Developing Integrated Weed Management Systems for Cotton

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ABSTRACT

The Australian cotton industry is responding to increased pressure to reduce reliance on pesticides. An important part of this program is the examination of weed control and herbicide use patterns. Attention is now being given to the significant amounts of herbicide being applied in cotton rotations and possibilities for herbicide reduction. Currently there are no known cases of herbicide resistance within Australian cotton fields but prevention and limitation of resistance is a major objective. An integrated weed management (IWM) system has existed by default in the cotton industry, due mainly to inter-row cultivation and hand hoeing to control weed escapes. However, a formalized IWM strategy needs to be developed to ensure that the use of herbicides is sustainable in a viable cropping system. Recent new advances in herbicide chemistry, genetic engineering and machinery design offer the opportunity to combine these with existing weed control techniques to achieve a more environmental and economically sustainable weed management strategy.

Introduction

Public scrutiny is widening its focus to include all pesticides, including herbicides, in their assessment of the impacts of growing cotton on our communities and the environment. The present field situation in Australia can be summarized by the following: high rates of residual herbicides (Charles *et al.*, 1995), frequent inter-row cultivation and manual hand hoeing. 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. In addition, recent studies of some of the major riverine systems in which cotton is grown in Australia, have detected the common cotton herbicides in the river waters, albeit at very low levels (Muschal, 1997). The Australian cotton industry is responding to this by developing an integrated weed management strategy (IWM) with two main goals 1) reduce residual type herbicide use and 2) delay the development of herbicide resistance. This will have the dual benefits of reducing herbicides accumulating in the soil and riverine systems as well as slowing down herbicide resistance in our weed spectrum.

Developing the IWM strategy

As with other broad-acre agricultural IWM strategies, the framework for IWM in cotton involves combining as many methods of weed control as possible, including non-chemical forms of weed control, with a herbicide rotation strategy. In developing this low herbicide input IWM strategy it is important to recognize the limitations of the current system. In its quest towards soil sustainability, the Australian cotton industry has moved towards permanent beds, reduced cultivation and stubble retention. In addition, the control of resistant *Helicoverpa* spp., a major threat to the viability of the Australian industry, necessitates the use of soil disturbance as soon as possible after picking to kill over-wintering pupae.

Cotton growers have also developed a 'zero tolerance' attitude to weeds in fields. This attitude is a carry over from the initial growers who turned grazing country into cotton fields and weed control was paramount in achieving economic yields and facilitating harvesting. As research continued, weeds were found to be hosts for insects and diseases and the impetus for eradication was entrenched. The legacy of this is a standard recipe approach that relies heavily on high rates of residual herbicides.

Any weed management package must therefore be designed with the above constraints in mind, realizing that weed control will not always be the highest priority and that individual cotton growers will determine their own order.

The components of the IWM strategy

Record maintenance

The recording of weed control methods and effectiveness for individual fields in every year is critical to deciding on the most appropriate strategies for weed management. Likewise, initial weed pressure should be assessed every year before selecting control strategies for individual fields. In high weed pressure situations the use of high rates of residual herbicides and inter-row cultivation will be the most effective and economic method of control. However, where weed densities are low then the options increase for managing weeds without the heavy reliance on herbicides. Data derived from field experiments examining the effect of herbicides on early cotton growth and final yield in fields that have been in cotton production for greater than 20 years, show that combinations of high rates of pre-plant herbicides can provide excellent control of grasses (Table 1). However, the initial weed pressure was low in these fields and the value of aiming to achieve this level of control is debatable, given that 2.22 kg/ha of active ingredient was required. The combination of prometryn + fluometuron would have provided acceptable control of grasses while still controlling broad-leaved weeds should they have been present, yet using half the herbicide. In future, if some herbicides are to be eliminated from the system, we will need to develop economic thresholds for individual weed species so that we know when to reapply the appropriate herbicides. This will involve predictive modelling of the weed species, possibly by grouping several species together, and in depth knowledge of the ecology of the target weeds.

The concept of weed thresholds is not new but the detailed experiments to determine how many weeds/m are expectable before economic damage occurs have only been conducted for a limited number of weeds. It could be argued that on some fields, such as the field studied in Table 1, aiming for eradication could be a feasible objective. To achieve total eradication is very difficult and is unlikely to be achieved without massive herbicide input, particularly when irrigation and floods can replenish the seed bank. On the other hand the concept of living with a known number of weeds in the field and continually monitoring their presence will be a difficult concept to extend to growers.

In Table 1 the average number of grasses/m2 is very low but the means disguise the variability in the data, with the control plots varying from 6 to 270 grasses/100m2. Spatial variability of weeds within the field favours herbicide strategies that target the highest expected density, imposing another problem in weed control. While this problem is not unique to cotton, the high rates of residual herbicides applied to entire fields suggests that large reductions in herbicide could be achieved by applying herbicide only where it is needed. The concept of precision weed control that is being developed around the world, is ideally suited to isolated weeds or weed patches common to cotton fields.

Should herbicide resistance develop in the cotton weed spectrum, accurate records of weed control methods and their effectiveness will be imperative in determining how the resistance developed and devising strategies to prevent further expansion of the problem.

Rotations

The control of weeds in crops that are rotated with cotton is critical in keeping weed populations at a low level. Specific problem weeds may also be managed more effectively by attacking the weed when cotton isn't grown. A method for controlling mintweed (*Salvia reflexa*) in cotton rotations suggests that under high mintweed populations, the use of a rotation crop such as sorghum would form part of IWM strategy against that weed (Roberts and Gibb, 1998). Similar anecdotal evidence supports the use of competitive winter cereals in managing nutgrass (*Cyperus* spp.) in cotton rotations.

Herbicides and Herbicide Tolerant Varieties

While herbicide resistance has not occurred in the common weed species found in cotton in Australia, the risks of it occurring increase with every herbicide application. Although desirable, the ability to rotate herbicide chemistry is limited in cotton. The majority of cotton fields receive at least one application of Prometryn, Fluometuron or Diuron (all inhibitors of photosynthesis at photosystem II) combined with Trifluralin or, to a lesser extent, Pendimethalin (both inhibitors of tubulin formation), every time cotton is grown. These herbicides are classified in the moderate risk category in terms of developing resistance. The introduction of Pyrithiobac-sodium, a new post emergent herbicide, has the potential to exacerbate the problem as it is in the high-risk category, and its use pattern can partially replace manual chipping or other post-emergent directed sprays.

Glyphosate is widely used as a non-selective herbicide in cotton production. Due to its mode of action, it was initially considered to be one of the herbicides least likely to lead to resistance. However, the recent appearance of glyphosate resistant ryegrass in southern Australia in a wheat-pasture system (Pratley *et al.*, 1996) has shown that inappropriate use even of so called safe chemicals can eventually cause resistance.

The eventual deployment of herbicide tolerant cotton varieties will broaden the post-emergent herbicide choice available. However, herbicide tolerance will not provide the answers to all weed management options, so varieties need to be carefully incorporated into an IWM strategy to prolong the usefulness of the technology. The greatest benefits to be gained from this technology will be the ability to target a larger weed spectrum and the substitution of pre-plant, residual herbicides that often require incorporation, with post-emergent herbicides. This will be particularly useful in rain-fed cotton systems where the maintenance of surface stubble to stop soil erosion limits the use of pre-plant herbicides and cultivation. A range of herbicide tolerant varieties would provide the opportunity for herbicide chemistry rotation, an important criterion in resistance management.

Improved Inter-row Weed Management

The reduced cost of accurate global positioning systems, improvements in weed detecting sensors, the release of accurate vision guidance systems and a greater adoption of shielded spray technology will significantly advance inter-row weed control. Inter-row cultivation provides a non-herbicide control option to which weeds will not develop resistance. The negative side of inter-row cultivation is that it requires another tillage pass and weeds cannot be controlled within the plant line. In addition, there are possible yield penalties from inter-row cultivation: two inter-row cultivations produced significantly ($P<0.001$) less lint at 1452 kg/ha than non cultivated cotton at 1674 kg/ha (Roberts unpublished). The decision to cultivate for weed control must therefore take into consideration a range of issues. The ability to substitute inter-row cultivation with shielded canopy spray rigs using weed detecting sensors that only apply a concentrated herbicide after detecting a weed, may overcome some of the problems. There is vast potential for reduced post emergent herbicide use with this technology in addition to reduced inter-row cultivation.

Manual Hand Hoeing

Manual hand hoeing has been an extremely valuable management tool in controlling in row weeds that have evaded other forms of weed control. It has undoubtedly contributed to the prevention of herbicide resistance within the Australian cotton industry. However, growers would like to replace manual hoeing to escape spiralling labour costs and work place regulations that are being forced upon them. 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. Roberts (1998) suggested a possible weed management strategy that minimizes cultivation and manual hoeing to one late season pass only, primarily to remove survivors of an intensive herbicide strategy. This approach relies almost exclusively on herbicides as its main form of control, and is undesirable from an IWM prospective. Hence the trade off in removing manual hoeing is increased pressure on utilizing herbicides as the main form of weed control. A practical approach is to use late season manual hoeing after utilizing other weed management tactics, to control potentially resistant escapes relatively inexpensively.

Field Quarantine

Minimizing new weeds entering cotton fields is essential to any IWM strategy. Cleaning down planting, cultivation, spraying and harvesting equipment between fields and between cotton growers properties can help minimize new weeds and reduce new weeds entering the system. If new weeds are detected, eradication and frequent monitoring should be given high priority while they are in small patches. By maintaining clean irrigation channels and earth water storage structures to limit the movement of weeds around irrigation properties would support the goal of preventing new weeds entering fields.

Conclusion

Improved IWM is possible in cotton by combining all the techniques of weed control: pre-emergent residual and post-emergent herbicides, shielded and weed detection sprayers, improved guided inter-row cultivation, appropriate rotation selection, herbicide tolerant varieties and manual hand hoeing. The importance of maintaining records of weed control and their effectiveness and selecting the appropriate IWM strategy based on the potential weed problems in individual fields, is paramount in the quest to reduce herbicide usage.

As with many agricultural strategies the weakness is often in the extension of the concept and adoption by the growers. As cotton is a high value fiber crop in Australia and herbicide resistance has not yet manifested itself, it is tempting for cotton growers to rely on high rates of residual herbicides as insurance policies against weed infestations. We must challenge this thinking by demonstrating that a well-planned and implemented IWM strategy would gain many benefits without economic loss. The adoption of an IWM package with an emphasis on reducing residual herbicide use should be a primary goal of the cotton industry. Apart from the direct benefits to growers it would help demonstrate that the industry can take steps to limit its impact on the environment and surrounding communities.

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Table 1. Residual cotton herbicide efficacy against *Urochloa panicodes* and *Echinochloa spp*. in a low density field infestation.

Herbicide rate active ingredient g/ha	Grass/100m2
Fluometuron 1710 g/ha	8.3
Prometryn 1750 g/ha	8.3
Prometryn 550 g/ha + Fluometuron 550 g/ha	3.3
Trifluralin 1120 g/ha	5.0
Trifluralin 1120 g/ha + Prometryn 550 g/ha + Fluometuron 550 g/ha	0.0
Control	16.0