HERBICIDE TOLERANT COTTON – PREPARING FOR CHANGE

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Abstract Transgenic cotton (*Gossypium hirsutum* L.) cultivars capable of tolerating topical applications of glyphosate have been developed for commercial release in Australia. A dryland field experiment comparing conventional and post-emergent herbicide systems utilising a glyphosate tolerant cotton cultivar were conducted to asses the impact of this technology on weed management. Weed control was adequate in the target weed species susceptible to glyphosate when over-the-top and directed applications of the herbicide where applied according to label recommendations. Glyphosate only treatments require repeated applications based on seasonal rainfall and weed emergence, hence an understanding of the target weeds population dynamics is essential. No yield penalties were obtained in cotton compared to unsprayed weed-free hand hoed plots confirming the tolerance mechanism was adequate under the field conditions tested. The implications of this technology for weed management in cotton farming systems is discussed with the importance of maintaining integrated weed management to delay herbicide resistance.

INTRODUCTION

The current approach to weed control in cotton involves using high rates of pre-emergent residual herbicides (Charles *et al*., 1995), frequent inter-row cultivation and manual hand hoeing. Recently all these residual herbicides have been detected in the major riverine systems in which cotton is grown in Australia, albeit at very low levels (Muschal, 1997). There is currently only one cotton safe over-the-top post-emergent herbicide, Pyrithiobac-sodium, registered for cotton which has a limited number of target weeds and efficacy range. It is also a member of the benzoate group of herbicides and inhibits acetolactate synthase as its mode of action, placing it in the high risk group in terms of herbicide resistance. Cotton will be the first broadacre cropping industry in Australia to have access to cotton cultivars that have been genetically modified to tolerate specific herbicides. The release of cultivars tolerant to glyphosate in the beginning and a range of other herbicides in the future including bromoxynil, glufosinate ammonium and 2,4-D, including stacked combinations within the same plant, will greatly broaden the post-emergent weed control options for this crop. The introduction of this technology will augment the existing integrated weed management strategy (Roberts, 1998b) and with careful management contribute to the reduction of broad spectrum residual herbicides and minimise soil erosion by reducing cultivation. The technology is likely to be adopted in both irrigated and rain grown cotton production systems with large benefits accruing to the latter due to increased flexibility in weed management. In order for this technology to be evaluated and adopted a comparison between conventional and new weed management systems utilising a glyphosate tolerant cultivar was conducted. A field experiment utilising this cultivar examined a range of pre and post emergent herbicide strategies for dryland cotton production. The implications of integrating this new technology into the current farming system are discussed.

MATERIALS AND METHODS

A dryland field experiment was established at Edgroi in 1998, 30 km North of Narrabri NSW utilising a glyphosate tolerant cultivar (Sicala V2RR) bred by CSIRO incorporating Monsanto's™ Roundup Ready® gene. The cultivar is similar to Sicala V2 but has the addition of the single gene (CP4 gene) that codes for the production of a version of the EPSPS enzyme (CP4-EPSPS) which allows the plant to function normally in the presence of glyphosate. The tolerance is not absolute and as such the label requires no more than 0.98 kg ha^{-1} active of glyphosate to be applied over the top and only up to the fourth true leaf stage of the cotton plant. Two additional applications can be made in crop but directed at the base of the plant, minimizing foliage contact. The experiment consisted of nine herbicide treatments an unsprayed control and weed-free hand hoed plot (table 1) in a randomised complete block design with four replicates. Plot size was 18 m × 2 m and planted in a single skip formation common to dryland cotton production. Residual herbicides were applied the day after planting and post-emergent herbicides applied according to cotton and weed growth stage. The residual herbicides diuron, pendimethalin and fluometuron were applied at 1.71, 0.99 and 1.25 kg a.i. ha^{-1} respectively. The post emergent herbicides glyphosate, pyrithiobac-sodium and haloxyfop were applied at 0.49, 0.1 and 0.08 kg a.i. ha^{-1} respectively. Haloxyfop was used as a salvage herbicide when Liverseed grass (*Urochloa panicoides*) was not adequately controlled in treatments without glyphosate. Herbicides were applied with a high clearance motorized experimental boom delivering 100 L ha^{-1} of spray solution. Directed applications of glyphosate were applied when cotton plants reached 40 cm in height with same the boom but utilising dropper extensions to place the spray nozzles between the plant rows, approximately 30 cm from the ground and angled away from cotton plant foliage. Incorporation of herbicides occurred via heavy rainfall the day after application. The number of grass weeds were measured by either 2 m^2 quadrats in three sampling positions and averaging or counting the total number per plot when grass numbers were low. Two in crop counts were made and one at the end of the season after picking (table 1). Plots were machine picked with a spindle picker and hand ginned with a 20 saw research gin to obtain lint percentage.

RESULTS

The were two important facets to this experiment: 1) comparative cotton yield and 2) weed control against the main target weed, Liverseed grass (*Urochloa panicoides*).

Cotton yield Liverseed grass is highly competitive against cotton with a 61 % yield reduction recorded in this experiment (table 1). The only herbicide treatment that was significantly lower than the weed-free treatment had a combination of pendimethalin, pyrithiobac and two applications of haloxyfop culminating in a 25 % yield decrease. The poor cotton yield obtained in this experiment was a combination of late season insect pressure and the limited choice of glyphosate tolerant cultivars for dryland cotton production. As such the surrounding field was managed for a cultivar with a higher level of insect tolerance and different maturity exposing the cultivar to sub-optimal conditions.

Weed control At the four leaf stage of the cotton there was a large population of Liverseed grass across all treatments. Surprisingly the pre-emergent residual herbicides had only made a small impact on density and haloxyfop was required on all treatments other than glyphosate treatments. Both herbicides were effective in killing the entire population, however, a second emergence occurred with subsequent rainfall. At this stage reduced grass emergence was apparent in treatments which had residual herbicides with the highest grass number in the glyphosate only treatment (table 1). The second application of post-emergent herbicides eliminated the grass population again allowing the cotton plants to gain partial canopy closure and limit any further weed problem by competition for light. Final weed counts after harvest showed a significantly reduced number of poor, stunted grass plants that were still active but with limited capacity to set large volumes of seed.

DISCUSSION

An increasingly important aspect of dryland cotton production will be the ability to achieve cost effective weed management without the use of pre-emergent incorporated residual herbicides. These herbicides can lock cotton growers out of other crops should a replant or change be required usually as a result of unpredictable weather patterns common to the cotton areas of Australia. In addition the incorporation of the residuals makes stubble retention more difficult and leaves the soil bare and prone to water and wind erosion. The residual herbicides used in this experiment would have worked more effectively with incorporation but this is contrary to the objectives of modern farm management which utilises stubble retention and zero or minimal tillage practices.

There appeared to be no yield penalty associated with the application of glyphosate as per the label, however, the later the application of glyphosate, the more likely early season fruit retention will be affected as shown in the U.S. by Jones and Snipes (1999). This may have yield limiting implications when the technology is utilised in shorter growing season environments and erroneous circumstances prevent timely applications of glyphosate. Once a grower has outlayed money for the technology they will likely want to capture the full benefit and may disregard the four true leaf label restriction pushing the tolerance to the limit.

It would appear that without incorporation the residual herbicides require significant rainfall to move into the weed germination zone and kill young grass weeds. Once activated they reduced grass numbers significantly and contributed to a lower population at the end of the season.

Table 1. Herbicide treatments, timing of application, Liverseed grass density and cotton lint yield.

Cotton growth stage			Grass No. m^{-2} days after planting			Lint kg ha^{-1}	% Weed-free
Post plant pre-emergent	4 leaf	40 cm high	35	65	170		
Weed-free (hand hoed)			0	0	0	339	
Control			56	40	45	130	-61%
Diuron	Haloxyfop	Haloxyfop	25	10	2	344	2%
Diuron	Glyphosate	Glyphosate	35	24	2	316	-6%
Pendimethalin	Haloxyfop	Haloxyfop	40	13	3	316	-7%
Pendimethalin	Glyphosate	Glyphosate	43	33	6	322	-5%
Pendimethalin	Haloxyfop	Pyrithiobac-sodium *	52	10	3	248	-25%
Pendimethalin + Diuron	Haloxyfop	Haloxyfop	30	4	2	310	-8%
Pendimethalin + Fluometuron	Haloxyfop	Haloxyfop	33	5	4	277	-17%
	Haloxyfop	Pyrithiobac-sodium *	54	25	5	327	-3%
	Glyphosate	Glyphosate	48	42	11	299	-11%
		LSD (P=0.05)	13.5	9	2.7	67	

* These plots also sprayed with haloxyfop 7 days before.

A deficiency with glyphosate tolerant cotton is the four leaf over-the-top timing limit. The switch to directed spray applications below the canopy until flowering has several draw backs. The greater number of grass weeds after the second glyphosate application compared to haloxyfop (table 1) is a result of plants left within the plant line that were either shielded by cotton plants or did not receive enough herbicide from the directed spray application. In setting up the directed spray nozzles the ability to overlap the spray patterns is reduced unless a compromise in cotton leaf coverage occurs, threatening the safety of the application. In addition spray conditions need to be ideal with minimal wind and an extremely stable spray boom and delivery system. In practice the use of shielded canopies is more likely to be feasible but this then limits the in-plant line coverage of the spray reducing the tolerance technology to a 'drift safener'.

The same results as above were obtained in a similar experiment in the previous season (data note shown) when the target weed was Noogoora burr (*Xanthium pungens*). Repeated applications of glyphosate are required and the number and rate required will depend on seasonal rainfall and the emergence of the weed species. In practice weed control efficacy will be a combination of herbicide rate and timing given that ground application is the only method of applying directed minimal foliage contact applications.

The results presented above are only for glyphosate tolerant cotton but the implications of this work are equally appropriate when other post-emergent herbicide tolerant genes are utilised, with of course, due consideration to efficacy and species targeted of the respective herbicides.

Weed management implications The obvious question is will glyphosate (and other herbicide) tolerant cotton lead to greater use of herbicides and place the entire system at jeopardy due to herbicide resistance? The advent of this technology is likely to result in substitution of the pre-emergent residual herbicides rather than a straight addition. In irrigated cotton particularly, the adoption of a hybrid system where both types of herbicides are utilised is likely to occur. Shuffling the combinations to match the selectivity and strength of each against the target weed population probably resulting in some removal of residual herbicides from the mix.

Figure 1 highlights the importance of glyphosate in the cotton farming system and its new use patterns. It also highlights how many applications can be applied within a year and the importance of integrated weed management in maintaining its longevity within the rotation. Roberts (1998b) eluded to the potential problem in attempting to substitute glyphosate tolerant cotton for cultivation and hand hoeing. A late season hand hoe will be one of the most effective weapons in preventing resistance and maintaining cultivation could be effective as well. Here in lies a potential conflict within the industry that is not easily quantifiable or readably solvable.

The use of herbicide tolerant cotton also invites research on the old, complicated and time consuming topics of 'weed thresholds' and 'weed dynamics'. The fact that some Liverseed grass survived or emerged later in all treatments to replenish the seed bank in this experiment and that more survived in the glyphosate only treatments is an indicator of a weakness in the strategy. The low population numbers and poor fitness of these residual grasses disguises the true survivability of this weed. If the Australian cotton industry is to go even further in reducing its use of herbicides then it will be appropriate to know when a pre-plant residual herbicide, a post emergent herbicide or a combination of the two would be the most appropriate. The only way of knowing this is an understanding of the ecology and dynamics of the target weeds in question. This also leads onto the more important topic of dynamic economic weed thresholds. As the cotton industry has generally always had a prophylactic standard pre-emergent herbicide 'recipe' approach to weed control the use of simple static economic weed thresholds has had little relevance. However, as weed control costs increase, research on dynamic long term population management will be required. This becomes even more crucial when farmers are paying a technology licence fee for the privilege of growing a herbicide tolerant cultivar. In low weed frequency fields it may be appropriate to leave out the pre-plant residual herbicide, utilise the transgenic cultivar and associated herbicide as either an insurance or for minimal herbicide control, particularly late season, even if a static economic threshold has not been reached, in order to escape greater costs in future years. Thus the economic analysis of herbicide tolerant crops can become very complex if the true value to the farmer is to be derived.

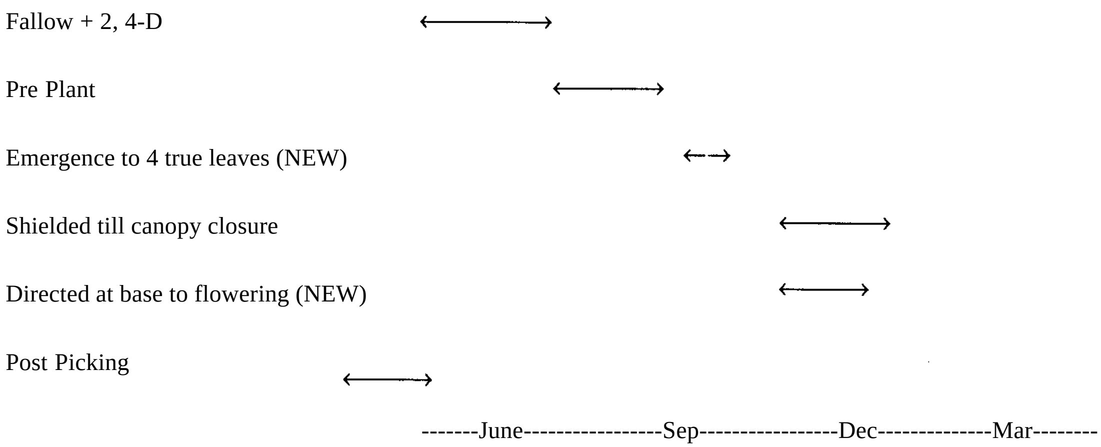

Figure 1. Existing and new potential use patterns of glyphosate within the Australian cotton industry with glyphosate tolerant cotton

In general the success of herbicide tolerant technology in cotton production will depend on how robust the herbicide tolerance is, the number and type of tolerance genes used, the efficacy of the herbicide used, cost of the technology and willingness of the farmers to utilise it, given a higher level of management is required.

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REFERENCES

Charles, G.W., Constable, G.A. and Kennedy, I.R. (1995). Current and future weed control practices in cotton: the potential use of transgenic herbicide resistance. In*: Herbicide-resistant crops and pastures in Australian farming systems*. Eds. G.D. McLean and G. Evans. Bureau of Resource Sciences, pp. 89-100.

Jones, M.A. and Snipes, C.E. (1999). Tolerance of transgenic cotton to topical applications of glyphosate. *Journal of Cotton Science* 3, 19-26.

Muschal, M. (1997). *Central and north west regions water quality program, 1996/97 report on pesticide monitoring*. Land and Water Conservation: Parramatta, Australia, pp. 15-52.

Roberts, G.N. (1998a). Management of weeds in a cotton system. *In- Proceedings of the 9th Australian Cotton Conference*, August 12-14, Broadbeach, Qld., pp. 145-152.

Roberts, G.N. (1998b). Developing integrated weed management systems for cotton. *Proceedings of the 2nd World Cotton Conference*, September 6-12 Athens, Greece, (in press).