Management of weeds in a cotton system

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Summary

Cotton is one crop with an opportunity for a true integrated weed management strategy to be implemented. New herbicide chemistry, genetic engineering and new machinery when combined together offer the prospects of achieving a more environmental and economically sustainable weed management approach for the industry. This paper aims to briefly discuss three weed management issues for the cotton industry. Firstly, examining current weed management systems in the cotton industry, high-lighting some of the advantages and potential problems associated with current management strategies. Secondly, addressing weed management techniques that are likely to be adopted in the future and thirdly a discussion on the future of using manual 'chipping' in the industry.

Current Weed Management Strategies

The present situation in cotton fields can be summarised by the following -: High rates of residual herbicides (Charles *et al.* 1995), frequent inter-row cultivation and manual hand chipping. The result is often low weed density populations escaping these forms of control with limited post-emergent control options to stop seed set from these survivors. The practice of using rotation crops in strategic sequences can also be important for some problem weeds. Focusing on controlling the problem weed when cotton isn't being grown may be the best solution. An example would be utilising atrazine or atrazine/metolachlor mixes in sorghum to control mintweed before planting back to cotton in a following season (Roberts and Gibb 1998).

Current weed management strategies already have the makings of an integrated weed management (IWM) system, utilising cultivation and chipping as forms of non-herbicide mechanical weed control. However, the use of cultivation to control weeds in fallows and in-crop along with chipping is not seen as a long term sustainable solution.

Problems arising in the current system

The shift towards permanent beds, reduced cultivation and stubble retention by some growers is putting increasing pressure on herbicides to provide all the weed control. While herbicide resistance has not occurred in the common weed species found in cotton, the risks of this occurring are increasing all the time. Table 1 lists some of the common herbicides utilised in cotton fields. The majority of cotton fields receive at least one application of

herbicide from both the C and D group, every time cotton is grown in the field. The introduction of Staple®, a group B herbicide, increases the chances of attaining a herbicide resistant weed. There are also very few opportunities for herbicide rotation, a common strategy for delaying herbicide resistance. Removing cultivation and chipping actually removes some of the non-chemical forms of weed control and will put more pressure on the current herbicide groups.

Table 1. Herbicides classified according to mode of action that are common to cotton rotations.

Risk category[1]	Herbicide Group	Common herbicides
High	Group A	Verdict, Falcon, Sertin, Fusilade, Fusion, Select
High	Group B	*Sulfonylurea group*, Staple
Moderate	Group C	Cotoran, Gesagard, Diuron, Bromoxynil
Moderate	Group D	Stomp, Trifluralin
Moderate	Group F	Zoliar
Low	Group I	*Phenoxy group*, Starane, 2,4-D
Low	Group K	Dual, MSMA
Low	Group L	Paraquat, Diquat, Sprayseed
Low	Group M	Glyphosate
Low	Group N	Basta

[1]Risk category- the higher the risk, the increased chance of weeds developing resistance.

The question of which weed management strategy is the best in the cotton industry is a very difficult one. Rather than answer this, perhaps the question should be, what type of weed management strategy do we want in the future? The following is a suggested list of attributes that would be desirable in a sustainable IWM strategy for the cotton industry.

1. Reduction in total herbicide usage.
2. Reduced reliance on residual type herbicides.
3. Stop herbicides accumulating in the soil or entering the riverine environments.
4. Improved timing of weed control
5. Stop new and existing weeds entering fields from the river, channels, storage dams and machinery.
6. A reduction or removal of cultivation just for weed control allowing crop residues to be easily retained.
7. The elimination of manual chipping.

Some of the above concepts are already achievable and future research is aiming to integrate more of these ideas into a sustainable integrated weed management package.

Future Weed Management Techniques

We are at the beginning of entering a new era in weed management. Advances in gene insertion technology, new herbicide chemistry and engineering design are allowing the cotton industry to proceed into the next millennium with an increased number of options, which if combined together, will form a powerful strategy for combating weeds in our cotton systems. In addition, research is now being directed to manage weeds throughout the entire farming rotation with an emphasis on reducing the total amount of herbicides applied in each phase of the rotation.

Transgenic Herbicide Tolerant Cotton

Gene insertion technology has brought the cotton industry to the forefront of broadacre weed management in Australia. Cotton is the first broadacre crop in Australia to have genetically transformed plants tolerant to herbicides at the commercial release stage. Indeed the number and types of herbicides that cotton can be made tolerant to appears only to be limited by the willingness to do so. The politics involved in ownership of the genes and the gene transfer technology appears to at least as important as the science behind the technology.

There are currently four different herbicide tolerance traits being tested at various stages in the research programs. These are cotton plants that have had genes inserted into them to provide tolerance to over the top applications of either glyphosate, bromoxynil, glufosinate-ammonium (Basta®) or 2,4-D. Of these glyphosate tolerant cotton going under the name of Roundup Ready® cotton will possibly be released on a limited commercial trial program in 1998. Herbicide tolerant varieties will not provide the answers to all weed management options. Issues to consider in relation to herbicide tolerant cotton varieties:

1. Broadens post-emergent weed control options. This will greatly reduce the risk of a weed control 'blow out' should there be a reduction in pre-emergent herbicide use when transferring to herbicide tolerant varieties.
2. Stubble becomes less of an issue with non-residual, post-emergent herbicides. Thorough and accurate spray coverage is more important with post emergent herbicides.
3. Pre-plant herbicides will most probably still be required, particularly in high weed pressure situations. It is unlikely that we will be able to completely do away with pre-plant incorporated herbicides. However there is definitely scope for herbicide reduction, complete reliance on post-emergent herbicides is very difficult unless low weed pressure already exists in the field.

4. Application timing is critical. All post emergent herbicides work more efficiently when they are used against small, actively growing weeds. The ability to apply these herbicides across large areas at the correct time may limit their effectiveness.
5. The effectiveness of these herbicides is still unclear. Experimental work is still being conducted, however, for the grower the final result will be a combination of the efficacy of the herbicide against the target weed and the growers ability to apply these herbicides at the correct growth stage of the weed and the cotton plant.
6. Increased selection pressure for resistant weed species will undoubtably occur if we rely purely on post-emergent herbicides and neglect other forms of weed control.
7. Label adherence and vigilance when growing the herbicide tolerant variety will be extremely important. Any mistakes such as spraying the wrong field, or spraying after the label recommended times could be disastrous, possibly resulting in total crop failure.

Herbicide Tolerant Varieties and Dryland cotton

With the gradual increase of dryland cotton it is becoming more critical that management techniques are developed to reduce water runoff and limit soil erosion. Yule and Rohde (1996) measured the effects in their dryland experiments and concluded that retained crop residues can increase water infiltration and reduce soil loss due to runoff. The aim of a dryland weed management program is therefore to try and control weeds without cultivation. Cultivation practices ultimately incorporate residues leaving the soil surface bare and susceptible to erosion especially with high rainfall intensity events common to cotton growing regions. The use of post-emergent herbicides will improve the ability to control weeds without cultivation. In addition to Staple®, which is currently an expensive herbicide for dryland cotton growers, the ability to apply broad spectrum non selective herbicides, such as glyphosate, over the top of cotton that is grown in a stubble retained field will be a great advantage.

We conducted an experiment at Bellata in 1997/98 to compare conventional herbicide strategies with a glyphosate tolerant strategy. Cotton with glyphosate tolerance was planted and experimental treatments were applied. The year was disappointing due to high temperatures and minimal rainfall on our experimental site, however the result in Table 2 suggests there were no differences in yield between treatments. The target weeds in this experiment, noogoora burr, yellow vine, barnyard grass and liverseed grass were all easily controlled with a combination of broad-leaf and grass weed control herbicides or the post emergent applications of Roundup CT Xtra.

Table 2. Bellata 1997/98 - Dryland skip row herbicide experiment

Pre Plant	Planting	Post Planting	Yield bales/ha
		Roundup CT Xtra 2.2 L/ha	1.26
Trifluralin 2.8 L/ha			1.18
Trifluralin 2.8 L/ha		Roundup CT Xtra 2.2 L/ha	1.13
	Cotoran 3.5 L/ha	Fusilade 1 L/ha	1.11
Weed-free			1.10
Trifluralin 2.8 L/ha		Diuron 1.9 kg/ha	1.10
Trifluralin 2.8 L/ha		Gesagard 3.5 L/ha	1.08
Trifluralin 2.8 L/ha	Cotoran 3.5 L/ha		1.05
		Diuron 1.9 kg/ha + Fusilade 1 L/ha	1.00
		Gesagard 3.5 L/ha + Fusilade 1 L/ha	1.00
	Stomp 3 L/ha + Cotoran 3.5 L/ha		0.97
	Stomp 3 L/ha + Cotoran 3.5 L/ha	Roundup CT Xtra 2.2 L/ha	0.93
			Not significant

The conclusion from this experiment is that glyphosate tolerant cotton varieties would enhance the weed control options available to dryland cotton growers eliminating the need for cultivation. Provided the variety cost plus glyphosate cost did not exceed the current weed control strategy costs, there would be a definite environmental gain. No economic analysis can be conducted until the cost of the transgenic package (licence + herbicide cost) is known.

New Herbicide Chemistry

The advent of pyrithiobac-sodium (Staple®) has allowed for the first time an 'over the top' cotton safe option of controlling weeds post-emergent. The widespread usage by growers since its release, despite its price, is testament to the need for a herbicide that can be applied safely to cotton post-emergent. Its ability to control broad-leaf weeds in row and supplemented with a grass herbicide have allowed a reduction in chipping in some fields. Staple®, is not however perfect, and requires that the majority of weeds be small and actively growing for robust weed control. Its cost also limits aerial applications and it is usually applied in a band requiring a ground rig application. As with all post emergent herbicides, ensuring the herbicide is applied at the correct time is critical for success, and missed opportunities due to weather, irrigation scheduling or other unforseen reasons can be disastrous. As previously mentioned Staple® is a Group B member which places it in the high risk category for developing herbicide resistance. Survivors must be destroyed.

The release of herbicide tolerant cotton has opened up new previously unavailable herbicides to be applied to cotton. Not all of these will be released due to the massive

combinations of insect × herbicide × variety combinations that could occur. However the combinations that are released will need to be strategically utilised in the IWM strategy to maximise there effectiveness and prolong their usefulness.

It is hoped that in the future additional cotton herbicides will be released increasing the available options, however, we should not always be looking to herbicide manufactures for the answers to our problems. Indeed, herbicides should not necessarily be the first choice in management of weeds as the herbicide itself may be become more of a problem than the weeds it controls.

Engineering Developments

Precision Weed Control

Precision weed control is a smaller part of the precision farming concept which encompasses many areas from super accurate soils maps, variable fertiliser application to precise yield monitoring. The improvements in accuracy and reduction in price of Global Positioning Systems (GPS) has made precision agriculture a commercial reality. The use of the Differential GPS system allows accurate mapping of individual weeds or patches well below 1m. Growers can then return to these spots to eradicate the weeds. However precision weed control is more than just using a GPS.

The vision guidance systems being developed at the university of Southern Queensland (Billingsley and Schoenfisch 1996) could also be utilised to improve the accuracy not only of inter-row cultivation, but in the future, selective weed control closer to the plant line. Also, at least two spray systems capable of detecting weeds both in fallows and furrows and selectively spraying them have been developed in Australia and are nearing commercial release. If successful they will greatly reduce the amount of herbicide applied and will improve precision weed control with herbicides immensely. They have the ability to determine when a weed is present, then spot spray it with an appropriate herbicide.

Shielded Sprayers

The concept of limiting herbicide drift and/or reducing herbicide damage to cotton plants within rows is not new but will need to be utilised more frequently in the future. The advantages of using shielded sprayers is that they can eliminate inter-row cultivation for weed control. The release of Roundup Ready® cotton will markedly increase the safety margin when utilising glyphosate through shielded sprayers. In addition other herbicides will also be able to be utilised once herbicide tolerant varieties of that herbicide are released.

If shielded spraying is to be developed further and the use of herbicides that are not 'over the top' cotton safe are to be utilised through these, then we must advance from the all-

too common plastic spray drum cut in half that typifies a large number of shielded spray units at the moment. There are already new more sophisticated designs available in Australia and Ginn *et al.* (1998) have published an American design, which could be modified for Australian row crops, that eliminates wind-blown drift and confines the herbicide to the target zone.

The Future of Manual Chipping

This subject has probably been debated ever since 'chippers' were introduced into the industry. The cotton industry would obviously like to replace manual chipping to escape from the spiralling labour costs and work place regulations that are being forced upon them. In addition the gradual enforcement of increasingly stringent occupational health and safety regulations and the potentially hazardous nature of the work is placing extra pressure on the industry to find alternatives. Hand chipping, is however, an extremely valuable tool in controlling 'in the plant line' weeds that have come through either residual sprays or post-emergent applications. The use of chipping has undoubtedly been a contributing factor in preventing herbicide resistance in the cotton industry.

It is unlikely that we can do away with chippers altogether as there are very few weed management tools more accurate or effective that a human with a hoe in light weed pressure situations. I have however attempted to suggest a possible strategy for weed control with minimal use of chipping in table 3.

Table 3. Future weed control strategy utilising glyphosate tolerant cotton and one late season chipping.

Timing	Grass control	Broad-leaf control
Pre - emergent	Trifluralin	Diuron or Fluometuron or Fluometuron + Prometryn or
Planting	Stomp or Dual	Fluometuron or Fluometuron + Prometryn or Glyphosate
Early post-emergent	Grass herbicide (ie Fusilade or Falcon)	Glyphosate (over top) or Staple (over top)
Late post-emergent onwards	Grass herbicide (ie Fusilade or Falcon)	Glyphosate (directed/shielded) **SPOT CHIPPING**

It should be noted that the deletion or addition of other herbicides as lay-by applications or the substitution of glyphosate with bromoxynil or Basta in varieties tolerant to these herbicides is also an option. The above herbicide program eliminates inter-row cultivation and minimises chipping, however it relies heavily on herbicides for weed control, an undesirable characteristic of integrated weed management systems.

Conclusions

The release of transgenic herbicide tolerant cotton combined with new herbicide chemistry and improved engineering designs to deliver the products will certainly go a long way to achieving the cotton industry's weed management goals.

There is no doubt that we must make an increased effort to reduce the amount of herbicides being applied to cotton fields, as the environmental movement widens its focus to include all pesticides, not just insecticides, as an area of concern. I believe some of the tools to do this are already available and with increased research support we will be able to integrate them into a sustainable IWM package that is more environmentaly acceptable yet still economically feasible.

In many ways the Australian cotton industry is a leader in new weed management techniques and systems, however with environmental concerns, the threat of herbicide resistance and weed species shifts constantly at our doorstep, we must ensure that we embrace new technology and concepts as they become available. Provided we do not rest on our past achievements and the industry becomes more 'weed aware' we should be able to progress into the next century without being overrun by weeds.

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