus-galli	barnyard grass
Salvia reflexa	mintweed

Table 2. Herbicides used by the Australian cotton industry, estimated from Charles 1991, based on a cotton area of 260 000 ha.

HERBICIDE CHEMICAL NAME	TRADE NAME	AMOUNT USED ('000 kg a.i. in 1989)	
PRE-EMERGENT GRASS CONTROL			Totals
Trifluralin	various	180	
Pendimethalin	Stomp®	61	
Metolachlor	Dual®	17	257
PRE-/POST-EMERGENT BROADLEAF CONTROL			
Diuron	various	482	
Fluometuron	Cotoran®	193	
Prometryn	Gesagard®	80	
MSMA	various	21	776
FALLOW WEED CONTROL			
2,4-D	various	52	
Glyphosate	various	45	98
CHANNEL WEED CONTROL			
Atrazine	various	43	43
		Industry total	1174

Table 3. Examples of possible future farm programs arising from the adoption of minimum tillage and pyrithiobac (F1) and the adoption of accurate computer guidance systems (F2).

MONTH	CURRENT FARM PROGRAM (C)	FUTURE FARM PROGRAM (F1)	FUTURE FARM PROGRAM (F2)
August	glyphosate	glyphosate	glyphosate
September	trifluralin	pendimethalin	pendimethalin
October	fluometuron	fluometuron	fluometuron
November	cultivation & chipping	cultivation	cultivation
December	cultivation & diuron	pyrithiobac	pyrithiobac
January	chipping	cultivation & chipping	cultivation
June	cultivation	2,4-D amine	2,4-D amine
July	2,4-D amine	glyphosate	glyphosate

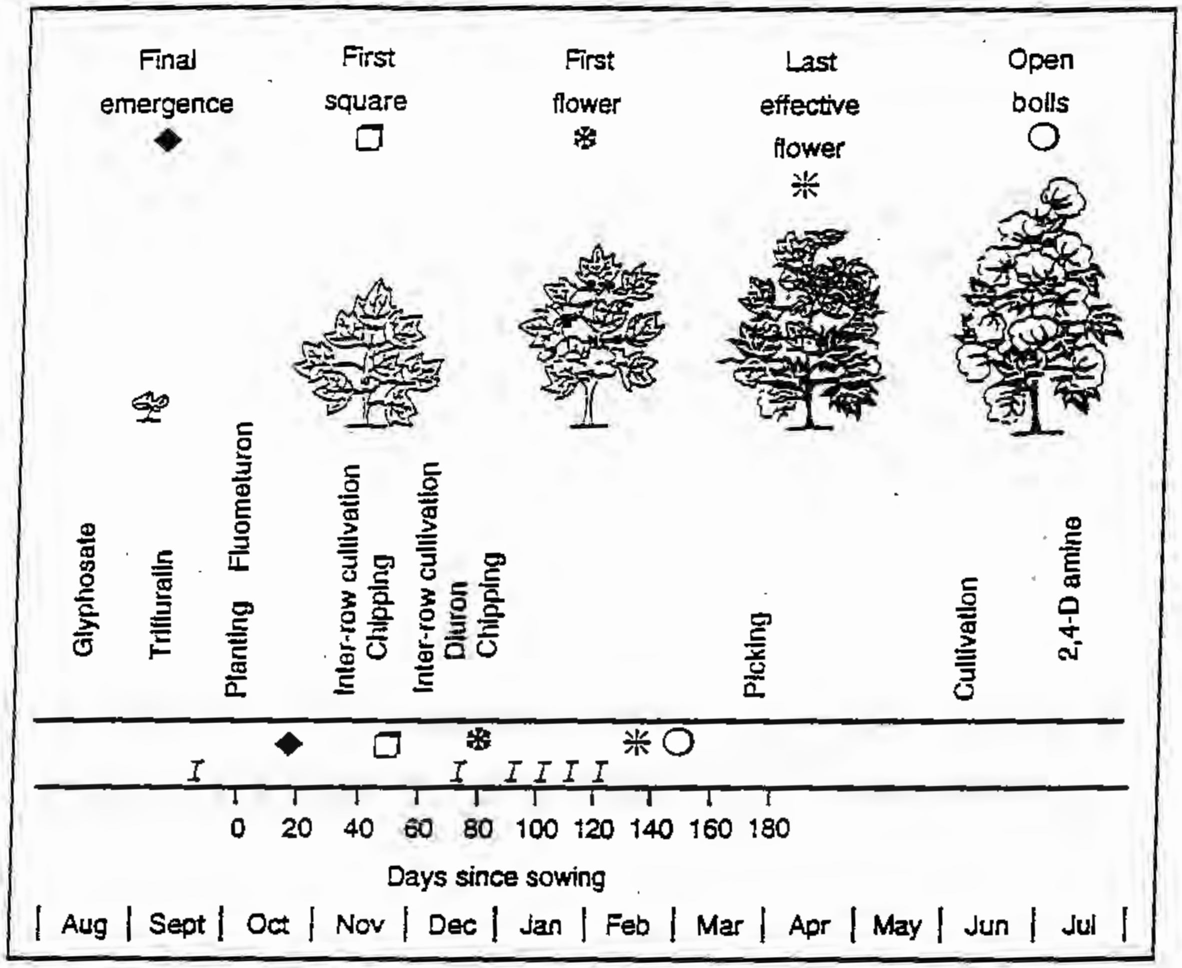
Table 4. A comparison of current and future weed management systems for Australian cotton production. This table excludes channel weed control. Costs are based on Patrick (1994). We have assumed no additional cost for herbicide resistant cotton seed. The pyrithiobac price* is an estimate only.

	RATE (L)	BAND (%)	COST ($/L)	APPLICAT-ION COST	TOTAL COST ($/ha)
CURRENT FARM SYSTEM (C)					
glyphosate	1		11.25	2.27	13.52
trifluralin	2.8		7.00	6.00	25.60
fluometuron	5	50	13.30		33.25
chipping	2			25.00	50.00
inter-row cultivation	2			4.83	9.66
diuron	2.3	50	12.26		14.10
cultivation				5.60	5.60
2,4-D amine	1.3		5.75	2.27	9.75
				Total	161.48
FUTURE FARM SYSTEM (F2)					
glyphosate	1 * 2		11.25	2.27	27.04
pendimethalin	3		10.50	6.00	37.50
fluometuron	5	50	13.30		33.25
pyrithiobac	0.14	20	600*		16.80
inter-row cultivation	2			14.83	29.66
2,4-D amine	1.3		5.75	2.27	9.75
				Total	154.00
FUTURE FARM SYSTEM (FB) (with bromoxynil resistant cotton)					
glyphosate	1 * 2		11.25	2.27	27.04
pendimethalin	3		10.50	6.00	37.50
fluometuron	5	50	13.30		33.25
inter-row cultivation	(2)			4.83	9.66
bromoxynil	1.5 * 2	50	13.00		21.77
chipping				10.00	10.00
2,4-D amine	1.3		5.75	2.27	9.75
				Total	148.97
FUTURE FARM SYSTEM (FG) (with glyphosate resistant cotton)					
glyphosate	1 * 2		11.25	2.27	27.04
pendimethalin	3		10.50	6.00	37.50
glyphosate	0.75 * 3		11.25	2.27	32.13
2,4-D amine	1.3		5.75	2.27	9.75
				Total	106.42

Table 5. A comparison of herbicide use in current and future weed management scenarios proposed for the Australian cotton industry. This table excludes channel weed control.

	RATE	NUMBER	BAND	QUANTITY	INDUSTRY USE ('000 kg a.i.)	
	(L)		(%)	(L/ha)	TOTAL	RESIDUAL
CURRENT FARM SYSTEM (C)						
glyphosate	1	1		1	117	
trifluralin	2.8	1		2.8	291	291
fluometuron	5	1	50	2.5	325	325
diuron	2.3	1	50	1.15	239	239
2,4-D amine	1.3	1		1.3	169	
		Industry total		8.75	1141	855
FUTURE FARM SYSTEM (F1)						
glyphosate	1	2		2	243	
pendimethalin	3	1		3	257	257
fluometuron	5	1	50	2.5	325	325
pyrithiobac	0.14	1	40	.06	12	
2,4-D amine	1.3	1		1.3	169	
		Industry total		8.9	1006	582
FUTURE FARM SYSTEM (FB) (with bromoxynil resistant cotton)						
glyphosate	1	2		2	243	
pendimethalin	3	1		3	257	257
fluometuron	5	1	50	2.5	325	325
bromoxynil	1.5	2	50	1.5	78	
2,4-D amine	1.3	1		1.3	169	
		Industry total		10.3	1072	582
FUTURE FARM SYSTEM (FG) (with glyphosate resistant cotton)						
glyphosate	1	2		2	243	
pendimethalin	3	1		3	257	257
glyphosate	0.75	3		2.25	263	
2,4-D amine	1.3	1		1.3	169	
		Industry total		9.55	932	257

Figure 1. A typical farm program. Irrigations are indicated by 'I' and cotton development stages are represented with symbols. The timing of herbicides applications and other farm activities are also shown.



SUCCESSFUL NUTGRASS CONTROL IN COTTON

Graham Charles

NSW Agriculture, Australian Cotton Research Institute

Introduction

Nutgrass (*Cyperus rotundus* L.) is a major weed of cotton production. It is very competitive, can spread rapidly and resists most control measures. Nutgrass produces large numbers of under-ground tubers, or 'nuts'. These may remain dormant in the soil for long periods, but rapidly produce a new plant under favourable conditions. These tubers are large, up to 2 cm long and 1 cm in diameter, and produce vigorous plants which easily compete with slow growing cotton seedlings. Heavy nutgrass infestations can substantially reduce cotton yields, while uncontrolled infestations preclude cotton production. Over the years, many cotton growers have found the combination of good soil moisture, good soil nutrition, and a lack of strong competition from cotton have led to an isolated nutgrass patch becoming a major problem.

The good news is that nutgrass can be controlled. The bad news is that successful control is a long-term venture. Nutgrass control requires good management over a number of seasons, and will be expensive, but the alternative is far worse.

In a recent Cottongrower article, Kylie May, agronomist at Norwood, Moree, emphasises that:

"Perseverance, patience and full commitment are key requirements for a nutgrass control program."

Research results

Experiments over the last 4 seasons at Norwood, have shown the value of components which may be part of a nutgrass control program.

The Norwood field was in fallow in the 1990/91 and 1991/92 seasons. It had a low level of nutgrass infestation in spring 1990, averaging 2 tubers per kg soil, taken from a 0 to 15 cm soil core (Figure 1).

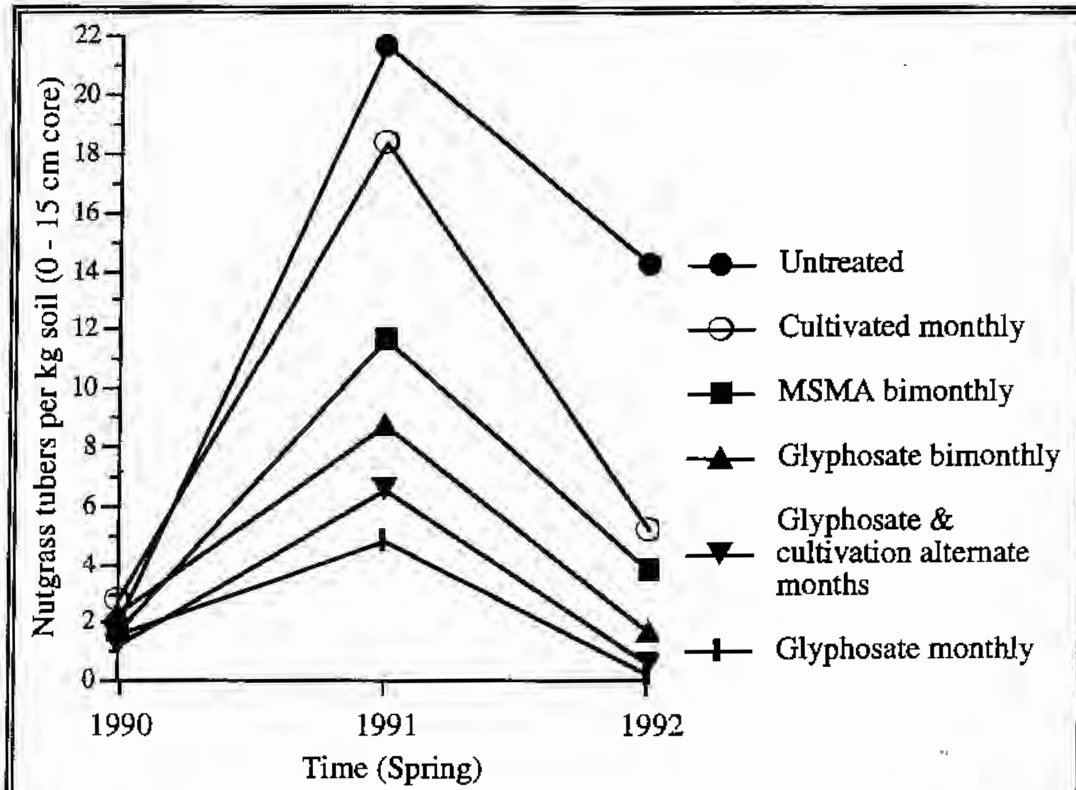


Figure 1. Nutgrass tuber concentration in a bare fallow at Norwood. Treatments were applied over summer (Oct to May). Glyphosate and MSMA were applied at 1.1 and 1.8 L a.i./ha.

However, the field was irrigated 4 times during 1990/91 (simulating a wet summer), and the infestation on untreated plots rose to 22 tubers in 1991. Summer 1991/92 was much 'drier', but only on the 'Glyphosate monthly' and 'Glyphosate & cultivation alternate months' treatments were the final nutgrass infestations, after two seasons in a bare fallow, less than the initial infestations.

These results clearly show the potential to get it wrong. Even monthly glyphosate applications couldn't control a nutgrass infestation in a 'wet' summer. In contrast, a 'dry' summer saw a 35% decrease in the nutgrass tuber population, even where no treatment were imposed, and almost complete nutgrass eradication on the intensive 'Glyphosate monthly' and 'Glyphosate & cultivation alternate months' treatments.

This was followed by a second experiment established on the same site, to examine nutgrass control in cotton (Figure 2).

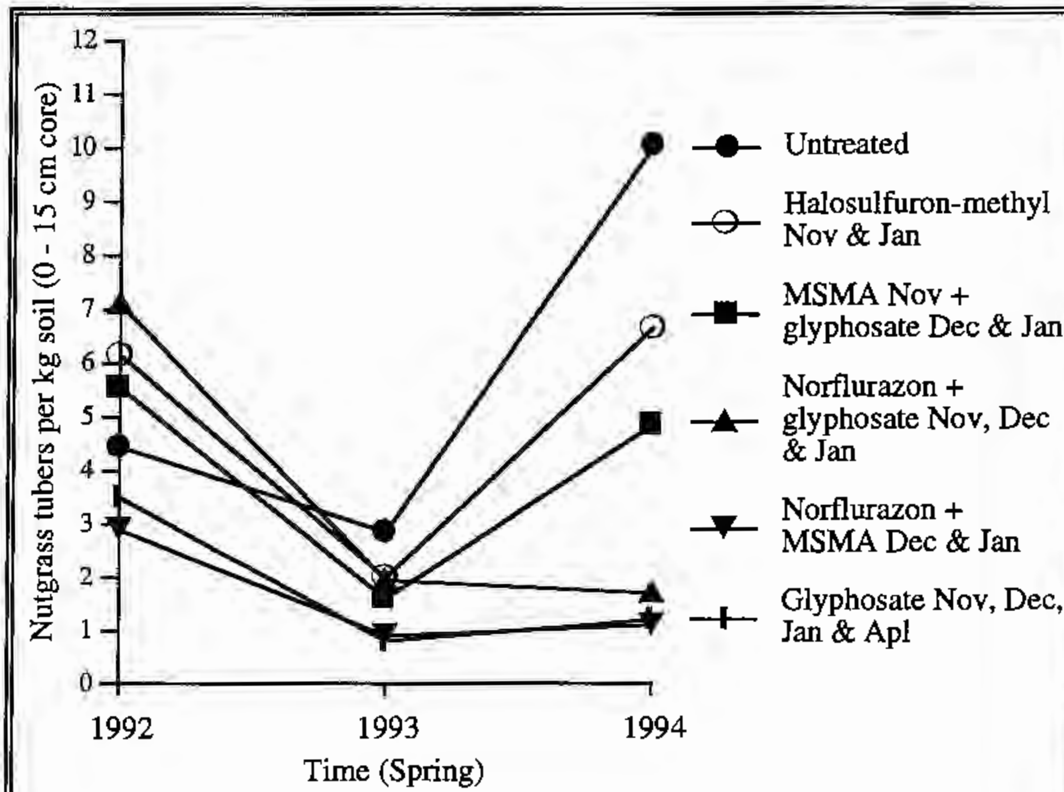


Figure 2. Nutgrass tuber concentration in back-to-back cotton at Norwood. Halosulfuron, glyphosate and MSMA were applied through a curtained sprayer at 35 g, 1.1 and 1.4 L a.i./ha, respectively. Norflurazon was applied at 3.2 kg a.i./ha, pre-plant.

In this experiment there was a further decrease in the nutgrass infestation on all treatments in 1992/93. At the end of the second season (1993/94), the smallest nutgrass populations were on the 'Norflurazon + glyphosate', 'Norflurazon + MSMA' and 'Glyphosate' treatments. Surprisingly, these three treatments had fewer nutgrass tubers at the end of 2 seasons of cotton than they started with. However, this reflects not only the treatments used, but also the seasonal conditions and the management imposed on the field, which encouraged rapid cotton establishment, and produced a strong and competitive cotton stand.

The strategy

Successful nutgrass control requires a long-term, integrated control program. The elements of this program are cultivation, herbicides and competition.

Cultivation. Nutgrass tubers are very susceptible to high temperatures and dehydration. Cultivation which cuts nutgrass roots and brings tubers to the soil surface during hot, dry conditions will rapidly kill tubers. However, cultivating wet soil achieves little except to spread the problem around the field. Good machinery hygiene between infested and clean areas is essential.

Inter-row cultivation can be an important tool to suppress nutgrass growth early in the cotton season, although if the soil is moist, herbicides are the better option.

Herbicides. MSMA, glyphosate, norflurazon and halosulfuron-methyl can give effective nutgrass control under the right conditions, but are ineffective when nutgrass is stressed during dry conditions. They need good soil moisture levels and/or nutgrass growth for maximum efficacy.

Norflurazon is a long-term, residual herbicide which is present and potentially active throughout the season, but is only active when soil moisture levels are high, and it restricts rotation options.

MSMA, glyphosate and halosulfuron-methyl are contact herbicides, and application technique and timing are essential for good nutgrass control.

Competition. Nutgrass is susceptible to shading and competes poorly against well established crops. Nutgrass is relatively shallow rooted and needs good soil moisture levels in the soil surface for maximum growth. Well established crops which dry the soil profile prevent nutgrass growth and allow nutgrass control through cultivation.

Good agronomy of cotton and rotation crops is essential to enable the crop to rapidly establish and shade emerging nutgrass.

A control program for a nutgrass infested field

The basic principles are: use competition to disadvantage nutgrass
use cultivation to control nutgrass in dry conditions
use herbicides to control nutgrass in moist conditions
avoid back-to-back cotton where ever possible

In-cotton - ensure good cotton agronomy. Sow the worst infested field last, to allow rapid cotton establishment and chemical or mechanical control of nutgrass that emerges before cotton planting and emergence.

Use inter-row cultivation or herbicides to control emerging nutgrass.

Never use cultivation for nutgrass control in wet conditions.

Use herbicide to control nutgrass at or after defoliation in a wet autumn.

In-fallow - use cultivation to control nutgrass after picking in a dry autumn.

Establish a strong rotation crop.

Control nutgrass with cultivation over a dry summer. In wet conditions, use a herbicide to control nutgrass and consider planting a rapidly growing summer crop such as lab lab.

Summary

From Kylie May's article:

"Once started, the (nutgrass) *program must be continued for several years. It must become an integral part of the overall farm management. Resources must be budgeted for as the costs involved are quite significant. Small patches are a lot easier and cheaper to control than large areas, so it is never too early to start the program."*

and

"Nutgrass control can best be described as fighting dirty - you must punch hard and often and out of turn."

There is no magical recipe for nutgrass control. A successful nutgrass control program is all about being able to use every available technique and every available opportunity to get on top of what is often described as the world's worst weed, nutgrass.

Further reading

The article by Kylie May entitled "A committed approach is necessary for nutgrass control" (The Australian Cottongrower, May - June 1994, pg 47 - 50), gives a good description of how one grower has developed a successful nutgrass control program.

My article from the 1992 Australian Cotton Conference (pg. 191 - 196) entitled "Nutgrass, a problem weed: a review of the literature", also provides a good explanation of the nutgrass problem and the tools available for nutgrass control.

Paper presented at the 7th Australian Cotton Conference, 1993
"The Fabric of Success"
Broadbeach, Queensland
p 289 - 294.

Keys to Nutgrass Control in Cotton

Graham Charles
NSW Agriculture, Australian Cotton Research Institute

This article is based on a paper presented at the recent Australian Cotton Conference and includes additional material covering some of the points raised by growers at this conference.

Introduction

Nutgrass (*Cyperus rotundus* L.) is a major weed of cotton production. It is very competitive, can spread rapidly and resists most control measures. Nutgrass produces large numbers of under-ground tubers, or 'nuts'. These may remain dormant in the soil for long periods, but rapidly produce new plants under favourable conditions. These tubers are large, up to 2 cm long and 1 cm in diameter, and produce vigorous plants which easily compete with slow growing cotton seedlings. Heavy nutgrass infestations can substantially reduce cotton yields, while uncontrolled infestations preclude cotton production. Over the years, many cotton growers have found the combination of good soil moisture, good soil nutrition, and a lack of strong competition from cotton have led to an isolated nutgrass patch becoming a major problem.

The good news is that nutgrass can be controlled. The bad news is that successful control is a long-term venture. Nutgrass control requires good management over a number of seasons and will be expensive, but the alternative is far worse.

In a recent Cottongrower article, Kylie May, agronomist at Norwood, Moree, emphasises that:

"Perseverance, patience and full commitment are key requirements for a nutgrass control program."

Research results

Experiments over the last 4 seasons at Norwood, have shown the value of components which may be part of a nutgrass control program.

The Norwood field was in fallow in the 1990/91 and 1991/92 seasons. It had a low level of nutgrass infestation in spring 1990, averaging 758 tubers/m^2, taken from a 0 to 15 cm soil core (Figure 1).

However, the field was irrigated 4 times during 1990/91 (simulating a wet summer), and the infestation on 'Untreated' plots rose to 7701 tubers in 1991. Summer 1991/92 was much 'drier', but only on the 'Roundup® monthly', 'Roundup® & cultivation alternate months' and 'Roundup bimonthly' treatments were the final nutgrass infestations, after two seasons in a bare fallow, less than the initial infestation.

These results clearly show the potential to get it wrong. Even monthly Roundup® applications didn't control a nutgrass infestation in a 'wet' summer (1990/91). In contrast, a 'dry' summer (1991/92) saw a 35% decrease in the nutgrass tuber population, even where no treatment were imposed ('Untreated'), and almost complete nutgrass eradication on the intensive 'Roundup® monthly' treatment.

This was followed by a second experiment established on the same site, to examine nutgrass control in cotton (Figure 2).

In this experiment there was a decrease in the nutgrass infestation on all treatments in 1992/93. At the end of the second season (1993/94), the smallest nutgrass populations were on the 'Zoliar® + Roundup® Nov, Dec & Jan', 'Zoliar® + MSMA Dec & Jan' and 'Roundup® Nov, Dec, Jan & Apl' treatments. Surprisingly, these three treatments had fewer nutgrass tubers at the end of 2 seasons of cotton than they started with. However, this reflects not only the treatments used, but also seasonal conditions and the management imposed on the field, which encouraged rapid cotton establishment and produced a strong and competitive cotton stand.

In most situations, Sempra® should give better results than occurred in this experiment. Greg Ferguson (Monsanto) (pers. comm.), reported that Sempra® at 50 to 100 g a.i./ha gave at least 70% control of nutgrass in cotton. In trials where there were light infestations of less than 50 nutgrass plants /m^2, the 50 g a.i. rate gave over 70% control.

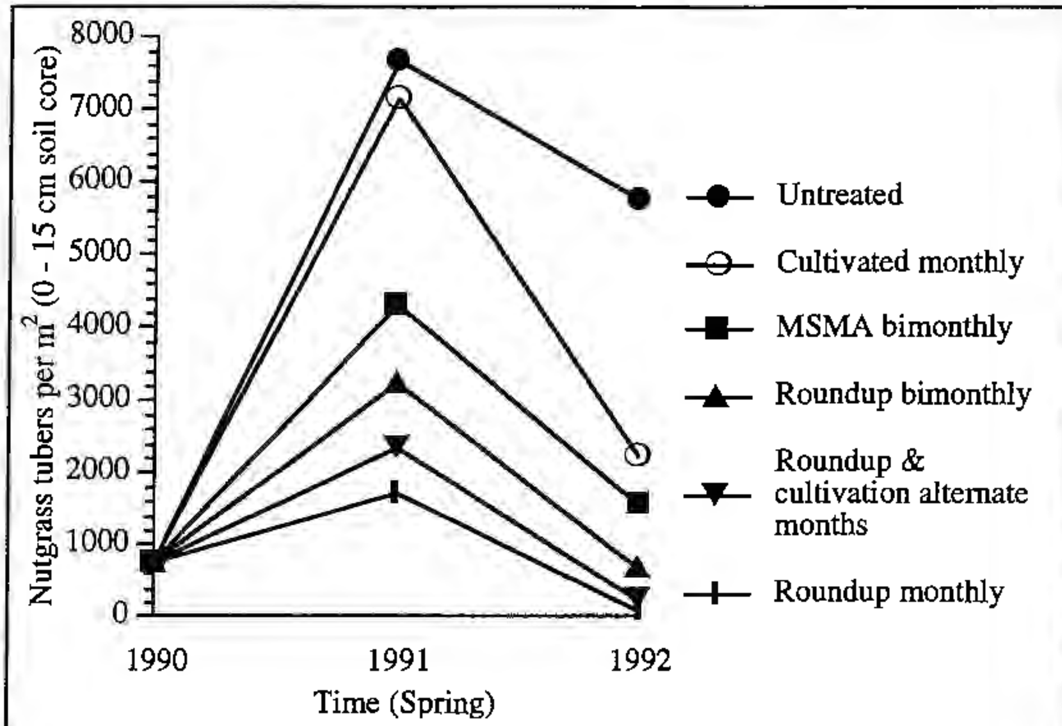


Figure 1. Nutgrass tuber concentration in a bare fallow at Norwood. Treatments were applied over summer (Oct to May). Roundup® and MSMA were applied at 1.1 and 1.8 L a.i./ha.

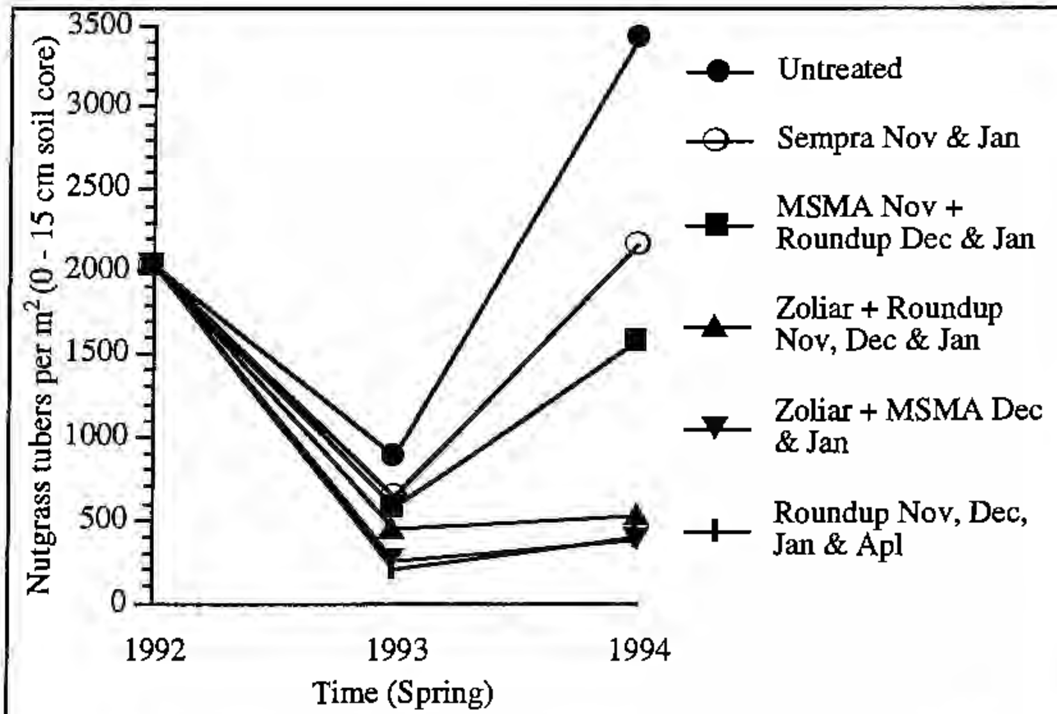


Figure 2. Nutgrass tuber concentration in back-to-back cotton at Norwood. Sempra®, Roundup® and MSMA were applied through a curtained sprayer at 35 g, 1.1 and 1.4 L a.i./ha, respectively. Zoliar® was applied at 3.2 kg a.i./ha, pre-plant.

A nutgrass control strategy

Successful nutgrass control requires a long-term, integrated control program. The main elements of this program will be cultivation, herbicides and competition.

Cultivation. Nutgrass tubers are very susceptible to high temperatures and dehydration. Cultivation which cuts nutgrass roots and brings tubers to the soil surface during hot, dry conditions will rapidly kill tubers. However, cultivating wet soil achieves little except to spread the problem around the field. Good machinery hygiene between infested and clean areas is essential.

In cotton: Inter-row cultivation can be an important early season tool to suppress nutgrass growth, although if the soil is moist, herbicides are the better option. Some growers have found that repeated early season, inter-row cultivation and a 100% rotation program has allowed them to grow cotton in heavily nutgrass infested fields.

In fallow: In a dry soil, deep ripping and chisel plowing can effectively reduce tuber numbers. Rotation crops such as wheat and safflower are important tools to dry the soil profile. However, its essential to ensure good crop establishment on nutgrass infested areas.

Herbicides.

Two herbicide strategies are available. The use of soil sterilants and residual herbicides is effective, but may be very expensive and will restrict cropping options. Contact herbicides require accurate application and timing, and may need to be repeated, but some herbicides can be used in crop and won't interfere with cropping rotations.

In cotton: MSMA, glyphosate, Zoliar® and Sempra® can give effective nutgrass control under the right conditions, but are ineffective when nutgrass is stressed during dry conditions. They need good soil moisture levels and/or nutgrass growth for maximum efficacy.

Zoliar® is a long-term, residual herbicide which is present and potentially active throughout the season. Nevertheless, although Zoliar® has the advantage that only a single application is necessary in a season, it needs to be applied over at least 3 seasons, and is only active when soil moisture levels are high. Zoliar® fields need special management, and Zoliar® will restrict rotation cropping options.

MSMA, glyphosate and Sempra® are contact herbicides, and application technique and timing are essential for good nutgrass control. Glyphosate needs additional surfactant for nutgrass control (the amount of surfactant depends on the formulation used), and glyphosate may give poor results under low temperatures in early spring, particularly in the southern areas. The addition of Prep® to glyphosate might improve herbicide efficacy on vegetative nutgrass, although temperature limitations still apply. Sempra® is better suited for application to vegetative nutgrass, and good nutgrass growing conditions improve Sempra's activity (Ferguson pers. comm.).

Both Cotoran® and Dual® have shown some activity on nutgrass and may give some advantage in a nutgrass infested field.

Glyphosate applications at defoliation or immediately after picking can also be successful, although the results depend on seasonal conditions. Applying glyphosate to moisture stressed nutgrass is unlikely to be successful.

Non-cropping areas: Soil sterilants such as Arsenal® or high rates of Zoliar® may be useful to eradicate nutgrass on small patches. Regular applications of glyphosate can also be effective, but glyphosate requires a disciplined approach.

Competition. Nutgrass is susceptible to shading and competes poorly against well established crops. Nutgrass is relatively shallow rooted and needs good soil moisture levels in the soil surface for maximum growth. Well established crops which dry the soil profile prevent nutgrass growth and allow nutgrass control through cultivation.

Good agronomy of cotton and rotation crops is essential to enable the crop to rapidly establish and shade emerging nutgrass.

Summary

From Kylie May's article:

"Once started, the (nutgrass) *program must be continued for several years. It must become an integral part of the overall farm management.*

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Further reading

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My article from the 1992 Australian Cotton Conference (pg. 191 - 196) entitled "Nutgrass, a problem weed: a review of the literature", also provides a good explanation of the nutgrass problem and the tools available for nutgrass control.

Further herbicide information can be obtained from the respective chemical companies.

Note

Use of a particular brand name does not imply recommendation of that brand by either NSW Agriculture or myself.

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An update of weed control in the Australian cotton industry

G. W. Charles

NSW Agriculture, Agricultural Research Station, Narrabri NSW 2390, Australia.

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

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.

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.

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	% 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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References

Australian Bureau of Agricultural and Resource Economics (1992).

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 - 92.

A report to the Australian Cotton Research & Development Corporation, (1993).

Rotation crop herbicides - the pitfalls for cotton

by Graham Charles, NSW Agriculture, Narrabri

There have been many advances in herbicide technology over recent years, yet one of the major short comings of herbicides in rotational cropping systems remains. This problem is that the herbicides used on one crop may adversely affect the following crop or crops. With the enormous complex of herbicides now available, this problem may be less apparent, but the pitfalls are many and can be very costly. Damage from herbicide residues may be obvious, causing stunting, morphological deformation or even crop death, but more often, damage is not obvious and results in reduced crop vigour and yield.

Many of the current herbicides are active for only hours or days after application, but others may be active for weeks or months. It is essential to ensure that herbicide residues from one crop do not adversely affect a subsequent crop.

Unfortunately, there are many factors which affect herbicide breakdown, and no simple equation can estimate the reduction in herbicide phytotoxicity over time. Factors such as application rate and placement, temperature, cultivation frequency, depth and timing, ultra violet radiation, cropping history and previous herbicide and pesticide exposure, and soil factors such as moisture, clay and organic matter content, texture, nutrient status and pH can affect herbicide degradation. The relative importance of these factors may vary for each herbicide, site and season.

Most herbicides have recommended plant back periods[a] on the labels. These assume the herbicides are used at recommended rates and in the recommended manner. These plant back periods are conservative, containing some safety margin. Nevertheless when considering an unfamiliar herbicide or adverse conditions, recommended plant back periods should be treated with caution as they are necessarily based on results from a limited number of seasons and sites. Generally, plant back problems are more likely to occur when unusually dry conditions occur after product application, or when the rotation crop fails or is terminated, allowing an unplanned cotton crop to follow the rotation crop more quickly than normal.

Table 1. Herbicides for which plant back problems to cotton are not anticipated (products with recommended plant back periods of 1 week or less).

Product name[b]	Active ingredient[g]	Product name	Active ingredient
	amitrole	Assure	quizalofop ethyl
Avadex BW	tri-allate	Bladex	cyanazine
	bromoxynal	Cotoran[R]	fluometuron
	diuron[R]	Dual[R]	metolachlor
Fusilade[R]	fluazifop-P	Gesagard[R]	prometryn
Gramoxone	paraquat		glyphosate
Hoegrass	diclofop-methyl	Mataven	flamprop methyl
Puma	fenoxaprop-ethyl	Reglone	diquat
Sertin[R]	sethoxydim	Stomp[R]	pendimethalin
Targa	quizalifop-P		trifluralin[R]
Verdict	haloxyfop	Yield	oryzalin & trifluralin

[a] The plant back period is the minimum safe replant interval for a susceptible crop.

[b] Where the product is sold under more than one name, only the active ingredient is listed.

[g] Herbicides followed by an upper-case 'R' are registered for use in cotton.

This article covers the commonly used rotation crop herbicides and their likely affects on cotton. The article is intended only as a guide to those herbicides which may cause problems, and in no way replaces the information supplied by manufacturers on the product label.

Although plant back problems are not expected with these herbicides, this does not mean that these herbicides are necessarily safe to cotton. Glyphosate, for example, can be safely used in a fallow prior to cotton and between cotton rows using a ropewick applicator, because it has low volatility, has no residual activity and is rapidly inactivated on contact with the soil. However, cotton is not tolerant of glyphosate, and if glyphosate is applied to or drifts onto growing cotton, it can cause severe stunting and yield loss. Even herbicides which are registered for cotton can cause damage when used inappropriately or under adverse conditions. Most cotton herbicides will cause some leaf burn if applied directly to growing cotton, although this damage will not normally result in a significant yield loss (2).

In the past cotton season for example, there have been many cases of cotton seedling damage from residual cotton herbicides applied at planting, with damage from diuron being particularly common. The severity of this damage can be related to the very slow growth rate of cotton seedlings during the cool spring conditions, with associated seedling disease problems and the frequent occurrence of showers. Diuron is phytotoxic to cotton when absorbed through the root system, but crop safety is normally achieved by banding the chemical zone above the cotton seed. This strategy of differential placement is also used for many other commonly used herbicides. The damage to cotton in the past season has been caused by the combination of the chemical being washed down into the seedling root zone, slow seedling growth, and the cotton seedling producing a shallow root system, with far more surface roots than normal.

In a season with warm October conditions and no heavy rain immediately after planting, diuron damage should not occur. In herbicide experiments at the Narrabri Research Station, fluometuron damage to cotton seedlings has been apparent in each of the previous two seasons, but there has been no evidence of diuron damage, even when applied at up to 4 times the recommended rate.

Many growers have expressed concern regarding the possible build up of residual herbicides from repeated applications over many years. However, this is very unlikely to be a problem in cotton production. Walker (9) showed that if a herbicide with a half life of 1 year was applied annually for many years, the concentration 1 year after the last application would only equal the annual application rate. By comparison, the half lives of the current herbicides are measured in days or weeks.

Table 2. Herbicides for which plant back problems to cotton are not anticipated under normal circumstances[d].

Product name	Active ingredient	Product name	Active ingredient
Basagran	bentazone	Brodal	diflufenican
	dicamba	Garlon	triclopyr
Grasp	tralkoxydim	Igran	terbutryn
Lexone	metribuzin	Lontrel L	clopyralid
	MCPA	Starane	fluroxypyr
Tillmaster	glyphosate & 2,4-D		2,4-D

In a dryland cereal cropping area, Jolley (4) reported 10% or less annual carryover of trifluralin on loam soil, but found that on a drier, heavy clay site, trifluralin carryover generally ranged from 10 to 34%, with 92% carryover in one very dry season. Similarly, diclofop-methyl carryover ranged from 3 to 18% on the loam soil sites and topped at 42% on the heavy

[d]Plant back problems may occur if the label recommendations are not followed, or if these herbicides are used on fallows prior to cotton, or the rotation crop does not complete its normal course.

clay soil in one very dry season. However, most researchers have found that trifluralin does not accumulate in the soil over seasons (1,5), and that the rate of trifluralin dissipation may increase by up to 80% with repeated applications (7). Likewise, although diuron and fluometuron residues may persist for more than one season, they do not accumulate over seasons. Prometryn residues should not persist to the following season (5).

While the plant back period to cotton for 2,4-D is relatively short, cotton is extremely sensitive to this herbicide and problems have occurred, particularly where dry conditions occur after 2,4-D application. The recommended plant back period of 21 days commences only after rainfall of at least 15 mm (3).

Table 3. Herbicides for which plant back problems to cotton are likely if the label recommendations are not strictly followed.

Product name	Active ingredient	Product name	Active ingredient
Ally	metsulfuron		atrazine
Blazer	acifluorfen	Glean	chlorsulfuron
Logran	triasulfuron	Oust	sulfometuron
	simazine	Tordon 50-D	picloram & 2,4-D
Tribunil	methabenzthiazuron		

Soil moisture and soil pH are critical in determining the minimum recropping intervals for many of these herbicides. Most of our cotton soils are alkali, with soil pH ranging from about 6.5 through to 9. The only way to be sure that the soil is safe for cotton, is to successfully grow a small area of cotton through to maturity in the previous season. Scott (8) reported that the half life[e] of atrazine increased from only 23 days on a red-brown earth (pH 5.3) to 66 days on a black earth (pH 7.6) and 180 days on a black earth (pH 8.7). Similarly, he found that the half life of chlorsulfuron increased from only 10 days to 43 days and 109 days at these same sites. Clearly the black earths have potential for plant back problems and experience in one field and one season will not necessarily apply to another field or season.

The sufonylurea herbicides as a group (chlorsulfuron, metsulfuron, sulfometuron and triasulfuron) are highly efficacious and phytotoxic to sensitive plants at very low soil concentrations, and have long half lives on alkali soils. Over a range of soil types, Walker and Welch (10) found that herbicide degradation was strongly correlated with soil pH, with the half life for triasulfuron increasing from 33 days at pH 5.8 to 120 days at pH 7.4. To confound the potential plant back problem, they found that the growth of sensitive crops was severely affected at soil levels equivalent to less than 0.5% of the initial herbicide dose. In a worst case situation, using an initial application of 35 g and a half life of 120 days, the minimum plant back period would be greater than 30 months for a sensitive crop such as cotton.

Most broadleaf crops are very sensitive to Ally, and a plant back period to cotton of at least 14 months should be observed, although longer periods will be required on the more alkali soils.

The plant back period for atrazine is rate dependant and varies from 6 to 18 months or longer. A recent study (6) found trace levels of atrazine only in the 0 - 20 cm soil zone 12 months after application, with no detectable atrazine below this.

The plant back period for Glean is closely related to soil pH and varies from 18 months to 26 months or more.

Logran has a minimum plant back period of 24 months.

The plant back period for simazine is at least 9 months.

Tordon 50-D has a 12 month minimum plant back period.

Tribunil's plant back period is at least 18 months.

Conclusions

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[e] Half life is the time interval for the activity of a herbicide to decrease by half.

Under adverse conditions, many of the rotation crop herbicides have the potential to damage subsequent cotton crops. Cotton growers should be extremely wary of using unfamiliar herbicides on fields which are to be planted to cotton, and of planting cotton into fields were they suspect there may be a herbicide plant back problem. If in any doubt, growers should seek advice, as mistakes can be very costly.

References

1 Cotterill E. G. and Owen P. G. (1989). Enhanced degradation in soil of tri-allate and other carbomate pesticides following application of tri-allate. *Weed Research*, **29**: 65 - 68.

2 Hamilton K. C. and Arle H. F. (1977). Effect of height of directed applications of herbicides in cotton (*Gossypium hirsutum*). *Weed Science*, **25**: 492 - 494.

3 Hammond D. (1992). Managing 2,4-D in cotton fallows. *The Australian Cotton Grower*, **13**, no 5: 67.

4 Jolley A. (1992). Little fear of herbicide persistence... but be wary of dry years. *Australian Grain*, **2**, no 1: 6 - 7.

5 Miller J. H., Keeley P. E., Thullen R. J. and Carter C. H. (1978). Persistence and movement of ten herbicides in soil. *Weed Science*, **26**:20 - 27.

6 Noble B. and Hargreaves P. (1992). Are herbicide residues accumulating in our soils? *Australian Grain*, **2**, no 1: 8 - 10.

7 Parka S. J. and Tepe J. B. (1969). The disappearance of trifluralin from field soils. *Weed Science*, **19**: 119 - 122.

8 Scott G. (1992). Studies on the persistence and leaching of residual herbicides. *Australian Grain*, **2**, no 3: 11 - 12.

9 Walker A. (1987) Herbicide persistence in soil. In 'Reviews in Weed Science', Ed C. L. Foy, **3**: 1 - 17.

10 Walker A. and Welch S. J. (1989). The relative movement and persistence in soil of chlorsulfuron, metsulfuron-methyl and triasulfuron. *Weed Research*, **29**: 375 - 383.

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