COTTON RESEARCH & DEVELOPMENT CORPORATION

NSW AGRICULTURE

Sustainable Weed Management for Cotton on Permanent Beds

CRDC Project DAN 97C

Final Report

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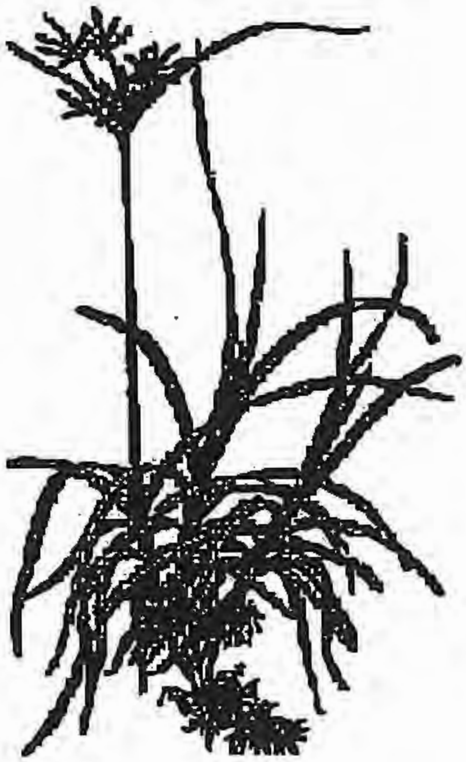

Summary

Aims of the project

Aims:

1. To quantify the effects of cropping systems on changes in weed spectrum and density.

2. To evaluate herbicides combinations for weed management in reduced tillage systems.

3. To evaluate the performance of glyphosate tolerant transgenic cotton and its use in weed management.

4. To further develop the nutgrass control strategy.

Summary

Development of sustainable, efficient, integrated weed management systems for cotton production is the primary goal of the weeds programs (CRDC and CRC funded).

This goal is being achieved through a range of approaches including determining a base level for weed management in the cotton industry, scientifically evaluating a range of alternative weed management strategies including different herbicide combinations and rates, alternative herbicides with transgenic, herbicide tolerant cotton varieties and alternative cultivation and stubble management practices, and developing specific weed management packages for difficult to control weeds.

This project has furthered the weeds goal in all aspects. An important highlight has been the development of a management strategy for nutgrass. Preliminary field evaluation of a range of weed management options including normal and transgenic cotton has also been undertaken. Work over the next 3 years will examine options for peach vine management, and management options with stubble retention.

Background

Research on the management of weeds in cotton began at the Australian Cotton Research Institute (ACRI) in late 1988 with the appointment of Graham Charles as Research Agronomist (Weeds). A second research position was created at the ACRI with the creation of the CRC for Sustainable Cotton Production. Grant Roberts was appointed to this position in August 1996. His work focuses on the development of sustainable, low input, management systems for weeds in low weed pressure situations in cotton.

Mr Charles' project began in 1988 with a survey of cotton growers, collating information on problem weeds, herbicide use patterns, cultivation, cropping rotations and research priorities. The survey established that weed control cost cotton growers on average $187/ha for chemicals, cultivation and hand chipping in 1989. There were many examples where costs were greater, 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.

Many research needs were identified by cotton growers at this time, with the area of highest priority identified as the control of nutgrass in cotton. The survey data showed that nutgrass was a serious weed on 79% of properties and the major weed problem on 15% of the cotton area. Of the other weeds growers identified, only 3 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 commenced in 1990.

In 1991 purple nutgrass (*Cyperus rotundus*) was identified as the nutgrass species most seriously affecting cotton production, costing the Australian cotton industry at least $13 million per year to control. Since then, project DAN 71C has commenced research into the management of nutgrass in cotton. This research, on what is considered to be the world's worst weed required further development, particularly to bring the nutgrass control strategy in line with the industry's move towards reduced cultivation and permanent beds.

The industry's move to adopt permanent bed and reduced tillage practices and reduce its reliance on chipping has been achieved by increasing reliance on herbicides, in particular residual herbicides as the main tool for weed control. This increasing dependence on residual herbicides has caused some immediate problems with herbicide damage and will damage the industries long-term sustainability by increasing the likelihood of herbicide resistance occurring in weeds and the potential for serious environmental pollution. Already atrazine registration for channel use has been revoked in response to pollution concerns and other herbicides may follow this path. There is also evidence that weed spectra are changing under the permanent bed strategy and new weed problems are likely to emerge. In contrast to these problems, new herbicides (such as Staple®) and new technology (such as herbicide resistant cotton) are just around the corner and it is important to understand how these tools can be used to overcome the industries problems.

In addition, long-term rotation trials have been established under the Cooperative Research Centre for Sustainable Cotton and it is important that the weed species and incidence on these trials be monitored to explore the possible impact of rotations and farming systems on weed populations.

Project's stated aims & objectives

Aims:
1. To quantify the effects of cropping systems and reduced tillage on changes in weed populations and species.
2. To evaluate best-bet combinations of current and future herbicides (such as Staple®) for weed management in reduced tillage systems.
3. To evaluate the performance of glyphosate tolerant transgenic cotton to glyphosate and the potential use of glyphosate tolerance in weed management.
4. To further develop the nutgrass control strategy and its adoption for use in permanent beds.

Objectives: (i) CRC long-term rotation experiments will be monitored at least 3 times each season. Growers fields will also be assessed as the opportunity arrises.

(ii) a long-term herbicide combination experiment will be established and monitored.

(iii) the tolerance of glyphosate transgenic cotton will be assessed as the material becomes available from the breeding program

(iv) field and glasshouse experiments each season will examine management strategies

Research methodology

(i) Reduced-tillage.

Weed spectrum and density were monitored on 3 occasions (before inter-row cultivation, after picking and mid-winter) on each treatment of the CRC long-term rotation experiments. These experiments incorporated a range of rotation cropping strategies. Weed populations were also monitored on the herbicide systems experiment at the ACRI (see *(ii)* below), on Dr. Nilantha Hulugalle's rotation experiment at Glenarvon (Glencoe) and on growers fields in the Macquarie (new and old fields on Milawa), the Namoi (Auscott and Glencoe), and the Macintyre valleys (Strathgyle) and the Darling Downs (Mayfield and Weroona), allowing comparison of the development of weed problems over time, under reduced tillage (the Glencoe field was under conventional cultivation, included as a comparison). Four commercial fields were chosen on each property, with 2 transects per field and 10 observations of 1 row by 50 m (50 m^2) per transect. The number of weed species and actual density of each weed were recorded for each observation. At each time, the observations was made at as close as possible to the same position in the fields. While it was recognised that the total area observed of 0.1 ha per field limited the accuracy of the data, the time taken to observe a larger area was prohibitive and the observations were considered to be sufficiently intensive to pick up any gross change in weed spectrum or density over time.

(ii) Herbicide systems for reduced-tillage

A replicated herbicide systems experiment was established on Field C4 at the ACRI in spring 1995. It included 15 treatments using pre- and post-emergent herbicide combinations. Five treatments included Roundup Ready (Roundup tolerant) cotton, although this cotton did not become available until the 96/97 season. Limited data was acquired from this treatment in 95/96 by treating the plots as if Roundup Ready cotton had been planted. Plots were 8 rows wide by 200 m long (field length) with 3 replicates.

The experimental design was modified in 97/98 to allow for the inclusion of bromoxynil tolerant and Basta tolerant cotton, and to allow Visor herbicide to be removed as it had been dropped from further commercial evaluation. The new design included 12 of the original treatments (imposed on the first 100 m of the 200 m field length), with bromoxynil tolerant cotton in the next 50 m and Basta tolerant cotton in the last 50 m, giving a total of 45 treatment combinations.

Cotton lint yields and weed incidence were recorded each season.

(iii) Transgenic glyphosate tolerant cotton

The performance of transgenic, Roundup tolerant cotton was included in the experiment described above in *(ii)*. It was anticipated that it would also be necessary to evaluate the performance of other Roundup Ready lines as these become available from the ACRI cotton breeding team. However, this did not occur. Roundup Ready cotton has been commercially released in the US and has generally performed well, although with problems in some areas. Commercial release in Australia is still some time away, hopefully enabling a sustainable weed management system based on Roundup to be developed for Roundup tolerant cotton before its commercial release.

This component of the project was replaced by a study of the field tolerance of transgenic, 2,4-D tolerant cotton developed by CSIRO in Canberra. The work was undertaken in close collaboration with the CSIRO Plant Breeding team at Canberra and Narrabri.

Replicated field experiments were established at Paloma (near Premer on the Liverpool Plains) in 1996/97 examining the effect of 2,4-D amine rates of 2 X, 1/2 X and 1/8 X normal field rates applied over-the-top of cotton at vegetative, flowering and boll-fill stages and in 1997/98 examining 2,4-D amine rates of 1 X, 1/5 X, 1/25 X and 1/125 X and MCPA at 1 X, 1/5 X and 1/25 X normal field rates applied over-the-top of cotton at vegetative, squaring, flowering and boll-fill stages. The treatments were situated in a maize crop in 1996/97 and a sorghum crop in 1997/98, with buffer rows between treatments to eliminate any problems with herbicide drift. The herbicide effect was assessed visually and by dry-matter cuts and plant mapping in 1996/97 and lint yields in 1997/98.

Mark Hickman, Industry Development Officer with the CRC contributed to the project with bug-checking in both seasons and with plant-mapping in 1996/97.

(iv) Nutgrass control

This work continued on from the work undertaken in DAN 71C, leading to the development of a nutgrass control strategy. Replicated field experiments were established at Norwood and Kilmarnock examining herbicide combinations for nutgrass control in cotton. Treatments included Zoliar, glyphosate, MSMA and Sempra with combinations of herbicides and applications times. Plots were 20 m by 4 rows with 4 replicates. Nutgrass tuber density and cotton lint yield were assessed annually. Additional experiments were conducted in the field and glasshouse at the ACRI examining aspects of nutgrass ecology and control.

Results & Discussion

(i) Reduced-tillage.

Additional background information

A comparative survey of weed spectrum and density on conventionally cultivated and permanent-bed fields was undertaken by Paul Castor and Max McMillan in 1991/92. This data was analysed as part of the current reduced tillage project and published in the proceedings of the Eighth Australian Cotton Conference in 1996 (Appendix 1). The results of the surveys indicated a potential problem with a few weeds becoming more serious problems under minimum tillage.

(a) Weed pressure on the cropping systems experiments.

A report covering the data from the 3 CRC cropping systems experiments is attached as Appendix 2, with a second report listed under publications.

A wide spectrum of weed species were identified on each site, with 53 species identified at Prospect (Warra), 43 species at Beechworth (Merah North) and 41 species at Auscott (Warren). Nevertheless, most of these species were present at very low levels, and many were observed on only 1 or 2 occasions. Also, not all species were present on all systems, as shown below in Tables 1, 2 and 3.

No obvious trends emerge from this data, although there are generally fewer species at high density on the continuous cotton systems than on the other systems. Of the weeds present, sow thistle is a major weed on all systems and all sites. No individual weed species appear to be increasing on any of the systems or sites, with large seasonal fluctuations in weed density masking any long-term trends.

Table 1. The total number of species observed on each system at Prospect, and the number of species occurring at average densities greater than 1/100 m^2 and 1/10 m^2.

	Cropping system	Total species	>1/100 m^2	>1/10 m^2
1	cotton/long fallow	32	5	1
2	cotton/sorghum	32	6	-
3	cotton/wheat double crop	33	6	-
4	cotton/chick pea	34	11	2
5	cotton/wheat	35	7	2

Table 2. The total number of species observed on each system at Beechworth, and the number of species occurring at average densities greater than 1/100 m^2 and 1/10 m^2.

	Cropping system	Total species	>1/100 m^2	>1/10 m^2
1	continuous cotton	31	12	3
2	cotton/faba beans	29	7	2
3	cotton/long fallow	28	11	4
4	cotton/wheat	26	14	5
5	cotton/lab lab	33	12	8
6	cotton/lab lab (high input)	34	12	8

Table 3. The total number of species observed on each system at Auscott, and the number of species occurring at average densities greater than 1/100 m^2 and 1/10 m^2.

	Cropping system	Total species	>1/100 m^2	>1/10 m^2
1	continuous cotton	30	8	4
2	cotton/long fallow	28	8	5
3	cotton/field peas	30	10	6
4	cotton/wheat (low input)	30	9	5
5	cotton/wheat (high input)	27	9	7
6	cotton/cotton/wheat	32	12	8
7	cotton/faba beans	35	12	9

A 'weed index' was developed to enable a comparison of the over-all weed pressure on the various cropping systems. Again no consistent trends emerge from comparison of the cropping systems and sites, even though there are large differences in weed pressure between some of the systems (Table 4).

Table 4. A comparison of the weed pressure on the various cropping systems and sites.

	Cropping system	Prospect	Beechworth	Auscott
1	continuous cotton		16.2	3.7
2	cotton/long fallow	1.5	35.9	3.9
3	cotton/wheat (low input)	2.1	40.1	1.5
4	cotton/wheat (high input)			1.7
5	cotton/cotton/wheat			3.5
6	cotton/wheat double crop	1.5		
7	cotton/sorghum	1.2		
8	cotton/faba beans		22.0	6.7
9	cotton/field peas			3.8
10	cotton/chick peas	1.8		
11	cotton/lab lab		32.4	
12	cotton/lab lab (high input)		44.6	

These data were further summarised to assist comparison of the systems (Table 5), but still no trends are apparent . For example, the lowest weed pressure at Auscott occurs on the cotton/wheat system, but this system had the highest weed pressure at both Prospect and Beechworth. While this result is unexpected, it does indicate that changing the farming systems did not create unmanageable problems for weed control. Control of grasses in wheat rotations and broadleaf weeds in the legume rotations was particularly difficult, but there has not been an unacceptable build up of these weeds in these systems over time.

Table 5. A comparison of the weed pressure on the various cropping systems and sites, summarised over some of the systems.

	Cropping system	Prospect	Beechworth	Auscott
1	continuous cotton		16.2	3.7
2	cotton/long fallow	1.5	35.9	3.9
3	cotton/wheat	1.8	40.1	1.5
4	cotton/sorghum	1.2		
5	cotton/winter legume	1.8	22.0	5.3
6	cotton/lab lab		38.5	

A factor leading to the lack of trend in the data is the complexity of the weed system, where each of the cropping systems can be affecting each weed in a different manner. For example, the summer fallow in the cotton/wheat system allows an opportunity for control of the summer weeds but reduced opportunity for control of winter weeds. Rainfall in summer may result in a germination of weeds which are subsequently controlled, or may result in those weeds setting seed and causing a problem in the following summer if wet or windy conditions prevent adequate early control of these weeds. Consequently, when all weeds are considered together, the interactions can mask the effects of the various systems.

Comparison of the effect of the cropping systems on a single species should allow a clearer understanding of the effect of the systems. This comparison was made using sow thistle, which was the most commonly occurring species on 2 of the sites and the second most common species on the third site (Table 6).

Table 6. A comparison of the effects of the cropping systems on the density of sow thistle (plants/m^2).

	Cropping system	Prospect	Beechworth	Auscott
1	continuous cotton		0.15	0.28
2	cotton/long fallow	0.04	0.16	0.71
3	cotton/wheat	0.09	0.26	0.39
4	cotton/sorghum	0.09		
5	cotton/winter legume	0.17	0.05	0.34
6	cotton/lab lab		2.20	

Again no consistent trends emerge over the sites even when only a single species is considered, although sow thistle control appears to be a problem on the cotton/lab lab system. Contributing to the lack of consistent trend is to the complex interaction of seasonal variations and management inputs. The interaction of weather conditions, especially rainfall, with the timing of weed management inputs having a large effect on weed density.

Based on these results, it is apparent that while heavy weed pressure was present on many of the cropping systems, weeds could be managed in all systems. Weeds did not become unmanageable on any of the systems, with no evidence of a major weed build up over time. Nevertheless, weeds should continue to be monitored on these sites as long as they are available and soil cores should be used to examine the effect of the cropping systems on the weed seed bank over time.

(1b) Weed pressure on permanent-beds on growers fields.

This work primarily aimed to determine the impact of reduced cultivation and permanent beds on the density and spectrum of weeds in cotton. The work examined weed incidence to determine which weed species, if any, would be more difficult to control with reduced tillage. On the basis of other observations, it was anticipated that there would be a build up over time of some of the perennial and tap-rooted species which are tolerant to glyphosate. Weeds such as tar vine, ryncho, and nutgrass were expected to become more of a problem with reduced cultivation and an increased reliance on glyphosate for weed control.

It is too early to be sure of trends in this data, but at this stage there is again no indication of weed pressure increasing over time (Table 7).

Table 7. Change in weed pressure over time on grower's fields as indicated by the weed index (small weed equivalents per m^2).

Property	1995	1996		1997		1998	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Mayfield	0.3	1.0	0.4	1.3	1.7	0.3	1.1
Weroona (rain fed)	0.2	1.2	3.4	1.2	0.1	0.9	3.5
Strathgyle	2.6	1.0	10.0	0.2	9.6	0.0	2.0
Auscott Narrabri	0.1	0.3	0.4	0.9	6.3	0.7	2.2
Milawa (old fields)	0.4	0.0	0.4	3.2	71.2	10.7	-
Milawa (new fields)	1.7	7.0	0.1	0.1	10.8	0.9	-
Glencoe	-	18.7	1.0	0.9	12.3	1.8	7.2

Weed pressure was generally higher in spring than autumn, but was very variable, with large differences between individual fields within a property, and large differences between properties and seasons. Weed pressure at any one time was greatly influenced by weather conditions. Weed pressure was generally low following a dry period and much higher following a wet period (as was expected).

Weed pressure was consistently low on the 2 Dalby sites, Mayfield and Weroona, but was quite high on the other sites on some occasions. Grass density was extremely high on one of the 'old' fields at Milawa in spring 1997, resulting in a very high weed pressure at this time, carrying through to high weed pressure in autumn.

With the exception on the 1997 data, the weed pressure was higher on the 'new' fields at Milawa than on the 'old' fields. The total number of weed species was similar on the 'new' and 'old' fields at Milawa although fewer species occurred at high density on the 'new' fields (Table 8). One of the two species occurring at high density on the 'new' fields at Milawa, burr medic, occurred at only low density on the 'old' fields. The presence of this weed at high density reflects the grazing history of these paddocks.

Table 8. The total number of species observed at each property, and the number of species occurring at average densities greater than 1/100 m^2 and 1/10 m^2.

Property	**Total species**	**>1/100 m^2**	**>1/10 m^2**
Mayfield	33	6	1
Weroona (rain fed)	51	12	2
Strathgyle	32	9	2
Auscott Narrabri	35	9	3
Milawa (old fields)	37	13	6
Milawa (new fields)	41	13	2
Glencoe	45	10	3

When only the 'difficult to control' weeds are examined there is still no indication of an increasing problem over time. For this comparison, the change in density over time of 11 weeds has been shown in Table 9. These weeds are: the perennial weeds - purple nutgrass, Downs nutgrass, polymeria takeall and haloragis takeall; the leguminous weeds - burr medic, snail medic, emu foot, rycho and verbine, and the tap-rooted weeds - bind weed and tar vine.

Table 9. The density of 'difficult to control' weeds per m^2.

Property	1995	1996		1997		1998	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Mayfield	0.00	0.01	0.00	0.02	0.00	0.01	0.01
Weroona (rain fed)	0.00	0.01	0.00	0.00	0.00	0.01	0.01
Strathgyle	0.03	0.01	0.02	0.01	0.03	0.0	0.08
Auscott Narrabri	0.01	0.88	0.29	2.53	2.05	1.53	0.90
Milawa (old fields)	0.03	0.00	0.05	0.14	0.67	0.09	-
Milawa (new fields)	0.14	1.70	0.01	0.01	0.07	0.05	-
Glencoe	-	1.21	0.03	0.20	1.48	0.52	1.46

The densities of the difficult to control weeds have remained generally low throughout the survey period, except at Auscott and Glencoe where purple nutgrass is a serious problem. At Glencoe this problem is being successfully treated with shielded applications of glyphosate, deep cultivation and a 1 year in/ 1 year out cropping rotation system. With this approach the nutgrass infestation at Glencoe has gone from 5.8% of the survey area in autumn 1996 to 2.1% of the area in autumn 1998. At Auscott the nutgrass infestation has risen from 0.03% of the survey area in spring 1995 to 4.5% of the area in spring 1998, with a peak infestation of 9.5% of the survey are in spring 1996. A nutgrass management system using Zoliar and glyphosate has also been adopted at Auscott resulting in a decrease in this infestation to the current levels.

The relatively high density of difficult to control weeds on the Milawa 'new' fields in autumn 1996 reflects the high density of burr medic present at that time.

Conclusions

The surveys on the rotation experiments and grower's fields indicate that the weed management tools currently available to the cotton industry are adequate to manage the weeds present on these sites. The adoption of different cropping rotation strategies, reduced tillage and permanent wheel tracks have not resulted in unmanageable weed problems. Nevertheless, the high cost of inputs and high weed densities present on some occasions emphasise the need to develop more efficient, effective and sustainable integrated weed management systems.

It will be important to continue monitoring these fields, particularly when the adoption of transgenic, herbicide resistant cotton results in another major change to the systems used. Continued monitoring will also ensure that current trends are continuing, and give early warning if problem weeds do begin to emerge.

(ii) Herbicide systems for reduced-tillage

An interim report on the results of this experiment were published in the Australian Cotton Grower (Appendix 3). The report discussed only the main-plot treatments, excluding sub-plots as only a single season's results were available for the sub-plots. In addition, there was insufficient bromoxynil tolerant cotton seed available for the bromoxynil sub-plots (2 row strips were planted), and no Basta tolerant cotton seed was available for these sub-plots. Also the transgenic seed used was genetically inferior, early-generation material from the plant-breeding team, as transgenic cotton varieties were not available in a commercial Australian line.

Consequently no cotton yield comparisons are possible from within the transgenic treatments, although some data on weed management for each treatment is available. Table 10 show the effects of the transgenic treatments on grass control.

Table 10. The effects of the transgenic treatments on grass density (grass plants/m^2).

Conventional herbicides	Roundup treated	Bromoxynil treated	Basta treated
trifluralin & Cotoran	0.0	0.0	0.0
trifluralin & diuron	0.0	0.0	0.0
trifluralin	0.0	0.2	0.0
Staple	164.2		312.6
-	291.7		224.7

Clearly, where a field has a grass problem, grass control will be a problem with each of the transgenic systems unless a grass herbicide is included in the system. This result was expected with Bromoxynil, which has no activity on grasses. While both Roundup and Basta have activity on grasses, grass control proved inadequate where a residual grass herbicide was not included. In both cases grass seedlings continued to emerge throughout the season and were difficult to control once they became established, particularly when they were moisture stressed.

The overall weed pressure on the treatments is shown in Table 11. These results largely reflect the very poor grass control on the treatments which did not include a residual grass herbicide. Very good weed control (both grass and broad-leaf) was observed on all systems which used pre-planting trifluralin in combination with the transgenic treatments.

Table 11. The overall weed pressure on the transgenic treatments expressed as small weed equivalents per metre square. The weed pressure on the best of the conventional herbicide treatments was 15.0.

Conventional herbicides	Roundup treated	Bromoxynil treated	Basta treated
trifluralin & Cotoran	22.2	18.6	35.3
trifluralin & diuron	28.8	24.9	29.9
trifluralin	6.8	7.3	12.9
Staple	177.4		335.3
-	347.9		243.3

Table 12 shows the weed pressure data after the grass data are removed from these results. While Basta gave good control of nearly all weeds other than the grass weeds, Roundup was weak on some of these weeds, with unacceptably high weed pressure occurring when no residual weed control was used. The Roundup/Staple combination gave good weed control and could result in very low weed pressure if combined with a residual grass herbicide.

Table 12. The overall weed pressure (excluding grass weeds) on the transgenic treatments expressed as small weed equivalents per metre square. The weed pressure on the best of the conventional herbicide treatments was 15.0.

Conventional herbicides	Roundup treated	Bromoxynil treated	Basta treated
trifluralin & Cotoran	22.2	18.6	35.3
trifluralin & diuron	28.8	24.9	29.9
trifluralin	6.8	7.1	12.8
Staple	13.3		22.8
-	56.2		18.6

Lint yield can not be properly compared between the transgenic treatments as the genes are in different varieties (at this point in time), and cotton with the Basta tolerance gene is still not available. With this qualification, yield comparison within the 2 transgenic lines are shown in Table 13.

Table 13. Comparison of lint yield (bales/ha) of the transgenic cotton and the closest conventional cotton treatments.

Conventional herbicides	Conventional	Roundup treated	Bromoxynil treated
trifluralin & Cotoran	5.3	6.6	5.4
trifluralin & diuron	3.8	7.6	5.7
trifluralin	-	8.6	5.8
Staple	-	4.8	-
-	-	4.4	-

Lint yields on all the bromoxynil tolerant cotton treatments are surprisingly good considering that the material used was a Coker cotton variety, poorly adapted to Australian conditions. Within the transgenic lines, the treatment which gave the best weed control (the trifluralin treatment) also gave the best the best yields. Dollar returns from these treatments are shown in Table 14.

Table 14. Dollar returns ($/ha) of the transgenic cotton and closest conventional cotton treatments as compared to the conventional treatment with trifluralin and Cotoran.

Conventional herbicides	Conventional	Roundup treated	Bromoxynil treated
trifluralin & Cotoran	$0	$726	-$6
trifluralin & diuron	-$848	$1325	$162
trifluralin	-	$1280	$251
Staple	-	-$314	-
-	-	-$416	-

Dollar returns show that the transgenic cotton varieties have the potential to contribute to the cotton industry on a strait economic basis, as well as through better weed management, increased weed management options and the potential to reduce the total amount of residual herbicide used per ha.

The experiment continues this season with 60 treatments, with treatment differences becoming more apparent with time. The herbicide interaction with diuron which is discussed in the Cotton Grower article (Appendix 3) is being further explored this season where an additional 15 sub-plot treatments have been included, with diuron, Cotoran and prometryn combinations with Stomp, Dual and trifluralin. In addition, the use of lower rates of residual herbicide in combination with over-the-top herbicides is being explored in the transgenic treatments.

It is anticipated that the experimental design will remain unaltered for a further season and then will be modified with an additional 2 main treatments being included. These treatments will be planted into wheat after picking, resulting in standing wheat stubble at planting time. Sub-plot treatments will include conventional and non-conventional herbicide strategies in the standing stubble.

Conclusions

This experiment will make a significant long-term input into the cotton industry through the development on a range of weed management options using both conventional and transgenic, herbicide tolerant cotton varieties. Results over the next 2 seasons, together with results from the herbicide replacement experiments run by Grant Roberts (NSW Ag/CRC) will enable the establishment of options which rely less heavily on residual herbicides and can be particularly targeted to areas of lower weed pressure. None of the herbicides being currently considered with transgenic herbicide resistance have the potential to replace all residual herbicides, although it may be possible to do this in a single season on fields with low weed pressure. This practice would not be sustainable in the long-term, but may have a fit in some situations.

(iii) Transgenic glyphosate tolerant cotton

As discussed earlier, work on transgenic 2,4-D tolerant cotton was substituted for the planned work on glyphosate tolerant cotton (which was covered under objective 2). The results of this work were published in the proceedings of the 9th Australian Cotton Conference and in the Australian Cotton Grower (Appendix 4).

Conclusions

2,4-D tolerant cotton performed very well in the field, even when exposed to extremely high herbicide levels. Good levels of tolerances where expressed at all plant growth stages. Tolerance to MCPA was only marginal.

The results of this work indicate that further development of this material should proceed as soon as is feasible.

(iv) Nutgrass control

A wide range of nutgrass ecology and management studies have now been completed, although there are still many aspects of this weed which are not well understood. The field work has resulted in the publication of two scientific papers. Numerous articles have also been published over this period (Appendix 5 for example) with many more articles to come. The work has culminated in publication of the CRC Research Review "Controlling NUTGRASS in Cotton" (Appendix 6), which gives a practical guide to the tools available to the cotton grower for nutgrass management.

A total of 31 glasshouse and 6 germination cabinet experiments have been completed, supplementing the results from the field work. Several experiments have looked at the effect of nutgrass age on the efficacy of glyphosate applications. These experiments have shown that there is no relationship between flowering and glyphosate efficacy and no consistent relationship between plant age and glyphosate efficiency. Other published data indicates that older plants are less affected by glyphosate. This data has been an important basis for the spraying recommendations.

Other experiments have examined translocation of the herbicides, comparing glyphosate and Sempra. These experiments showed that Sempra is poorly translocated, which is why it is not giving good long-term control in the field when applied through a shielded sprayer (it isn't translocating to unsprayed plants on the cotton hill). Glyphosate is not only giving a better long-term control of sprayed plants, but is also translocating, giving reasonable control of unsprayed nutgrass plants on the cotton hill.

Other experiments have looked at the effect of additives and water quality on glyphosate efficacy for nutgrass control, but have not shown any major problems or any advantage to particular products. More recent experiments (still on-going) are examining the effects of MSMA, Sempra and glyphosate on the 3 nutgrass species, *Cyperus rotundus* (purple nutgrass), *C. bifax* (Downs nutgrass), and *C. victorienses* (yelka). Although field work has shown that Downs nutgrass and yelka are much less of a problem, they are still of concern to some growers.

A scientific paper is currently under way which integrates the glasshouse and field data relating nutgrass density to cotton yield, showing that at high densities nutgrass will out-compete cotton, resulting in no harvestable cotton.

Another paper is under way looking at the spread of purple nutgrass and Downs nutgrass in the field.

Finally, a field experiment commenced at Norwood last season, which will be completed this season. This experiment looks at the effect of heavy (spot spraying) rates of Zoliar on nutgrass control.

Conclusions

The science of nutgrass management has progressed a long way under this project, culminating in the Research Review. Practical in-crop nutgrass management will become a much safer option with the introduction of Roundup Ready, Roundup tolerant transgenic cotton. The commercial release of this material is coming closer, although it still appears to be several years away.

A continuing, but small research input over the next few years should maintain this program at the cutting edge of nutgrass management.

Other Research

A number of other experiments have been undertaken as part of this project.

Of this research, the 2 most important components have been the completion of the noogoora burr and thornapple competition work, and the work on the takeall weeds.

The competition work has been completed with the publication of a scientific paper and article in the Australian Cotton Grower (Appendix 7). This work showed the potential impact of large weeds on cotton and the importance of maintaining weed control even when these weeds are at very low density. It is proposed to continue this work as a Post-Doctorial

Fellowship funded by CRDC. The work also prompted the publication of an article on seed production potential of these and other weeds (Appendix 8).

Research on the takeall weeds polymeria takeall and haloragis takeall has continued in parallel with the CRDC funded Ph D fellowship working on the biology and ecology of polymeria takeall. Management of polymeria-takeall with inter-row applications of heavy rates of glyphosate appears to be working successfully and should result in publication of these results next season. Haloragis takeall was easily controlled by glyphosate and will be covered in the article.

Experience gained through this project also contributed to development of the "Weed Management" section of the Australian Dryland Cotton Production Guide recently published by CRDC, and into the CRC for Sustainable Cotton Production with input into overseeing the CRC appointed weeds researcher and into the ongoing direction and policy of the CRC.

Discussion of results

The project has clearly achieved its aims and objectives with well defined and structured experiments, many of which are on-going. Dissemination of the results of these experiments has been effective and is continuing.

Assessment of the project's impact

There was no quantifiable effect of farming systems on the weed spectrum and density, indicating that either the expected impact of changes to the farming system is smaller than anticipated or that the system is more robust than expected. Consequently, this research will have no immediate impact on the cotton industry except to alleviate fears of the impact of changing farming systems. Nevertheless, this research needs to continue, firstly because this is an important component of the farming systems experiments and could not be dropped without reducing the value of the whole project, and secondly because the current result is not necessarily the future result as farming systems and technology continue to change. The commercial introduction of herbicide resistant cotton, new herbicides and equipment and the continuing move away from chipping and towards stubble retention will collectively impact on weed problems of the future. Now that the bench-mark has been established, it should be possible to quickly identify future adverse changes if and when these occur.

The herbicide systems experiment will have a long-term impact through the development of efficient and sustainable weed management systems using both conventional and transgenic cotton varieties. Already this experiment has impacted through identification of the possible negative impact of diuron on herbicide systems (results over this season and next will quantify this) and through the development of the transgenic cotton. This experiment is of major importance in continuing to obtain GMAC support for the development of the transgenic materials. Development of efficient, less environmentally damaging and sustainable weed management systems must continue to be a fundamental aim of the cotton industry.

Given the problems of 2,4-D damage to the cotton industry last season and the on-going problems with 2,4-D, the successful field evaluation of this material is of great value to the industry.

While nutgrass remains a problem for many cotton growers, the development of the nutgrass management package is of large value to the cotton industry. This value can be measured in terms of improved sustainability through a halt to the decline in productive areas in some fields, through a reduction in ongoing problems as nutgrass escapes into new fields are controlled before they become of importance and through increased cotton production on fields infested with nutgrass.

It is concluded that this research has and will continue to benefit the cotton industry both through its direct input and by way of leadership and input into the other projects on farming systems and weed management.

Recommendations on these activities

This project has had and will continue to have a big input into the direction and policy of the CRC for Sustainable Cotton Production. The developments of the project are being complimented and supplemented through the research program of the CRC's weeds researcher based at the ACRI and through the CRC's program based at UNE.

The current work is being continued through the new 3 year project funded by CRDC and it is proposed to expand the work through a new CRDC funded Post Doctorial project. The weed management systems aspect of the work will also be expanded with the appointment of a farming systems Scientist through the CRC.

Extension of the results from this work will continue to be a priority of the new project, leading to the development of units for "WEEDpac".

List of participants

The project has been undertaken by: Mr Graham Charles
Research Agronomist
NSW Agriculture.

Technical assistance was given by: Mr Stan DaSilva
Technical Officer
NSW Agriculture

and with the help of various casual staff.

Additional input into aspects of the project was made by: Mr Mark Hickman
Industry Development Officer
NSW Agriculture

Dr. Bob Murison
Statistician
NSW Agriculture

and the CSIRO Plant Breeding team at ACRI and Canberra.

Publications arising

Scientific Journals

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Charles G. W. (1997). Herbicide strategies for reducing nutgrass (*Cyperus rotundus L.*) density in cotton (*Gossypium hirsutum* L.). *Australian Journal of Experimental Agriculture.* **37**, 231 - 241.

Charles G. W. (1995). Nutgrass (*Cyperus rotundus L.*) control in cotton (*Gossypium hirsutum* L.). *Australian Journal of Experimental Agriculture.* **35**, 633 - 639.

Other

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Charles, G. W. (1996). Controlling nutgrass in cotton: a guide to developing a nutgrass control program for your property. Upper Namoi Valley nutgrass field day, March 21, 5 pp.

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APPENDIX 1

THE EIGHTH AUSTRALIAN COTTON CONFERENCE

Organised by

The Australian Cotton Growers' Research Association

WEDNESDAY 14th, THURSDAY 15th & FRIDAY 16th

AUGUST 1996

COMMUNITY INVOLVEMENT

MOVING FORWARD

NATURAL RESOURCES

cotton ON TO the future

CONFERENCE PROCEEDINGS

Conrad Jupiters

BROADBEACH, GOLD COAST, QUEENSLAND

SUSTAINABLE WEED MANAGEMENT ON PERMANENT BEDS

Graham Charles
NSW Agriculture
Australian Cotton Research Institute, Narrabri

Summary

Weed management systems in cotton are continually evolving, particularly in response to reduced cultivation and chipping and increased use of herbicides. The use of permanent beds and reduced tillage is likely to cause a shift in the problem weed spectrum, towards perennial weeds and those with rhizomatous root systems, which have previously been controlled with cultivation.

A survey of 23 properties found that most weeds were much worse on fully cultivated fields than permanent bed fields. The exceptions were rhyncho, datura, nutgrass and polymeria, which were much worse on permanent bed fields.

These data support the use of permanent beds as a way of reducing over-all weed pressure, but emphasise the need to develop control strategies targeted at perennial and rhizomatous weeds.

Introduction

Weed management in cotton is a constantly changing and evolving science. Management systems vary from field to field, farm to farm and season to season, in response to weed pressure (density and species), environmental conditions, cropping rotations, soil type and moisture content, time, labour, equipment and financial constraints, previous experience and individual preferences. Soil management, insect management (pupae busting), irrigation/rainfall method and timing, and stubble levels and management (stubble burning, stubble incorporation or stubble retention on the surface) also impact on weed management.

With continuing expansion of the cotton industry and in particular the rain-fed area, a wide range of systems for weed management have developed over time, ranging from heavy reliance on cultivation and chipping to heavy reliance on herbicides. These systems developed particularly in response to climatic and cultural differences, and to accommodate reduced tillage, permanent-beds, controlled trafficking and stubble-retention systems.

Over the decade, there has been a general reduction in the use of hand-chipping, with substitution of residual herbicides. Over the industry, diuron and trifluralin use has increased, while fluometuron, prometryn, pendimethalin, dicamba and glyphosate use has substantially increased. Of the remaining herbicides, only MSMA use bas declined.

These changes in approach to weed management have both benefits and costs. Benefits should include reduced weed competition with improved yields and efficiency, but this may not actually be the case. Systems reliant on herbicides may well be more expensive than more conventional systems and herbicide damage to seedling cotton is becoming a more common and more serious problem. Greater reliance on herbicides and especially residual herbicides may also lead to a build up of herbicides in the cotton environment and to environmental contamination. Herbicides may select out a new range of weeds which have in the past been controlled by cultivation, and heavy herbicide use may lead to the emergence of herbicide-resistant weeds as a major problem.

The ACRI's role

With the introduction of new berbicides (Staple and Sempra), herbicide-resistant transgenic cotton, and the continuing spread of problem weeds, it is likely that weed management will continue to evolve over the next decade. The primary aim of weeds research at the ACRI is to help the industry to assess the impact of changing management systems and to develop sustainable weed management systems for the future which rely less heavily on herbicides. In order to achieve this, my project includes a regular weeds survey of the 3 CRC farming systems sites, as well as another farming systems site, 5 permanent bed sites, and a fully cultivated site. Also, I have a weed management system experiment at the ACRI and am involved with the development of weed management systems for herbicide-resistant transgenic cotton.

A second weed scientist, Dr. Grant Roberts, has now commenced work at ACRI and will be focusing on developing sustainable, low-input weed management systems for fields which do not have heavy weed pressure, including rain-fed cotton production areas.

Permanent beds

Farming systems generally are moving towards the concept of minimum-tillage, and where possible, controlled trafficking. Implementation of this concept is leading to greater efficiency, with improved production and reduced soil degradation, but is also likely to cause a change in the weed spectrum. Weed spectrums evolve over time, as pressure from environmental conditions, cultivation, herbicides and crop competition select species tolerant of prevailing conditions. Species controlled by a component of one management system, may not be controlled by a new system, and over time numbers may increase until the weed becomes an important pest.

However, these weed problems, though important, may be slow to emerge. In many instances, weed spectrum will relate more closely to field history than to current practices, as many of the more difficult to control weeds of cotton are hard-seeded and seeds persist in the soil for very long periods. High levels of seed production and seed longevity in the seed-bank may mean that a lapse in weed control on just one occasion may ensure a weed problem over many years.

Reduced tillage, with increased reliance on herbicides, in particular glyphosate, will lead to the selection of a new weed spectrum, consisting of those species tolerant to the herbicides. This is likely to include perennial weeds and those with rhizomatous root systems. It is unlikely that these will be new weeds, but will be weeds already present at low frequency and being controlled with cultivation. Weeds which will probably become more important under reduced tillage, permanent bed systems, include: sow thistle, medics, emu-foot, rhyncho, verbine, the takealls (polymeria, haloragis & vigna), bindweeds, tar vine, nutgrass and oxalis.

Field data

To gain information on the impact of permanent beds, Paul Castor and Max McMillan undertook a survey of 23 properties in the Gwydir and Macintyre valleys in the 91/92 season. Fully cultivated and permanent bed fields were surveyed on each property. This survey included information on cropping history, herbicides used, and irrigation practice at planting (pre-irrigation or watering-up). Weeds were assessed using quadrats, with counts of hill and furrow areas.

Thirty five different weed categories were identified; categories consisted of a single weed species or a collection of similar and closely related weeds which were not readily distinguished. Densities of these weeds averaged over all properties and fields are shown on the following page.

The most common weeds were grasses, medics, peach vine, bladder ketmia and sesbania, each occurring at greater than I weed per m^2. Many of the other weeds occurred at very low densities (< 0.1 per m^2).

Table 1. The average density of 35 weed categories recorded in the 1991/92 survey of weeds on 23 properties in the Gwydir and Macintyre valleys.

Weed Category	Weeds per m^2	Weed Category	Weeds per m^2
Grasses (*Poaceae*)		Small broad-leaf weeds	
Barnyard grass	0.06	Amaranthus sp.	0.62
Black oats	0.03	Geranium	0.01
Other grasses	2.00	Goose foot	0.03
		Pig weed	0.02
Legumes (*Fabaceae*)			
Emu foot	0.81	Polymeria	0.14
Medic	2.96	Sensitive plant	0.02
Rhyncho	0.36	Sida	0.02
Vigna takeall	0.06	Spurge	0.09
Vine weeds		Medium broad-leaf weeds	
Aust. bindweed	0.07	Bathurst burr	0.06
Bindweed	0.03	Bladder ketmia	1.74
Devil's claw	0.29	Chinese lantern	0.84
Melon	0.03	Mallow	0.03
Peach vine	3.08	Mint weed	0.77
Wire weed	0.02	Prickly lettuce	0.04
Yellow vine	0.73	Sow thistle	0.04
Perennial weeds		Large broad-leaf weeds	
Nut grass	0.28	Anoda	0.02
Polymeria takeall	0.09	Datura sp.	0.35
		Noogoora burr	0.73
		Sesbania	1.62

Data collected by Paul Castor and Max McMillan.

Further analysis was undertaken of those weeds which were present at greater than 0.1 per m^2. Where cultivation, pre-irrigation method, or position in the row had a significant ($P<0.05$) effect on weed density, these data are presented on the following page. There were no significant effects on sesbania density.

Table 2. The effect of culture, irrigation technique at planting and position in the row, on the average density (number per m^2) of weeds occurring at densities greater than 0.1 per m^2. Data are only presented where the effects are significant ($P<0.05$).

Weed category	Culture		Irrigation		Position	
	Fully Cultivated	Permanent beds	Pre-irrigated	Watered-up	Hill	Furrow
Grasses						
Total grasses	4.2	0.0			1.9	2.3
Legumes						
Emu foot	1.0	0.6	0.5	1.2	0.1	1.5
Medic	4.6	1.3	3.9	2.0	0.5	5.4
Rhyncho	0.1	0.6	0.5	0.2	0.1	0.6
Vine weeds						
Devil's claw	0.6	0.0	0.0	0.6		
Peach vine	5.6	0.5	2.8	3.3	1.1	5.1
Yellow vine			0.2	1.2	0.3	1.2
Small broad-leaf						
Amaranthus sp.	1.2	0.0			0.0	1.2
Medium broad-leaf						
Bladder ketmia			2.0	1.5	0.4	3.1
Chinese lantern	1.7	0.0	1.7	0.0	0.8	0.8
Mint weed	1.5	0.0				
Large broad-leaf						
Datura sp.	0.0	0.7	0.7	0.0	0.2	0.5
Noogoora burr	1.5	0.0	1.5	0.0	0.4	1.1
Perennial weeds						
Nut grass	0.0	0.6			0.1	0.4
Polymeria	0.1	0.4			0.1	0.4

These analyses indicate that weeds are generally worse on fully cultivated fields than permanent bed fields. The exceptions to this were rhyncho, datura, nutgrass and polymeria, which were much worse on permanent bed fields, and sesbania, which was not affected by cultural technique. Planting irrigation had little effect on weed density, as might be expected, although Chinese lantern, datura and noogoora burrs were much worse on pre-irrigated fields, and devil's claw and yellow vine were much worse on watered-up fields. Weeds were consistently worse in the furrow than on the hill, probably indicating that banded herbicides were working effectively.

To achieve an overall analysis, a weed index was developed as follows:

weed index = (grasses + legume + small broad-leaf weeds) +
2 * (vines + perennials + medium broad-leaf weeds) +
4 * (large broad-leaf weeds)

Analysis of the survey results using this index showed that overall, irrigation had no effect on weed pressure, but that there were significant ($P<0.001$) differences associated with cultural technique and position in the row, as shown below.

Table 3. The effect of culture and position on the weed index, which includes all observed weeds. The effect of pre-planting irrigation was not significant ($P>0.05$).

	Culture		**Position**	
	Fully Cultivated	Permanent Beds	Hill	Furrow
Weed Index	52.5	16.5	21.0	48.0

This finding, that weed problems are far worse on fully cultivated fields supports the concept that permanent beds and minimum cultivation are helpful approaches in developing a sustainable, profitable cotton industry which relies less heavily on chemicals. Sustainability will, however, depend on developing strategies targeted at controlling problem weeds such as sesbania, datura, rhyncho, nutgrass and polymeria.

Appendix 2

The Australian cottongrower

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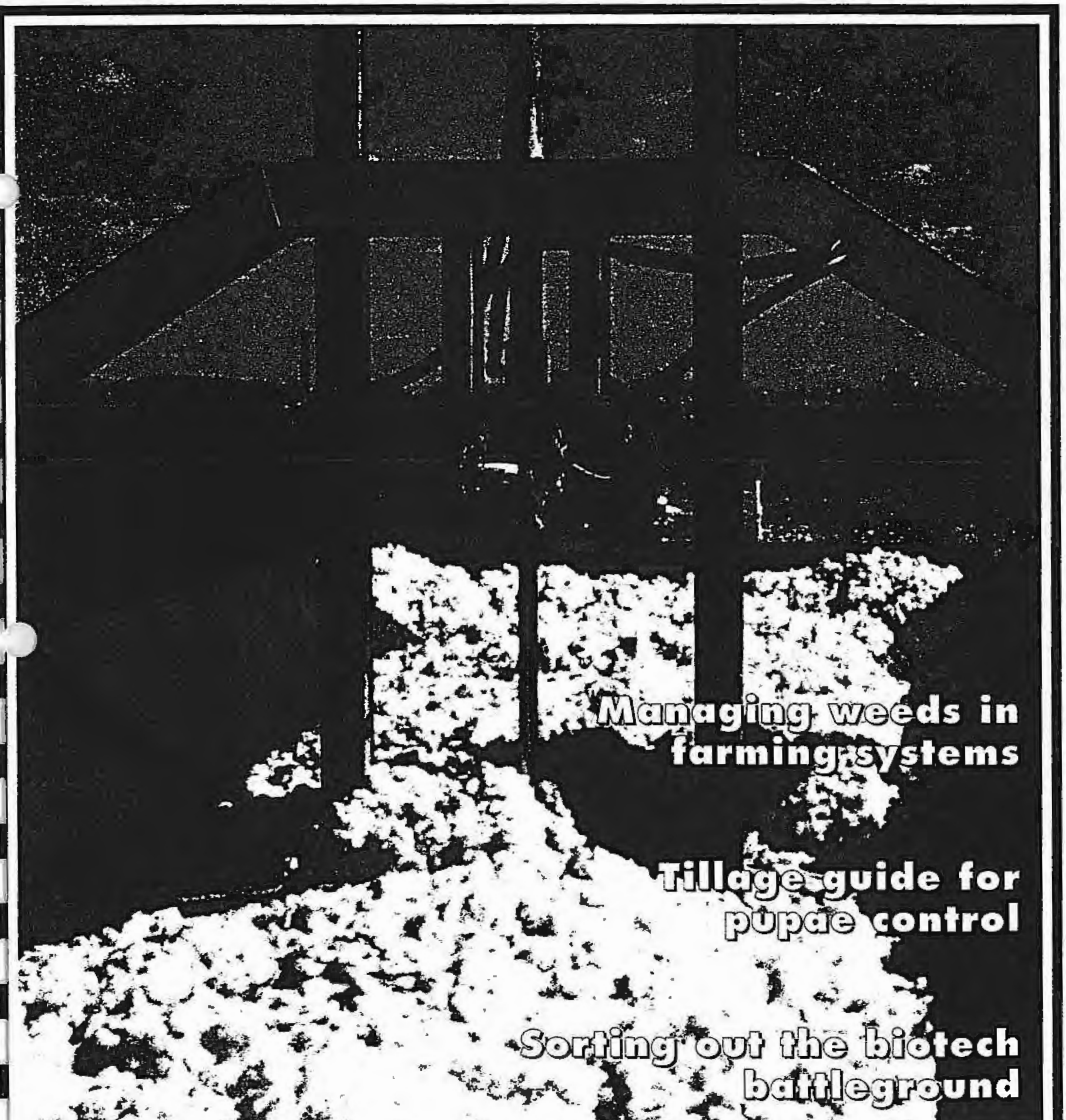


Managing weeds in farming systems

By Graham Charles, Australian Cotton Research Institute

Farming systems experiments are a core component of the CRC for Sustainable Cotton Production. Experiments are established on irrigated fields at 'Auscott' Warren, at 'Beechworth' Merah North, near Wee Waa, and on a non-irrigated field at 'Prospect' Warra, near Dalby. A large number of scientists are involved in monitoring various components of the systems, including soil characteristics, crop yields, water use, nutrition, disease incidence, and weed pressure.

Weed management is a constant problem in all farming systems, with infinite variations in weed spectrum and weed pressure. Weed problems are difficult to manage as they vary enormously between systems, between fields and within fields. Weed 'patchiness' is a normal but difficult to manage component of this problem.

Cotton and wheat plots in the cropping rotation systems experiment at Beechworth.

Ideally, different herbicides and rates are required in various parts of each field, to match weed occurrence. But this is next to impossible to achieve with current technology. Weed problems also vary from year to year and season to season, making it difficult to predict the need for pre-emergent herbicides.

Weed pressure in a field may reflect an inadequacy in a farming system, but also may reflect historic events, invasion of weeds from other sources, or unfavourable conditions at a critical time which allowed weeds to establish and set seed. Weed control on the CRC systems experiments is further complicated by very close proximity of different crops, which sometimes limits herbicide options because of the high risk of drift to neighbouring plots.

CRC RESULTS

Weed pressures over the three CRC sites are very different, both in weed species and in weed densities, with the greatest pressure at Beechworth, Merah North. Common factors over the three sites were the development of volunteer crops as important weeds, and the presence of high densities of sow thistle at all sites.

To allow a better understanding of the dynamics of weed populations on these sites, I've selected three systems from Beechworth: a continuous cotton system; a cotton/bare fallow rotation; and a cotton/wheat rotation.

These systems are shown in Figure 1, and the resulting weed pressures in Figure 2. Thirty eight different weed species were identified at Beechworth over three seasons, although peach vine was by far the most numerous and most important, with densities as high as 28 seedlings per square metre recorded.

Peach vine is being controlled in cotton at Beechworth using Cotogard at planting and Gesagard at lay-by. In the 1995–96 season, for example, Cotogard at 2.5 litres per hectare was applied at planting,

20 ▷

FIGURE 1: The crop rotations used in cropping systems

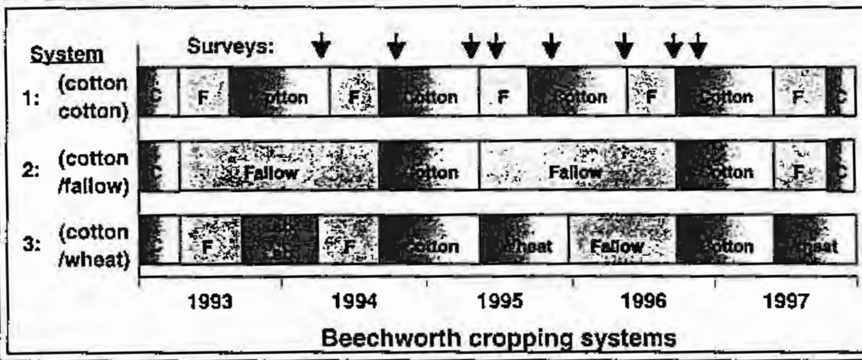
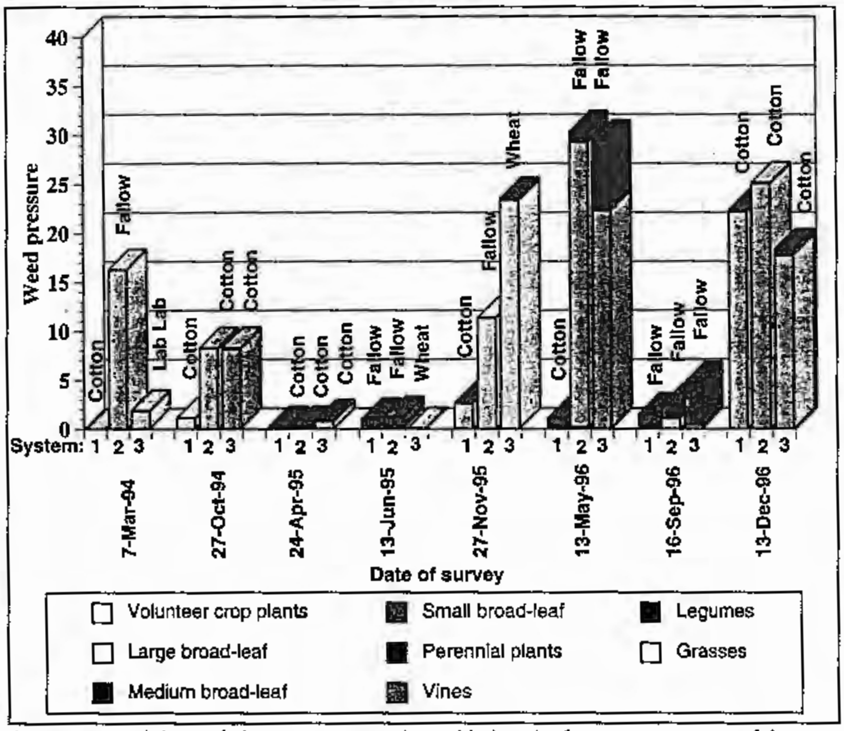


FIGURE 2: Weed pressure (small weed equivalents per square metre) on the Beechworth rotation experiment



The systems and dates of observation are indicated below the figure. Comparison of the systems can most accurately be made when all three are in the same cropping phase, as occurs on the 2nd, 3rd and final two observations.

and Gesagard at 2.5 litres per hectare was applied as a lay-by treatment.

Wild turnip was also present in the fallow of the cotton–wheat rotation at up to seven seedlings per square metre.

Overall, the continuous cotton system had the lowest average weed pressure, with comparatively low weed pressure on all but the last occasion. Nevertheless, it is significant that after three seasons of comparatively low weed numbers, this system does not have the lowest weed pressure in the current cotton season. There are a number of possible reasons for this result.

WEED SOURCE

It may be that the seed-bank of peach vine seed is so large at Beechworth that control over three seasons has not yet made an appreciable difference. Alternatively, it may be that peach vine seed is coming on to the field from external sources such as storage dams or supply channels.

A third possibility is that even though the peach vine levels on the continuous cotton systems have been comparatively low, there may still be enough seed produced in this system each year to generate the numbers seen at the final observation.

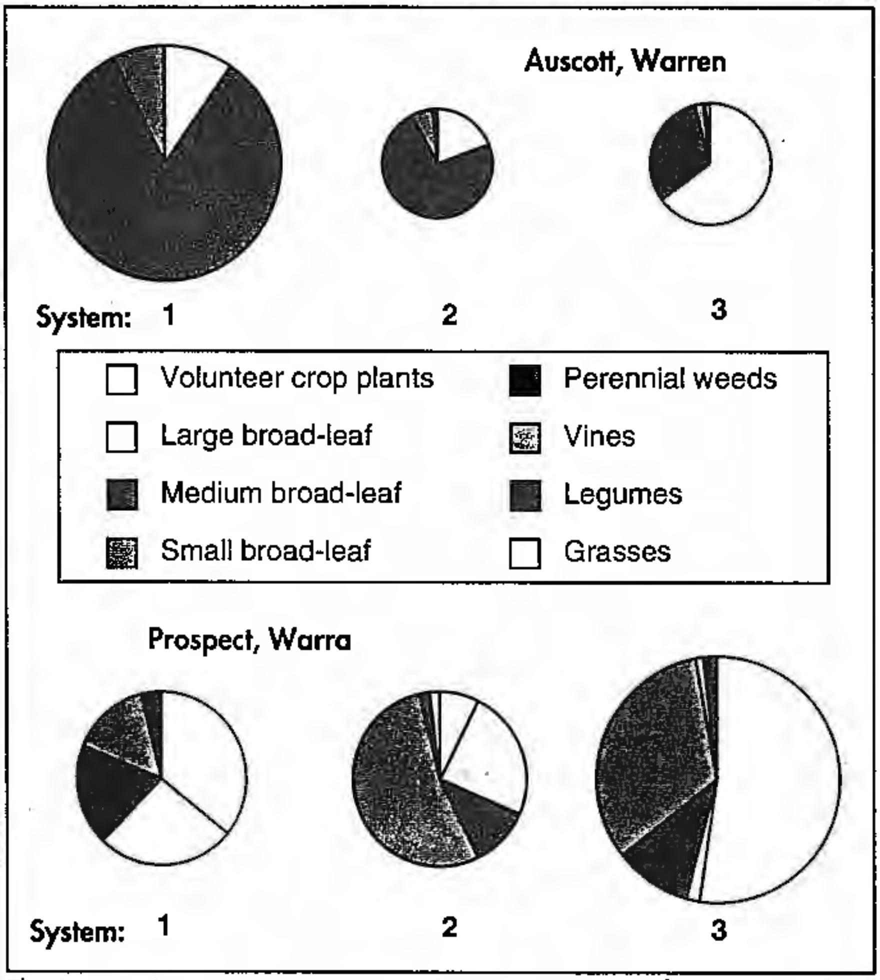
Other work has shown that the levels observed — of 0.2 peach vine per square metre in autumn — could have produced 158 seeds per square metre. This is more than sufficient to give the 22 peach vine seedlings per square metre observed here at the final observation. A better understanding of the source of the peach vine problem may allow the development of more effective management solutions. Work over the next season should clarify the issue.

The comparative advantage of the continuous cotton system at Beechworth was not apparent at the other two sites (Figure 3), although the large weed index on the continuous cotton at Auscott was largely due to a single occasion when the other two systems were in fallow. Also, the expected weed control advantage from a fallow component in a system is not apparent at this point.

Possibly the advantage is being masked by the large seed-bank present in the soil. Similarly, although broad-leaf weeds have been almost impossible to control in the broad-leaf rotation crops, these weeds are not yet showing up as long-term problems.

Over the three sites, the data to this point have not indicated any major advantages or disadvantages for weed management on the various cropping systems. It seems that historic events and seasonal conditions are having a larger impact on weed populations than the cropping systems used. Data over the next couple of seasons should clarify this result.

FIGURE 3: Weed pressure (small weed equivalents per square metre) on the Auscott, Warren and Prospect, Warra rotation experiments



The Auscott Warren systems were:
1 - continuous cotton;
2 - cotton/fallow rotation;
3 - cotton/wheat rotation.

At Prospect Warra (the non-irrigated site), the systems were:
1 - cotton/fallow rotation;
2 - cotton/wheat rotation;
3 - cotton/wheat/fallow rotation.

The Australian cottongrower

APPENDIX 3

GWC

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Sorting out cotton weed control options

By Graham Charles, Cooperative Research Centre for Sustainable Cotton Production

The arrival of new herbicides and new technology brings a fresh challenge to the science of weed management in cotton. The challenge is how best to use these resources to develop weed management systems which are sustainable and profitable, with less reliance on chipping, cultivation and herbicides. The introduction of genetically modified, herbicide tolerant cotton varieties particularly brings new possibilities to reduce the use of pre-emergent, residual herbicides.

Research over the past three seasons at the ACRI at Narrabri has compared 12 herbicide systems (see Table 1), assessing the resulting weed pressure and cotton yield under each system. Herbicide timing and rates were adjusted to reflect weed pressure on each treatment. At the start of the experiment, the field ranged from very clean at one end, through to very dirty (high grass population) at the other end. Noogoora and Bathurst burr were present in the middle of the field.

Summary

- Grass weeds were very difficult to control in systems without residual herbicides.
- Weed pressure was very high in systems without residual herbicides.
- Cotton yields were higher in conventional systems and systems using Roundup Ready cotton.

TABLE 1: Herbicide management systems

The following numbered treatments describe the herbicide management systems referred to in this article. Systems 9 to 12 are Roundup Ready treatments

1= Pre-emergent: Trifluralin
Plant: Cotoran
Post-emergent: Gesagard

2= Pre-emergent: Trifluralin and Diuron
Plant: Cotoran
Post-emergent: Gesagard

3= Pre-emergent: Diuron
Plant: Dual and Cotoran
Post-emergent: Gesagard

4= Pre-emergent: Diuron
Plant: Dual and Cotoran
Post-emergent: Gesagard

5= Pre-emergent: Diuron
Plant: Dual
Post-emergent: Staple and Gesagard

6= Pre-emergent: Diuron
Post-emergent: Falcon and Gesagard

7= Post-emergent: Staple, Falcon and Gesagard

8= Pre-emergent: Zoliar
Plant: Cotogard and Diuron
Post-emergent: Gesagard

Roundup Ready treatments

9= Pre-emergent: Triflurolin
Post-emergent: Roundup

10= Pre-emergent: Trifluralin and Diuron
Post-emergent: Roundup

11= Post-emergent: Staple and Roundup

12= Post-emergent: Roundup

The herbicides and rates used are shown in Table 2. Rates marked with an * were split applications.

Grass control

Barnyard grass pressure was low on all systems in 1995–96 (Figure 1), but blew out over the next two seasons on systems not including a pre-emergent grass herbicide (Systems 7, 11 and 12). Fusilade was used as a post-emergence grass herbicide in Systems 6 and 7 in 1995–96, but performed poorly and was replaced by Verdict in 1996–97. Verdict also performed poorly and was replaced by Falcon last season. Falcon gave very good grass control on System 6, but failed in System 7 where it was used in combination with Staple (Staple applied on November 6 and Falcon on November 7). The Staple inactivated the Falcon when used this way, and a second Falcon application on November 17 again gave no grass control.

Barnyard grass control was also poor on the two systems using Roundup Ready cotton without a pre-emergent grass herbicide (Systems 11 and 12). The grass was controlled by Roundup at each herbicide application, but as Roundup has no residual activity, it did not control successive weed germinations and the grass got out of control when wet and windy conditions prevented timely herbicide application. In the 1997–98 season, for example, the cotton was to be watered up, but emerged on rain. Roundup was applied on November 6, killing most grass seedlings. A second directed application was planned for late November, but the weeds (and cotton) were moisture stressed and the field was irrigated on November 19. Rain occurred before the field dried out and the Roundup application was delayed until mid-December, by which time the grass was large and competing strongly with the cotton.

Broad-leaf weed control

Dwarf amaranth, wild gooseberry and caustic weed were the most numerous of the smaller broad-leaf weeds. These weeds were again worst on systems which did not include pre-emergent herbicides (Sys-

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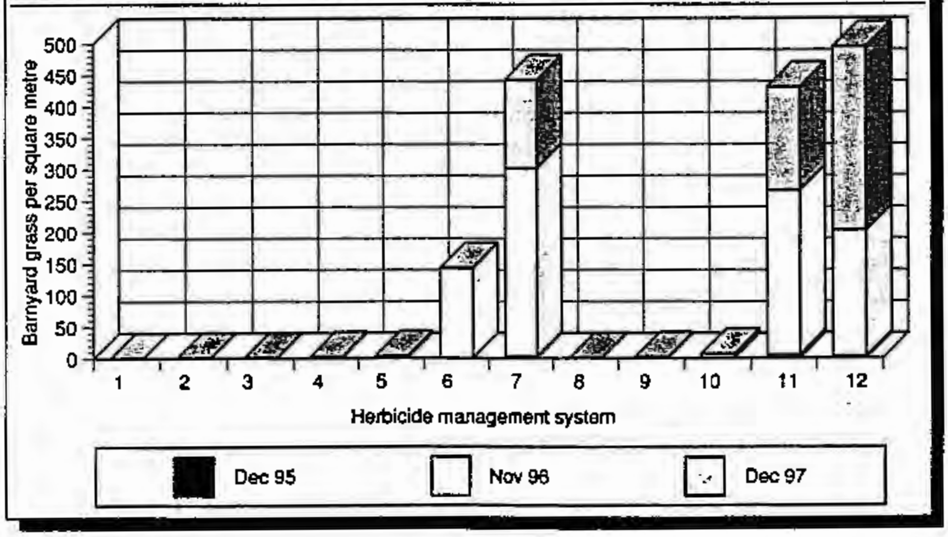
FIGURE 1: Barnyard grass density over the three seasons. Falcon herbicide was used only in the 1997–98 season, with Fusilade used in 1995–96 and Verdict in 1996–97 (Systems 6 and 7)



< 13...WEED CONTROL OPTIONS

tems 7, 11 and 12), with both pre-emergent grass and pre-emergent broad-leaf herbicides showing some activity on these weeds (Figure 2). Roundup killed most of these weeds, but gave inadequate control as the weeds continued to germinate throughout the season.

TABLE 2: Herbicides used in the trials

		Total herbicide rate applied (l or kg/ha)		
		1995–96	1996–97	1997–98
Pre-emergent herbicide (applied in early September)	Trifluralin	2.5	2.7	2.9
	Diuron	1.7	2.7	2.9
	Zoliar	1.4	1.3	1.5
Planting herbicide (early October)	Cotoran	3.8	3.8	3.8
	Dual	2.1	2.1	2.1
	Cotogard	1.0	1.0	0.9
Post-emergence herbicide (November & December)	Fusilade	2.4*		
	Verdict		2.1*	
	Falcon			0.18
	Staple	0.20*	0.23*	0.24*
	Roundup CT	2.4*	2.0*	4.3*
	Gesagard	2.0	6.2*	2.2

FIGURE 2: The density of small and medium-sized broad-leaf weeds over the three seasons. Dwarf amaranth, wild gooseberry and caustic weed were the most numerous of these weeds

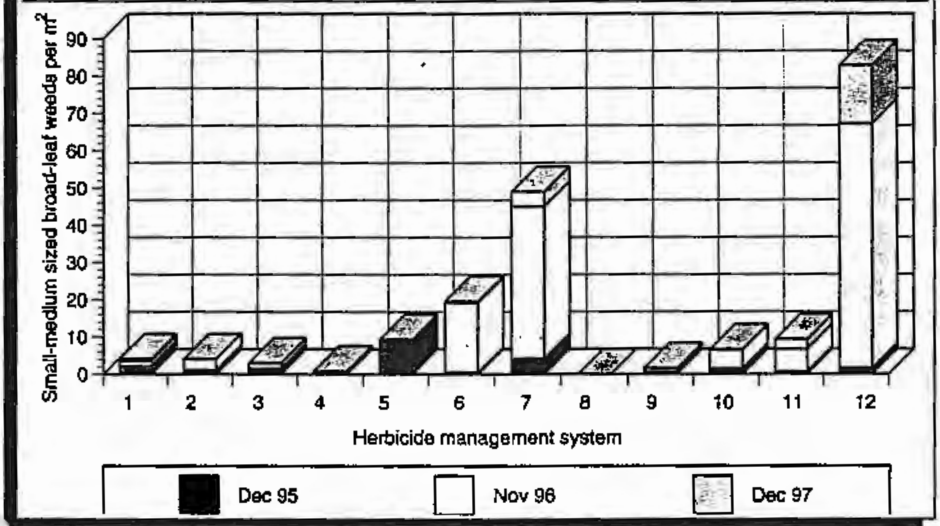
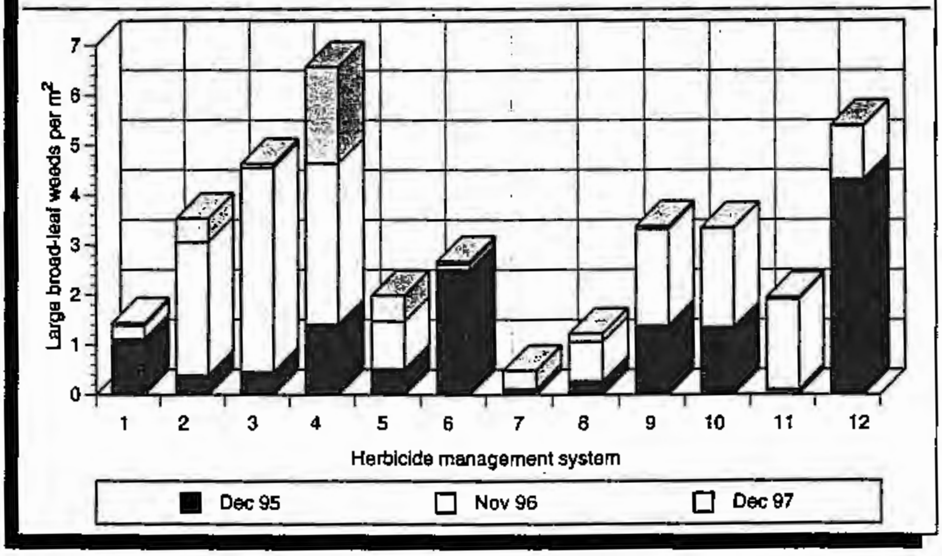


FIGURE 3: The density of large broad-leaf weeds. Noogoora and bathurst burrs were the most common



Dwarf amaranth was well controlled in systems which included trifluralin or Dual, and Staple gave some control. Dwarf amaranth was not controlled in the system using only Roundup. Wild gooseberry was controlled in all systems which included a pre-emergent herbicide, while caustic weed control was much better in systems including Dual when compared to those including trifluralin.

Noogoora and bathurst burr were the most common large broad-leaf weeds with relatively high numbers in most systems (Figure 3). Unlike the smaller broad-leaf weeds, the best large broad-leaf weed control occurred in System 7, which included no pre-emergent herbicide. Of the remaining systems, those including Staple gave a reasonable level of control, although burr germination occurred season-long, and control was limited to two Staple applications.

Using Gesagard as a lay-by broad-leaf weed control tool appeared to be a largely ineffective strategy. In systems where broad-leaf weeds were a problem, these weeds emerged well before lay-by, and so were not controlled by this herbicide application. The Gesagard rate was increased and applied as a split application in the 1996–97 season, but the lay-by component of this application (4 l/ha applied on January 6) was still largely ineffective as most weeds had emerged before this application.

Weed pressure index

A weed pressure (competition) index was developed to allow an overall comparison of the weed pressure on the systems. This index gave higher weighting to larger weeds to reflect the relative competitiveness of the different species, resulting in a weed pressure index expressed as 'small weed equivalents' per square metre. The

Weed pressure increased in systems without residual herbicides.

weed index was dominated by the high grass density in some systems, and was highest on systems not including pre-emergent herbicides (Systems 7, 11 and 12).

The weed index was lowest in the 'conventional' system (System 1) and in System 8. Overall, systems which included trifluralin gave better weed control than those including Dual.

One unexpected result was a reduction in weed control in systems including diuron and trifluralin compared to those with only trifluralin (System 2 compared to System 1, and 10 compared to 9).

Cotton lint yield

Yield of the non-Roundup Ready systems (Systems 1 to 8) over the three seasons (Figure 5) was inversely related to weed pressure (Figure 4), with the highest yields on the systems with the lowest weed pressure. Overall, the conventional system (System 1) gave the highest yield, with the lowest yield on System 7.

The Roundup Ready systems (Systems 9 to 12) recorded high yields, with the highest yield on System 9. The high yields on these systems in 1996–97 can be partly attributed to the design, with Roundup Ready sown in small plots, with a large edge effect. But Systems 9 and 10 out-yielded System 1 (the best normal cotton system) by three bales per hectare in 1997–98 when all systems used the same plot size.

To better understand this result, an additional system was included last season, in which Roundup Ready cotton was treated as normal cotton using System 1. This additional system had the same weed pressure as System 1, but yielded 1.7 bales per hectare less than System 1. This result indicates that the high yield on Systems 9 and 10 was not due to Roundup Ready cotton per se, but may be due to an interaction with the Roundup and/or the reduction in the use of residual herbicides on these systems.

Surprisingly, even though there was a huge difference in weed pressure between the best (System 9) and worst (System 12) of the Roundup Ready systems, the lint yields were not that different, with System 12 yielding as well as the best of the conventional systems.

Comparison of the systems with and without diuron (System 2 compared to System 1, and 10 compared to 9) shows the combination of trifluralin and diuron resulted in a reduction in cotton yield as well as the increase in weed pressure previously noted. Further work will be undertaken to investigate this result, which is not easily explained, but was consistent over systems and seasons.

FIGURE 4: The overall weed pressure, expressed as small weed equivalents per square metre. Two pairs of systems are highlighted, where the resulting weed pressure with and without diuron can be compared

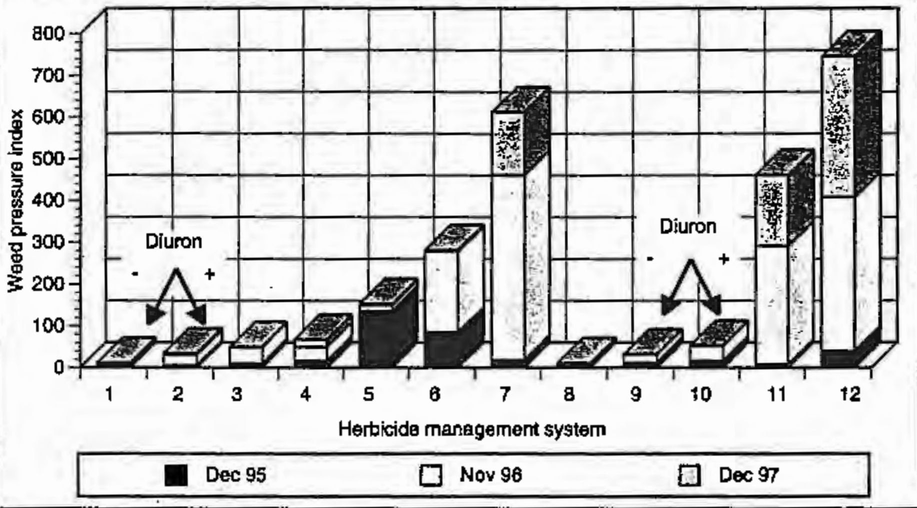
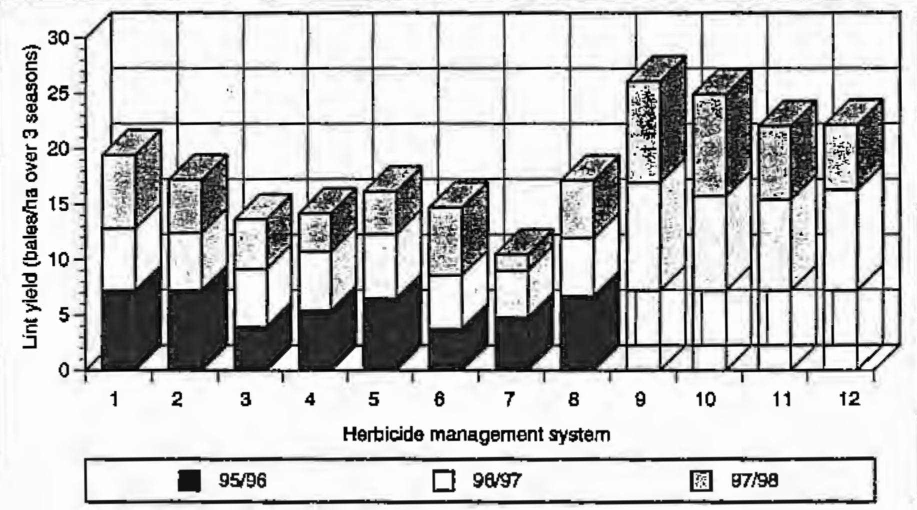


FIGURE 5: Cumulative cotton lint yield over the three seasons



NOTE: Roundup Ready cotton was not available in the 1995–96 season. A yield equal to that of the conventional system (System 1) is shown for Systems 9 to 12 for this season. The high yield on the Roundup Ready systems in 1996–97 is also misleading as only small sub-plots could be used in this season due to a shortage of seed. The 1997–98 yields represent a true comparison between all systems

Published work points to an interaction between these herbicides, where the pruning of surface cotton roots by trifluralin can 'safen' cotton to diuron, as diuron would be absorbed through these surface roots. But our work suggests the presence of other interactions. A similar effect might be expected when trifluralin is used in combination with either Cotoran or Cotogard at or before planting.

Of the other herbicides, there was a 71 per cent reduction in cotton establishment on the systems including Dual (Systems 3, 4 and 5) after rain following planting last season.

Gross return

Dollar return from each of the systems was compared to the conventional (System 1). The return was calculated as lint value minus the cost of herbicides and herbicide application, but excludes the cost of other inputs, which will be similar for most systems, although with reduced picking costs on the poorer yielding systems.

None of the non-Roundup Ready systems were as profitable as the 'conventional' system (System 1), with crop value mirroring the lint yield data. In all systems the yield of lint had much more effect on profitability than did the cost of the weed control system used. In the worst case (System 7), the system yielded nine bales per hectare less lint (over the three years) com-

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pared to System 1, with a loss of $5953 per hectare compared to this system.

However, the two Roundup Ready systems which included pre-emergent herbicides (Systems 9 and 10) had higher yields and lower cost than System 1, returning a profit of $3830 per hectare (System 9) and $3162 per hectare (System 10) more than System 1 (over three years), as well as a reduction in the input of residual herbicides when compared to System 1.

Conclusions

Growers should be careful about making radical changes in weed management, as the consequences of a mistake can be very expensive. But there may be considerable gains to be made in modifying herbicide systems. A system which is giving satisfactory weed control may not be the optimum management system.

Of the new technologies, Roundup Ready cotton gives the grower the potential to reduce the use of residual herbicides as well as increasing yields. Growers should seriously evaluate the potential benefit of this material to their cotton system and the possibilities for modifying their existing weed management systems.

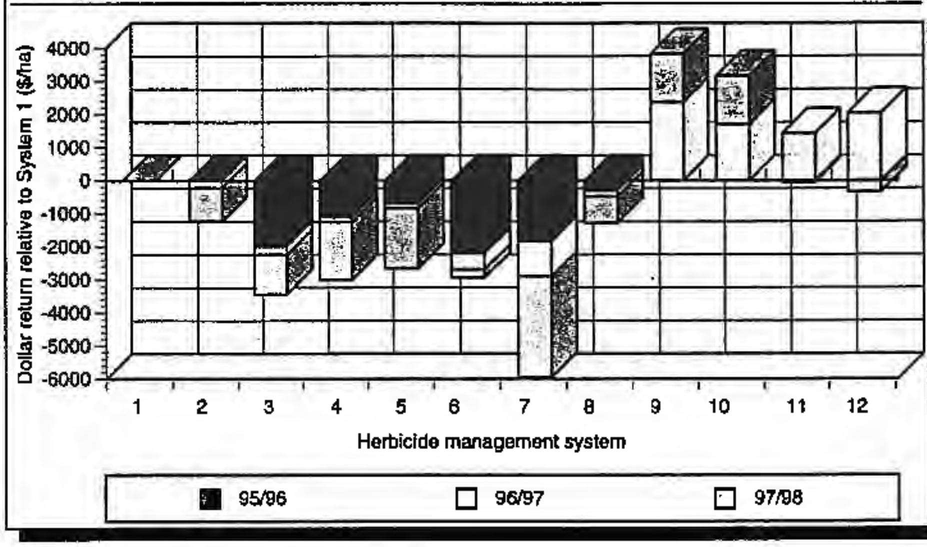
But growers would be well advised to retain most components of their existing weed management program at least initially, making modifications as more experience is gained with the technology. A weed management system using trifluralin and Roundup Ready cotton many prove satisfactory in many instances, while a system using Roundup Ready cotton without any residual herbicide may be practical in some situations, but may be unsatisfactory in some seasons and may not be sustainable in the long-term.

These experiments, which now include Basta tolerant and bromoxynil tolerant cotton, will continue, with some modifications, over the next three seasons.

A system giving satisfactory weed control may not be the optimum management system.

This work has only been possible through the financial support of the Cotton Research and Development Corporation, close cooperation with the CSIRO plant breeding team, and assistance from Novartis, Du Pont, Nufarm, Monsanto and Rhone Poulenc.

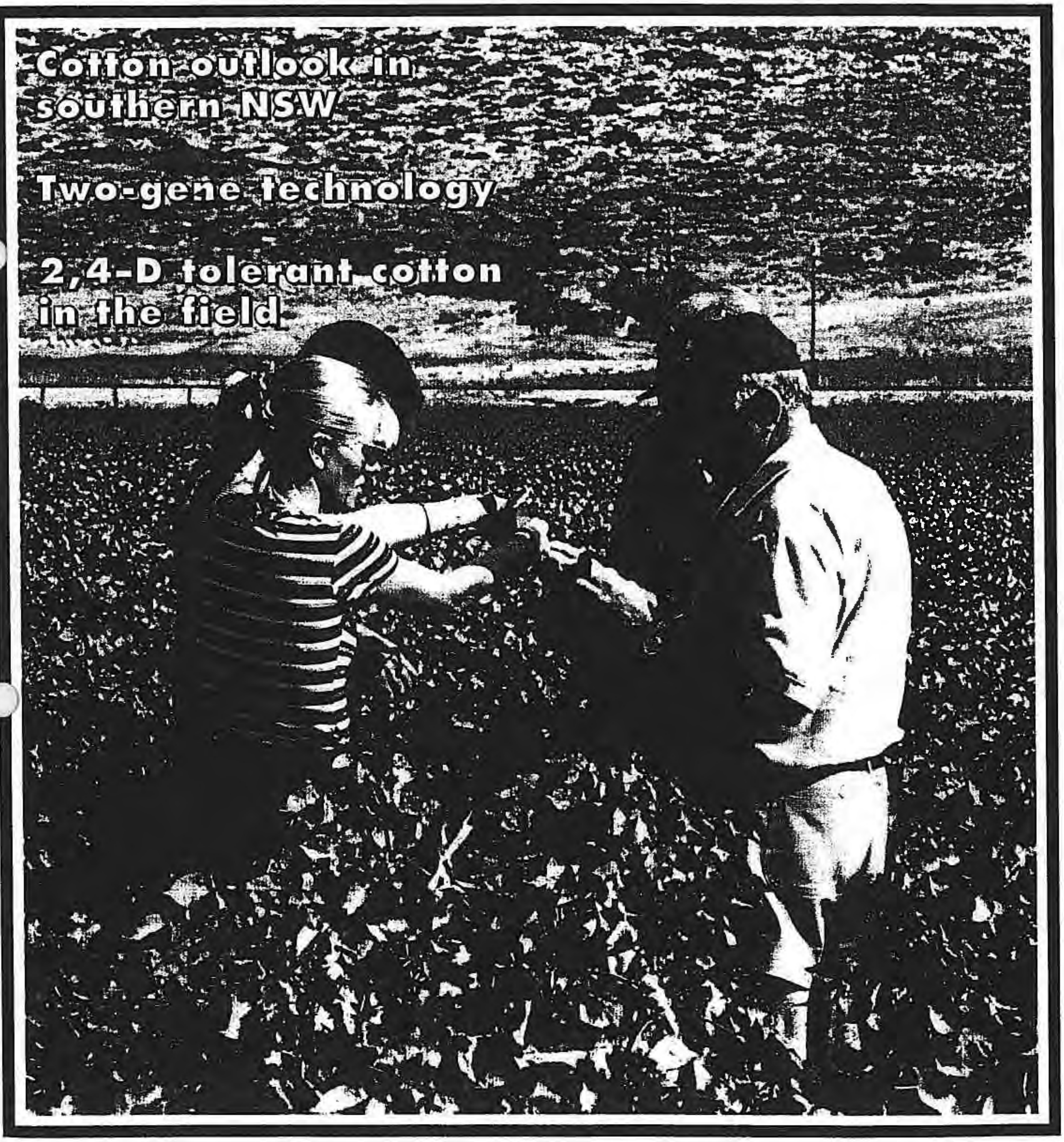
FIGURE 6: Dollar return of the systems compared to System 1. The return was derived from the value of the lint less the cost of herbicides and herbicide application. No value was entered for the Roundup Ready systems in 1995-96



The Australian cottongrower

Appendix 4

VOLUME 19, No. 5 $5.00 PRINT POST APPROVED Publication No. PP 405518/00026 SEPTEMBER – OCTOBER, 1998



2,4-D tolerant cotton in the field

By Graham Charles, Mark Hickman, Danny Llwewllyn and Greg Constable,
CRC for Sustainable Cotton Production

The efficacy of transgenic, 2,4-D tolerant cotton was field tested over the past two seasons in an irrigated field at Premer, on the Liverpool Plains of NSW. The material developed by CSIRO was a single transgenic line of Coker 315 containing an introduced 2,4-D degradation gene.

The effects of spraying both transgenic and normal plants with 2,4-D were monitored in the 1996–97 season using visual damage symptoms and dry matter production.

A similar trial was carried out in the 1997–98 season when conditions were more favourable and the plots were harvested to determine lint yield. Tolerance to MCPA was also assessed in this season.

BACKGROUND

Cotton is extremely sensitive to 2,4-D and even minute traces of herbicide can cause some visible damage. Damage normally shows up as deformed leaves, with leaf strapping, crinkling and cupping, and twisting of the petioles (leaf stems), stem and squares. Reddening of the leaves and petioles may also occur. In severe cases, 2,4-D damage can kill cotton plants.

2,4-D commonly comes in two formulations:

- 2,4-D amine, which is relatively non-volatile; and,
- 2,4-D ester, which is volatile.

Where 2,4-D is sprayed during the cotton season there is always a risk of off-target movement, but this risk is much greater with the ester formulation. Movement can be in the form of spray drift in windy conditions, or through volatilisation of 2,4-D ester, where the herbicide is correctly applied to the target, but then volatilises back into the air. These very fine volatilised droplets can be carried for long distances and may effect a cotton crop many kilometres from the site of application.

2,4-D damage can also occur when 2,4-D is applied to a fallow field in a dry winter. 2,4-D normally has a very short half-life in soil where its breakdown is dependent on the activity of soil bacteria. But under cold dry conditions, microbial activity can be minimal and sufficient residual 2,4-D may remain to damage cotton.

2,4-D is also quite difficult to remove from spraying equipment and damage can occur if equipment is used to spray 2,4-D in winter and not adequately decontaminated before use on a cotton crop.

Despite these difficulties, 2,4-D is an effective and relatively inexpensive herbicide which is often used for broadleaf weed control in fallows in winter, often as a tank-mix with glyphosate. It is also widely used for broad-leaf weed control in cereal crops and in summer for burr control in pastures, although this later practice should never occur in a cotton-growing region because of the sensitivity of cotton to this herbicide.

TOLERANT PLANT

CSIRO developed a cotton plant which was genetically altered to make it tolerant to 2,4–D. A gene isolated from one of the bacteria that breaks down 2,4–D in soil was inserted into the plants to allow them to detoxify 2,4–D to a less toxic chemical before the cotton is damaged.

The gene was introduced into Coker 315, an American cultivar not suited to Australia's cotton production system and breeding is being done to transfer the genes into Australian cultivars. As yet, all the field efficacy studies have been done on the Coker material.

The Coker transformant showed good tolerance to 2,4–D and some tolerance to MCPA in the laboratory, but it was necessary to evaluate the material's performance in the field. To do this a site was selected near Premer, on the Liverpool Plains. This site was sufficiently far from commercial cotton to ensure that 2,4–D could be used without danger to neighbouring crops.

THE 1996–97 SEASON

The cotton was first evaluated in 1996–97 in small plots within a commercial sorghum field, surrounded by buffers of a Siokra cultivar as required by GMAC, the regulatory authority controlling the field testing of transgenic plants.

Transgenic, 2,4–D tolerant cotton (two rows left of centre) and 'normal' cotton (two rows right of centre) sprayed at the vegetative stage with 2.2 litres of 2,4–D amine per hectare. Thirty days after application the transgenic, 2,4–D tolerant cotton is completely unaffected by the spray.

'Normal' cotton sprayed at the vegetative stage with 0.02 litres 2,4–D amine per hectare. Leaf strapping, crinkling and cupping is clearly seen 30 days after herbicide application.

The design was a split-plot, with transgenic and normal cotton side-by-side in each treatment. This design ensured that transgenic and normal plants were equally exposed to the herbicide, but gave the transgenic plants an advantage when the normal plants in the neighbouring rows were stunted or killed by the herbicide.

Unfortunately, the cotton established poorly and unevenly due to variable soil moisture at planting. 2,4–D amine was applied at vegetative, flowering and boll fill stages (January 27, March 4 and March 24 respectively), at 4.5, 1.1 and 0.28 litres per hectare, corresponding to 200 per cent, 50 per cent and 12.5 per cent of normal 2,4–D field rates.

The experiment was terminated on April 15, when plant mapping occurred and dry-matter cuts were taken to assess biomass production. There were no open bolls on the crop at this stage. The results are shown in Figure 1.

Dry-matter yield was most affected when 2,4–D was applied at the vegetative growth stage (Figure 1), with plant weight reduced by 90 per cent at the highest 2,4–D rate (weight of the normal cotton compared to the transgenic cotton). The result from the boll-fill application was inconsistent, with plants already having achieved their final size before 2,4–D was applied.

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◁45...2,4-D TOLERANT

Visual observations indicated that the transgenic material was mildly effected by the highest rate of 2,4-D, but they seemed to grow out of the effect after seven to 10 days, with no apparent effect on square development, flowering or boll retention. The transgenic plants treated with the lower rates showed no visible effects of 2,4-D.

But there was some indication of a depression in growth of the transgenic material from 2,4-D applied at high rates during flowering, suggesting that the tolerance gene is expressed less well later in development.

Nevertheless, the transgenic material clearly performed well when compared to normal cotton, exhibiting high levels of tolerance to extremely high levels of 2,4-D. The levels of 2,4-D used in the experiment were far higher than would be experienced by cotton under herbicide drift conditions.

THE 1997-98 SEASON

The experiment was repeated last season with basically the same design, but with the inclusion of MCPA and an additional application time. Also the herbicide rates used were lower, with 2,4-D amine applied at 2.2, 0.45, 0.09 and 0.02 litres per hectare, corresponding to 100 per cent, 20 per cent, four per cent and 0.8 per cent of normal field rates, and MCPA applied at 4.0, 0.8 and 0.16 litres per hectare, corresponding to 100 per cent, 20 per cent and four per cent of normal field rates.

Transgenic, 2,4-D tolerant cotton (two rows right of centre) and 'normal' cotton (two rows left of centre) sprayed at the vegetative stage with 2.2 L of 2,4-D amine per hectare. Sixty-four days after the application the transgenic, 2,4-D tolerant cotton was completely unaffected.

Transgenic, 2,4-D tolerant cotton (two rows left of centre) and 'normal' cotton (two rows right of centre) sprayed at the vegetative stage with four litres of MCPA per hectare. Eight days after the application, there is leaf burning on the 'normal' cotton and some damage on the transgenic cotton.

The cotton was planted on November 10 and establishment was again variable. The field was irrigated twice and had two insecticide treatments. Herbicides were applied at vegetative, squaring, flowering and boll-fill stages (January 7, January 30, February 27 and March 5, respectively), and the cotton was picked on June 11. Lint yields are shown in Figure 2.

Cotton lint yield following 2,4-D application was lower on the normal than the transgenic cotton at all times except for the lightest application when applied at boll-fill (Figure 2a). Generally, the level of lint yield reduction declined with later applications and declined as the 2,4-D rate was reduced.

Cotton lint yield following MCPA application was lowest at the vegetative and boll-fill stages (Figure 2b). There was relatively little impact of MCPA at flowering.

The transgenic cotton was not adversely affected by 2,4-D applied at the vegetative stage, but that there was a 30 per cent yield penalty from applying the full rate of MCPA at this stage. 2,4-D applied at squaring did reduce the yield even of the transgenic material, with a 45 per cent yield penalty at the highest rate.

This was still far better than the result for the non-transgenic cotton which was severely affected (95 per cent yield penalty). MCPA at the two higher rates also resulted in a yield penalty on the transgenic cotton, consistent with lower tolerance to MCPA observed in glasshouse trials.

2,4-D applied at flowering had little, if any adverse effect on the yield of the transgenic material, but MCPA at the two higher rates again resulted in a large yield penalty on the transgenic cotton of around 55 per cent.

The results for 2,4-D applied at boll-fill are inconsistent, but indicate there was no adverse effect on the yield of the transgenic material, and there was also probably no effect of MCPA on the transgenic cotton at this stage.

CONCLUSION

The transgenic, 2,4-D tolerant cotton showed very good field tolerance to 2,4-D at all tested rates over two seasons. But there does seem to be some decline in tolerance during the squaring phase of plant development, although tolerance increases again at flowering. The cotton also has significant tolerance to MCPA during the early vegetative growth stage, but less tolerance during later growth.

This level of tolerance to 2,4-D should be of great value to the cotton industry and if incorporated into Australian cultivars, should greatly reduce the occurrence of 2,4-D damage from drift. The field tolerance to MCPA is marginal and is likely to have little practical impact on the cotton industry.

FIGURE 1: Cotton dry-matter production of normal cotton relative to transgenic, 2,4-D tolerant cotton in 1996-97: 2,4-D was applied over-the-top of cotton at the rates and growth stages indicated

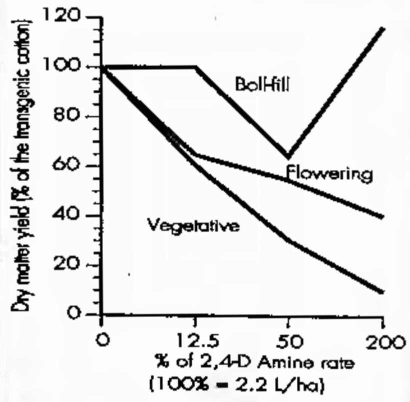
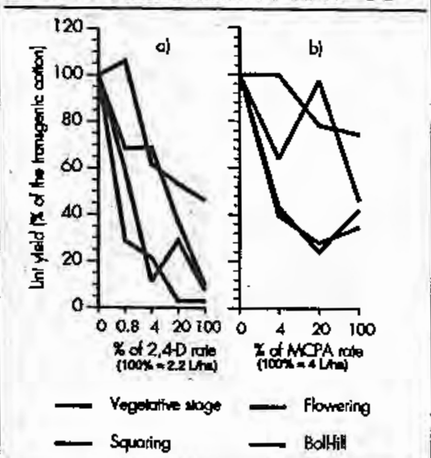


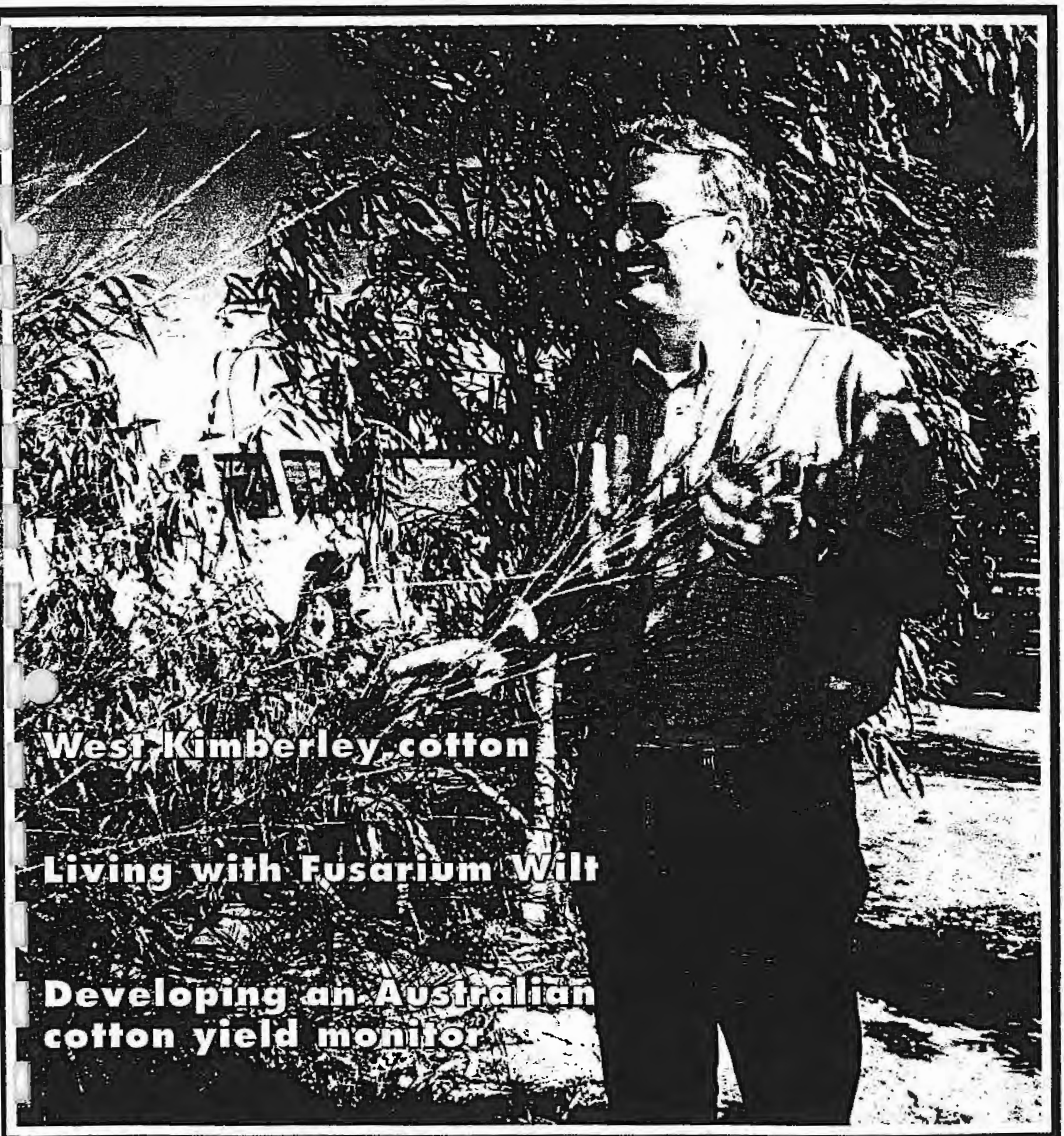
FIGURE 2: Cotton lint yield of normal cotton relative to herbicide tolerant cotton in 1997-98



The Australian cottongrower

Appendix 5

VOLUME 18, No. 5 $5.00 PRINT POST APPROVED Publication No. PP 405518/00026 SEPTEMBER – OCTOBER, 1997



Growing cotton, not nutgrass

By Graham Charles, Australian Cotton Research Institute, NSW Agriculture

Nutgrass *(Cyperus Rotundus L.)* can be controlled using a management strategy based on the concept of spraying the weed when it is actively growing in moist conditions, and cultivating in dry conditions. This conclusion is the result of research over the past six years.

One of the keys to nutgrass management is to develop a system which involves both herbicides and good farming practices — including ensuring a strong, competitive crop and maintaining good farm hygiene at all points.

FACTORS TO CONSIDER

Factors which must be considered in a nutgrass control program include:

• Ensuring positive identification of the nutgrass species. At least four different species are found in cotton fields and another four species occur in ditches and around fields. The appropriate management strategy will depend on the species present. Contact NSW Agriculture or Queensland DPI or myself for positive identification;

• Nutgrass is capable of multiplying at a rate of at least 2000 fold in a single season, so plants should never be left to be controlled at a later date. A reasonable kill of a small population from a spray in spring/early summer — with a later follow-up spray — is more cost effective than a good result on a much larger population;

• Nutgrass has dormant tubers and not all tubers germinate at any one time. In a mature nutgrass patch, there may be six to eight tubers for every nutgrass shoot. Sequential use of control measures can dramatically reduce a nutgrass population in a single season, but some dormant tubers will always remain for the next season, potentially re-infesting the area in later years;

• Nutgrass tubers can float in irrigation water, and so can easily move from channels into clean fields, or from other fields into clean fields. Tubers can also come in from the river system, particularly during floods;

• Nutgrass tubers are most commonly moved between fields on cultivation equipment. Cleaning down equipment between fields may be time-consuming, but it is one of the best ways to control the spread of nutgrass, as well as other weeds and diseases;

• Consideration of nutgrass patches is vital when land forming. This single operation has the potential to create a massive problem almost overnight;

• Nutgrass must still be controlled when the field is not in cotton. The same nutgrass management principles can be used in other summer crops, such as sorghum and sunflowers, where shielded sprays can be very effective. Well established winter cereals can be effective in competing against nutgrass in spring, and will allow a summer fallow for nutgrass control; and,

• Nutgrass is highly competitive. I have recorded nutgrass populations as high as 12,000 tubers per square metre (120 million tubers per hectare). Populations of this density easily out-compete cotton, resulting in no harvestable cotton. Nevertheless, nutgrass cannot tolerate shading, and so a strong, competitive cotton stand can out-compete nutgrass. Good cotton establishment and rapid early season growth is vital for high yields in nutgrass infested fields.

2.8 litres per hectare MSMA applied on December 15, 1995 and 2.4 litres per hectare Roundup CT on January 12, 1996 caused the large reduction in nutgrass density evident in the foreground plot compared to the plot directly behind it which was unsprayed. This photo was taken in November 1996 when the real impact of the previous season's treatment could be assessed.

OPTIONS FOR CONTROL

There is a range of options for nutgrass control, each of which has strengths and weaknesses.

Of the herbicides, glyphosate (sold under a variety of trade names) has consistently given the most cost effective nutgrass control in my experiments. It gives long-term control from multiple applications of rates down to 2.4 litres per hectare (three litres per hectare of the 360 gram a.i. per litre product).

But results from any single glyphosate application are variable and the herbicide is never 100 per cent effective. Results in the early part of the 1996–97 season in

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◁ 30...NUTGRASS

the southern cotton area were particularly poor due to cool seasonal conditions. A number of points to remember with glyphosate are:

- Regardless of which formulation is used, additional surfactant is needed;
- Applications to stressed nutgrass are unlikely to be effective. Moisture stress and temperature stress will greatly reduce glyphosate efficacy on nutgrass. Nevertheless, a glyphosate application to moisture stressed nutgrass can be effective when rainfall or irrigation occurs within 48 hours of application. Conversely, a glyphosate application on a warm day may be ineffective if it is followed by a series of cold days, as glyphosate is slow-acting in nutgrass, taking many days to translocate and kill the whole plant;
- Glyphosate efficacy is not related to nutgrass flowering. If anything, nutgrass is less sensitive to glyphosate in the flowering phase than any other phase. But glyphosate applications in spring are often less effective than those in autumn because the nutgrass plants are small (with a small leaf area), they are often temperature and/or moisture stressed and a significant percentage of tubers may still be dormant and not able to be treated;
- Any and every opportunity should be taken to treat nutgrass. Glyphosate should be applied whenever there is an opportunity — when plants have sufficient leaf area and are not stressed — whether that is before cotton is planted in spring, during the cotton season, at defoliation, or after harvest. While the autumn application may give the most visually impressive result, it is not necessarily the most cost effective time for treatment; and,
- Glyphosate cannot be safely applied to cotton except at or after defoliation. In-crop applications must be made through well designed and well set up shielded sprayers. These sprayers should use low-drift nozzles and operate at low pressure. If in doubt regarding the suitability of a particular shielded sprayer, growers would be well advised to test the result over a small area. The introduction of Roundup tolerant, Roundup Ready cotton will improve the safety of glyphosate applications.

A second photo in November 1996 comparing an untreated plot (left of photo) to the result achieved from a single Roundup CT application of 2.4 litres per hectare in mid January 1996 (right of photo). While nutgrass has not been eliminated from this field, the density was substantially reduced by the single, in-crop glyphosate application.

The edge of a field where glyphosate has been applied through a shielded sprayer. The sprayed furrow (right of centre) contrasts sharply with the unsprayed area (left of centre).

Daconate (MSMA) can be a useful herbicide. Strategic use of Daconate can enable a cotton crop to out-compete a heavy nutgrass population, although Daconate will not, by itself, actually reduce a nutgrass population. Daconate can be used as a directed spray, or applied 'over the top' of cotton with multiple applications possible. Over-the-top applications cause injury to older cotton and can result in significant yield reductions. I have recorded up to 25 per cent yield loss from repeated over-the-top applications, but this may still be a viable strategy in a heavily infested cotton crop, where the yield reduction due to uncontrolled nutgrass may be far greater than 25 per cent.

SUMMARY

Grower vigilance is the most important component of a nutgrass management program. It is essential to commence a nutgrass management program before the weed becomes uncontrollable.

The aim of a nutgrass management program must be to reduce the problem over time, not to eliminate nutgrass with a single treatment.

For additional information on controlling nutgrass, refer to the Research Review *Controlling Nutgrass in Cotton*, available from the CRC for Sustainable Cotton Production at Myall Vale, Narrabri, or contact the author on (02) 6799 1500.

Appendix 6.

ISSN 1327-0303

Weeds

RESEARCH REVIEW

Controlling NUTGRASS in Cotton

CRC Newsletter for the Research Extension Education Program
Volume 3 Number 1 March 1997

Reviewer: Graham Charles *
Researcher: Graham Charles

Summary

Nutgrass is a highly competitive and undesirable weed which severely affects cotton production. To control nutgrass in cotton a combination of the following management tools is needed:

1. ensuring a strong, competitive crop
2. using cultivation when nutgrass is stressed in hot, dry conditions,
3. using herbicide when nutgrass is actively growing in moist conditions
4. maintaining strict machinery hygiene to prevent the spread of nutgrass to new areas.

Background

Nutgrass, (*Cyperus rotundus L.*), or purple nutsedge, is the world's worst weed, infesting 52 different crops in 92 countries. A native of India, it grows from underground tubers and is able to produce new tubers within 4 weeks of shoot emergence.

In Australian conditions, a nutgrass plant establishing in spring from a single tuber can produce up to 2000 new tubers by autumn, each of which can produce a new plant in the following spring. Nutgrass is so highly competitive it can smother cotton, resulting in no harvestable lint. It may also harbour cotton pests and diseases and can reduce irrigation efficiency. Nutgrass contamination can down-grade cotton lint quality.

Controlling nutgrass is difficult because it can tolerate most herbicides. Dormant tubers are not affected by treatment with most herbicides.

Growth Habit

Nutgrass is a shallow rooted, grass-like weed, which tends to grow in clumps around a parent tuber. Plants grow rapidly in warm and wet conditions. Flowers produced on a prominent central stem are apparent from mid-summer through autumn. Seeds are produced, but are not the major source of infestation. Plants may be quite short (10 to 20 cm), but under favourable conditions may grow to 60 cm and occur in dense clumps. Nutgrass shoots are frost sensitive and plants normally become dormant over winter, with new shoots emerging in spring.

Nutgrass does not tolerate shading and will not flourish when overtopped by the crop.

A typical nutgrass plant with flower heads, daughter plants and new tubers.

Management Strategies

Nutgrass management strategies may aim either to contain the nutgrass sufficiently to achieve acceptable cotton yields or, to control the weed by reducing the population over time. A range of management tools is available to achieve these aims.

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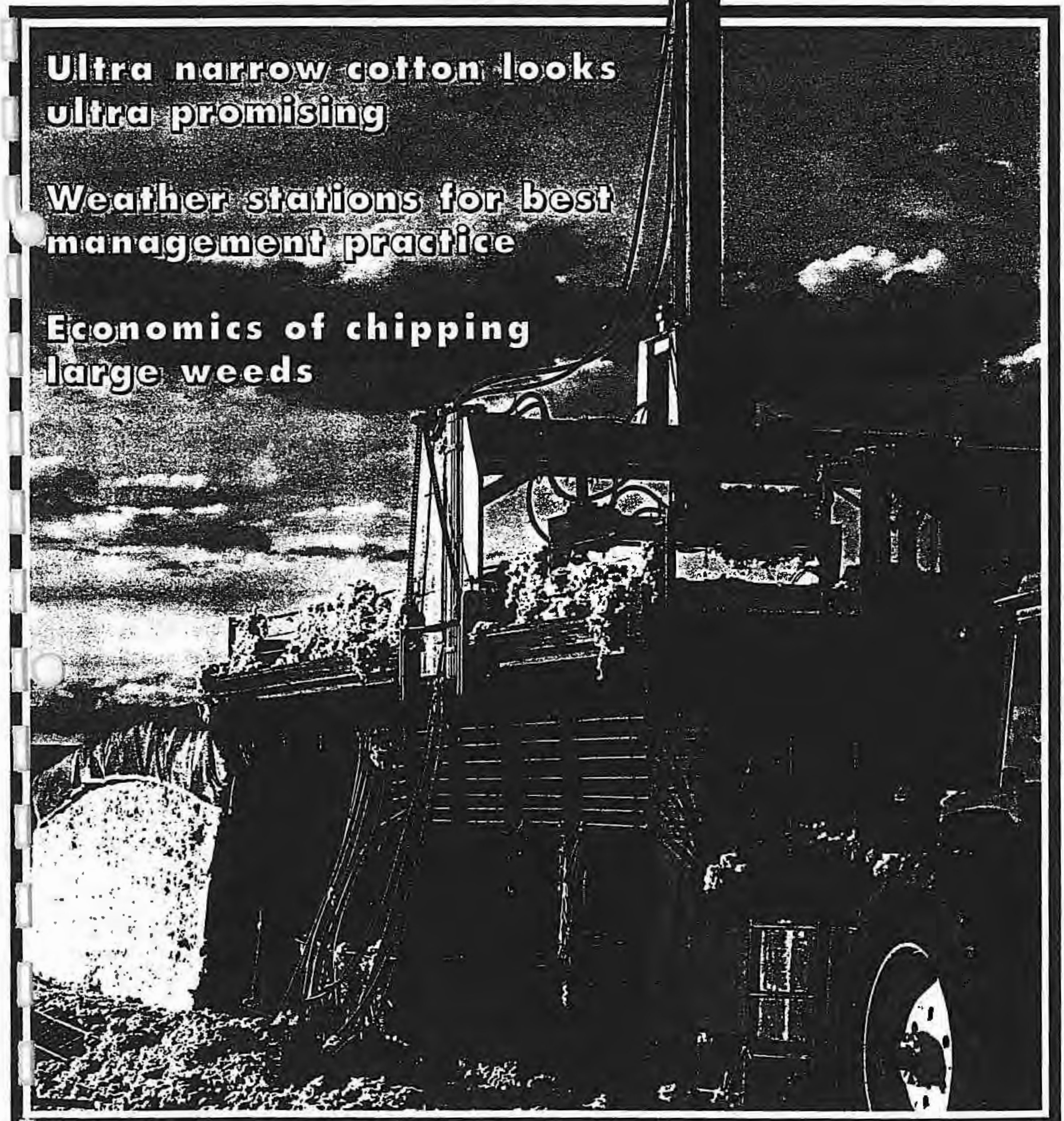
Cooperative Research Centre for Sustainable Cotton Production

The Australian cottongrower

APPENDIX 7

VOLUME 19, No. 2 $5.00 PRINT POST APPROVED Publication No. PP 405518/00026 MARCH – APRIL, 1998



The economics of chipping large weeds

By Graham Charles, Australian Cotton research Institute, Narrabri

The economic threshold for chipping large noogoora burrs *(Xanthium occidentale)* can be as low as one weed per 622 metres of cotton row, and as low as one weed per 178 metres of cotton for large thornapples *(Datura ferox)*.

This was the conclusion from three years' research at the Australian Cotton Research Institute, where the effect of single, large weeds on the yield of individual cotton plants was studied, using Siokra 1–4. These weeds emerged with or after the cotton, were in the row amongst the cotton and were not subsequently controlled.

Lint was hand-picked from individual cotton plants in the same row as the weed, and both the yield reduction due to the weed and the distance of influence of the weed (the maximum distance from the weed at which cotton lint yield was reduced) were estimated. At the same time the weeds were also harvested and both the weed canopy diameter and weed dry weight were recorded.

The distance of influence and yield reduction were most closely correlated to weed dry weight, although dry weight and canopy diameter were related, as shown in Figure 1. The noogoora burrs in this study were much larger than the thornapples (up to 9.9 kg compared to a maximum of 1.5 kg) and had larger canopies.

Both weeds caused large reductions in the yield of cotton plants and in the same row close to the weeds. No reduction in yields was observed in cotton in the row beside the weeds.

This lack of effect on cotton little more than one metre from the weed, but in a different row, shows that competition between the cotton and the weed was primarily below-ground, and would have been for nutrients and water. This occurred even though the cotton was irrigated and received normal nitrogen rates.

The largest observed noogoora burr caused a yield reduction of 55 per cent, while the largest thornapple caused a 33 per cent reduction.

These yield reductions were observed over distances of up to two metres on either side for noogoora burr and 2.4 metres for thornapple, with a total distance of influence (on both sides of the weed) of four and 4.8 metres respectively.

To develop economic thresholds for chipping cotton from this data, it was assumed that chipping cost $25 per hectare, cotton yield was 1500 kg lint per hectare and cotton was valued at $2.25 per kg. It was also assumed that at the low weed densities being considered, the

FIGURE 1: The relationship between weed dry weight and canopy diameter: the largest noogoora burrs were much larger than the thornapples

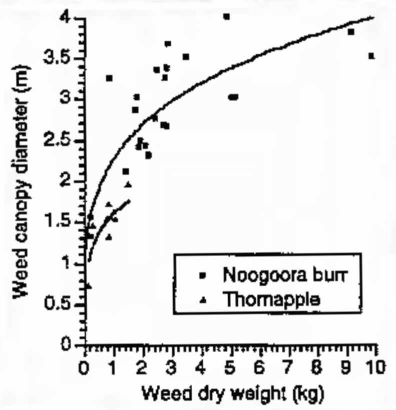
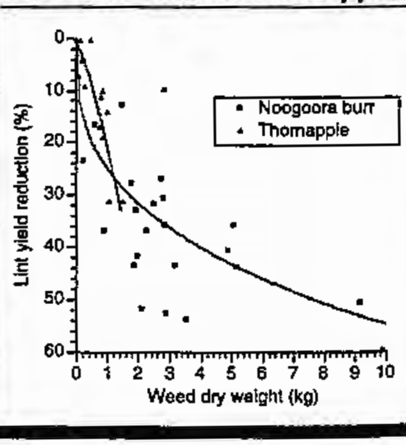


FIGURE 2: The relationship between weed size and the reduction in yield of surrounding cotton: the largest noogoora burrs reduced the cotton yield much more than the thornapples



cost of chipping did not increase as weed density increased.

Thresholds for chipping cotton derived from these assumptions showed that for the largest noogoora burrs observed, chipping could be justified at a weed density as low as one weed per 622 metres of cotton, and at one weed per 178 metres of cotton for large thornapples. These thresholds were related to weed size, so the threshold weed densities would be lower for smaller weeds. For example, the threshold would be one weed per 188 metres for a noogoora burr weighing three kg with a canopy diameter of three metres, and one weed per 40 metres for a thornapple weighing 0.5 kg with a canopy diameter of 2.7 metres.

FIGURE 3: The relationship between weed size and maximum distance of influence of the weed on cotton yield — as cotton on both sides of the weed was affected, this distance must be doubled to give the total distance over which cotton yields were reduced

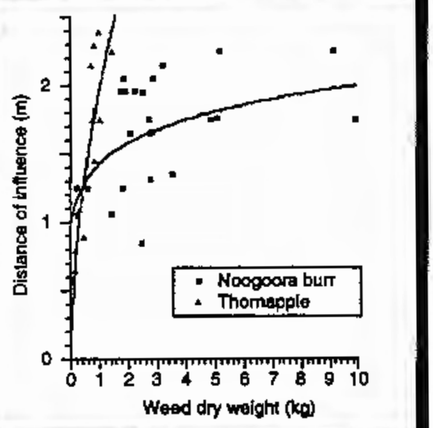
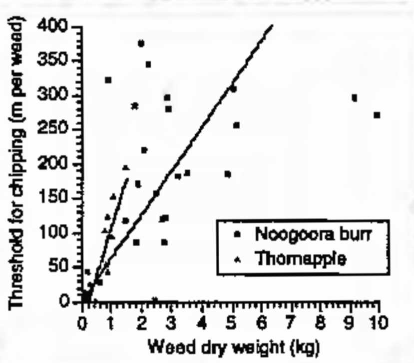


FIGURE 4: Relationship between weed size and threshold density for chipping: it would be economically sound to chip weeds at densities higher than those indicated by the relationships — the equations of the lines are threshold equals 62.7 multiplied by weight for noogoora burr and theshold equals 136 multiplied by weight minus 29 for thornapple



OTHER EFFECTS

These thresholds are based solely on the cotton lint reduction caused by the weed. Weeds also affect production in other ways. Weeds present at picking can:

- Contaminate cotton lint and reduce lint quality and value;
- Interfere with picking by blocking picker heads;
- Physically injure picker crews — for example weeds such as thornapple; and,
- Cause a delay in cotton maturity due to weed competition.

Earlier in the season, weeds may:

- Act as alternative hosts for pests and diseases;
- Reduce irrigation efficiency; and,
- Interfere with inter-row cultivation and other in-field operations.

Mature weeds also produce seeds which have the potential to multiply weed problems in later years. Other work has shown that a three kg noogoora burr produces about 2000 seeds, while a 9.9 kg plant produces 2800 seeds. A thornapple of 0.5 kg may produce as many as 8700 seeds, while a 1.5 kg plant produces 16,400 seeds. This seed production potential must also be considered when determining the economics of weed control.

So while the thresholds derived — based solely on yield — give a good indication of the very low thresholds for chipping large weeds, they are higher than the real thresholds, which take into account all factors. The thresholds are also sensitive to the cost of chipping, lint value, cotton yield and the competitiveness of the cotton crop.

Even lower thresholds for chipping would be appropriate for a higher yielding crop, while much higher thresholds would

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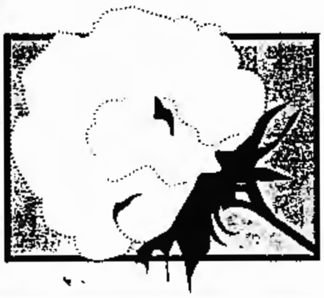
◁ 43...ECONOMICS OF CHIPPING

be appropriate for a lower yielding crop. For example, in a crop yielding 10 bales per hectare, (2270 kg lint per hectare), the threshold for chipping a large (9.9 kg) noogoora burr would be one weed per 940 metres or 11 burrs per hectare. In a 2.5 bale crop, the threshold would be one weed per 232 metres, or 43 burrs per hectare. The cost of chipping would increase at this density, further increasing the threshold.

Small weeds which emerge later in the season may not cause sufficient yield loss to justify their removal, but chipping may still be warranted when factors such as lint contamination and seed production are considered. Weeds which emerge in the furrow are easily removed with inter-row cultivation.



A large thornapple. Lint handpicked from individual cotton plants around the weed demonstrates a major yield reduction.

The Australian cottongrower

Appendix 8

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Understanding the weed seed menace

By Graham Charles, Australian Cotton Research Institute

ABOVE: A field badly infested with thornapple. Soil cores showed a seed-bank of 500 seeds per square metre.

The key to efficient and effective weed control lies in a better understanding of weeds, their life-cycles, competitive abilities and strengths and weaknesses. Initial work on the seed production and germination of five weed species was carried out in the past season and additional plants will be assessed in the coming season.

WEED SEED DORMANCY

Most weeds are successful because of their ability to produce large numbers of seeds, which germinate rapidly, producing vigorous seedlings and competitive plants. Nevertheless, many weeds produce 'hard' seeds which do not germinate readily, but may remain dormant in the soil for months or years. These dormant seeds can create long-term weed problems, even in fields which are kept 'clean' over successive seasons.

Seed production is generally correlated with plant size, with larger weeds producing more seeds. In the current work, weed size was estimated from the maximum width and breadth of the weed, and expressed as numbers per square metre, or from plant height (sesbania only).

Production ranged from 47 burrs (two seeds per burr) for a small Bathurst burr, through to an estimated 40,345 seeds from a large thornapple (Table 1). Seed production per fruit was also assessed, and whereas the burrs contain two seeds per burr, peach vine averaged three seeds per fruit, sesbania 31 seeds per pod, and thornapple 148 seeds per fruit.

The seeds of some species such as Chinese lantern appear to have no dormancy.

We attempted to germinate the seeds collected from these species, together with five other species, with mixed results (Table 2). The seeds of some species appeared to have no dormancy (Chinese lantern is the most obvious example), whereas others would not germinate without acid or mechanical scarification, and thornapple proved impossible to germinate at all with the techniques we used.

However, in the field, dormancy mechanisms are broken over time by influences such as leaching, repeated wetting and drying, temperature cycles, microbial attack and the actions of macro-organisms such as ants and birds.

WEED SURVIVAL

Not every seed will emerge as a new plant. Weed seeds are destroyed by various factors, most notably insect predation and microbial attack. Also, many seedlings germinate, emerge in unfavourable conditions and die. For example, on one treatment at the Beechworth, CRC Farming Systems site, 34 peach vine seedlings per square metre

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◁ 26...WEED SEEDS

emerged in May this year, all of which were killed by subsequent frosts. Consequently, although large numbers of weed seeds are present in autumn, numbers may be much lower by spring when conditions favour weed growth.

Data for wild oats, a plant most consider to have very hard seeds, showed the halflife of seed in the soil was only six months, with the population declining rapidly over time if seed production was prevented. Further research on this weed revealed that the weed's persistence is not due to the production of large numbers of hard seed in a single season, but rather, to the presence of a few small plants which emerge and produce seed each season, even when control measures are used. When seed production, rather than seedling germination is controlled, the weed seed-bank rapidly declines.

TABLE 1: Data range for smallest and largest weeds observed

Weed	Smallest		Largest	
	Size (m^2)	Seed (no.)	Size (m^2)	Seed (no.)
Bathurst burr	0.11	94	0.60	2305
Noogoora burr	0.25	242	3.20	1718
Peach vine	0.20	206	2.80	791
Sesbania	1.00 (m)	1091	2.70 (m)	18,644
Thornapple	0.86	4721	5.25	40,345

TABLE 2: Germination percentage of weed seeds at 25–30°C

Weed	Untreated seed	2% nitric acid for 2 mins	Mechanical scarification
Anoda	0	0	70
Bathurst burr	50	0	
Bladder ketmia	0	0	70
Chinese lantern	100	0	
Noogoora burr	60	20	
Peach vine	20	30	70
Polymeria takeall	20	30	
Sesbania	0	0	100
Thornapple	0	0	0
Velvet leaf	50	100	

WEED SEED BANKS IN COTTON

Extrapolating this data to the cotton situation, it seems likely that the weed seedbank is smaller than anticipated, even in heavily weed infested areas. In these areas, it is likely that weeds are germinating primarily from seeds produced by small weeds which emerge and grow in the cotton row each season and are not controlled, rather than from a heavy weed infestation which may have been present many years earlier.

My only data on seed-banks comes from an area at the ACRI, which was badly infested with thornapple. Fifty soil cores taken down to one metre revealed just under 500 seeds per square metre, with most seeds in the top 20 cm (Table 3). This seed density is quite small, considering thornapple's ability to produce 6400 seeds per square metre in a season, but still very high given the economic threshold for controlling thornapple is below 0.016 plants per square metre.

Work over the next two seasons will gain additional information on weed seed production and the size of the weed seed-bank, but current information makes it clear that good crop hygiene is a major step in the direction of sustainable cotton production with reduced reliance on herbicides.

TABLE 3: Density and distribution of thornapple seeds on a heavily infested site

Soil depth (metres)	Thornapple seeds (no.)	Thornapple seeds (per sq. metre)
0–0.1	16	163
0.1–0.2	19	194
0.2–0.3	4	41
0.3–0.4	3	31
0.4–0.5	3	31
0.5–0.6	1	10
0.6–0.7	1	10
0.7–0.8	0	0
0.8–0.9	1	10
0.9–1.0	0	0
Total	**48**	**489**