The Critical Period for Weed Control: Improving weed management decisions in herbicide tolerant cotton based on a weed control threshold.

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Introduction.

The last few years have seen some exciting developments in weed management in the Australian cotton industry. More accurate inter-row cultivation, the post-emergence herbicide options of Staple® and Envoke®, and the introduction of Roundup Ready® cotton that allows glyphosate to be topically applied are examples of some of the advancements that have allowed growers to develop more effective and flexible weed management systems. In the very near future it is likely that Roundup Ready Flex® and Liberty® cotton will also be introduced into Australian cotton production systems.

These new options allow growers to develop even more effective and flexible weed management programs, but a number of questions for weed management remain and growers will also be faced with a new set of challenges in managing these new technologies. Growers have to answer the questions; should I use pre-emergent/pre-plant herbicides? When should I inter-row cultivate or chip, or should I just apply another herbicide? Should I wait for later emerging weeds to germinate before applying a herbicide application? Should I use a lay-by herbicide or am I relying too heavily on herbicides? Does it really matter and what are the implications of the decisions that I am making?

Using more frequent herbicide applications may result in better weed control, but pre-emergence residual herbicides can contribute to establishment problems and will not necessarily give better yields, or improved returns. In fact, applying additional weed control treatments may just result in reduced profits or increase the selection pressure for resistance and species shift. So the question is, what weed management combinations give optimal weed control, but also maximise yields and returns?

The answer is complex and changes from field to field and season to season. The critical period for weed control is a concept designed to optimise weed management and herbicide use in systems reliant on post emergent herbicides for weed control and is particularly useful in systems into which herbicide tolerant crops have been introduced (Knezevic et al.2002).
Importance of integrated weed management in herbicide tolerant cotton systems

The widespread adoption of Roundup Ready cotton within the Australian cotton industry, estimated at 70% for 2005/06 season (G. Constable pers. comm.), demonstrates the significance of weeds in the farming system and the need for a flexible weed management package. With the transition from weed management systems relying on residual pre-plant and pre-emergence herbicides, to those with greater reliance on post-emergence herbicides, management decisions can be improved through an understanding of the critical period for weed control, ensuring that weed control tools are only used on weed populations that are below the economic threshold for control. This will result in more cost effective weed management and more judicious use of post-emergence herbicides, decreasing selection pressure on weeds and reducing the risk of herbicide resistance or weed species shift.

Changes in the weed spectrum in Roundup Ready cotton systems toward more glyphosate tolerant weeds (species shift) and the potential threat of herbicide resistance are two of the main reasons why integrated weed management systems should be adopted in the Australian cotton industry. The integrated weed management approach integrates a range of tools and technologies to manage weeds, rather than placing sole emphasis on a small group of herbicides. The critical period for weed control concept is another tool that can boost the effectiveness of integrated weed management by better defining the window for weed management.

The prudent use of herbicides will have greater importance with the release of Roundup Ready Flex® and Liberty® (glufosinate-ammonium tolerant) cotton varieties, as there will be a wider application window with these products. This wider application window potentially means that repeated applications can be made in the same season using the same product, increasing selection pressure for species shift and herbicide resistance. To maximise the potential of these herbicide technologies, but avoid uneconomic or unnecessary use, weed management decisions need to be made on the basis of potential yield impacts and not just on the presence or absence of weeds.

In many ways this concept is similar to that of IPM, which revolves around pest complex thresholds. Weed management decisions should similarly be based around weed thresholds which take into account the competitive impact of weeds on the crop.
Weed control threshold

In most situations, effective weed control using post-emergence herbicide options involves some reliance on the broad-spectrum residual herbicides and other management strategies. With the introduction of the new technologies growers may be tempted to increase their reliance on post-emergence herbicides rather than retaining some of the more traditional weed management options in a misguided attempt to maximise weed control and minimise costs. The application timing of post-emergent herbicides, especially those that can be used over-the-top of the crop, is crucial to maximise the benefit of these technologies while avoiding unnecessary or uneconomic use. Growers must balance spraying too often, which provides good weed control, but increases cost and selection pressure for herbicide resistance, against spraying too little, which may save costs but increases the risk of yield losses and a build up of weed seeds in the soil seed bank, contributing to future problems.

A weed control threshold is needed to help growers balance the pressures of spray efficacy and cost. The threshold must take into account the features of each weed species, their density in the field and the control options available to provide guidelines as to when a given weed population should be controlled.

Determining the economic threshold for weed control.

The decision to control a weed is influenced by crop growth stage, the availability of suitable herbicides, labour and equipment, the weather, and financial aspects such as lint price, expected yield, and the cost of control. The actual level of the economic threshold (the critical number of weeds that triggers a grower to control a weed infestation) is a personal choice reflecting how much loss a grower is willing to tolerate from a weed infestation before they decide that controlling the weed is justified.

For example, if a grower is contemplating using a herbicide and the herbicide application cost, including licensing fee (if any) and operator costs, is around $50 per ha, the grower may feel it is not worthwhile to use the herbicide unless the weeds will cause at least a $100 per ha yield loss. Prior to this point, the return on investment is too low (i.e. it is not worth spending a dollar on control to receive only a dollar back in yield). At a bale price of $400 and an expected yield of 10 bales per ha, this grower has effectively established an economic threshold for weed control at 2.5% of his expected yield (i.e. $100 per ha).
Understanding the impact of weed pressure

So, how can an understanding of weed control thresholds and economic thresholds be used in practice to formulate guidelines for weed management and in particular when should these weed management strategies be implemented? As was mentioned earlier, the weed control threshold must take into account the features of each weed species and their density in the field. The competitive ability of a weed relates to its growth rate and its architecture (height, shape, leaf size, branching characteristics, root structure, root depth, etc.), and varies with each weed species. Generally, smaller weeds are less competitive, and large weeds, such as thornapple and noogoora burrs, are very competitive.

The competitive impact of a weed is influenced by the time of its emergence and also the time of its removal. Weeds that emerge late in the season may have little impact on the crop’s yield, whereas even relatively uncompetitive weeds that emerge with the crop can impact on yields if not controlled.

Determining the yield loss from weeds

By understanding the competitive relationships between the weeds and the crop and combining this with an economic threshold it is possible to determine when and how often either a herbicide or another weed management strategy needs to be implemented. This is best demonstrated diagrammatically in Figure 1.

In Figure 1, the dashed line running across the top of the graph is the potential yield if there were no weeds in the field (the weed free yield). The broken line beneath that is the economic threshold for weed control, in this example representing a yield loss threshold of 2.5% of yield.

The dotted and dashed line is the potential yield loss from a weed infestation where the weed emerges with the crop and is removed at some time after emergence. This line shows that, for example, if the weed was removed at 500 day degrees, the potential crop yield is reduced to 70%, a 30% yield reduction. If the weed was removed at 1500 day degrees, potential yield would be reduced to 18%, an 82% yield reduction. The dotted line represents the effect on cotton yield of weeds emerging throughout the cotton growing season. For example if weeds were to emerge with the crop and left uncontrolled then it is expected that these would have the greatest impact on cotton yield, however if those weeds didn’t emerge
until much later in the cotton season then the effect of those weeds on cotton yield become minimal. The area between where these two curves intersect the economic threshold then from a yield perspective is the time frame during which weeds should be controlled, known as the critical period for weed control (CPWC).

![Figure 1. The impact of weed competition on crop yield](image)

Although only a single line is shown for simplicity in Figure 1, there will actually be a family of lines, representing weeds that emerge after each weed control input (inter-row cultivation, herbicide etc.). A further set of lines would be needed to show the impact of thornapple at another density, and still more sets of curves to show the impact of additional weed species.

The critical period for weed control concept defines the period during which weed control is required from a yield perspective, and conversely, the periods during which weed control can not be justified. For example, Figure 1 shows that where thornapples have emerged with
the cotton crop and are present at 1 plant per metre of row, there is no justification for controlling them before 360 day degrees of crop development.

This information is important for the management of all fields but can be particularly useful in helping to determine at what point herbicides should begin to be applied in relatively clean fields.

**Timing of herbicide applications**

Application timing is critical to achieving good results with post-emergent herbicides. Herbicides should be applied when they will provide effective control and before weeds begin to reduce crop yield potential, ideally at the start of the weed removal time. Best control with herbicides is obtained when weeds are small, when there is adequate soil moisture and when temperatures are ideal. However, the germination of weed seeds is mainly governed by temperature, light and soil moisture conditions, (it may also be influenced by seed dormancy). Consequently, there are normally a number of weed flushes throughout a season due to rainfall and irrigation events. The effect on cotton yield of these later emerging weeds decreases throughout the season due to the increased competitiveness of cotton for light and moisture. At full canopy closure many weed species do not germinate at all due to the absorption of red light as it passes through the crop canopy. Therefore the timing of herbicide applications also needs to accommodate the changes in weed/cotton competitiveness. Similarly, if growers have used pre-plant/pre-emergent herbicides as part of their weed management strategy then subsequent post emergent herbicide applications will be determined by the effectiveness of those weed control treatments.

By conducting a range of competition experiments it has been possible to modify the critical period for weed control concept to determine when weed control tactics should be employed in the above scenarios.

**Preventing weed seed set**

The aim of weed management is to minimise economic loss in the current crop, but also to protect future crops by preventing weeds from setting seeds and adding to future weed problems. To achieve this, weed management strategies need to be continued past the critical period for weed control. However, rather than focussing on controlling the weeds, emphasis needs to be placed on preventing those weeds from setting seed. This may be achieved by
inter-row cultivation, using a lay-by herbicide, or with spray topping, where a sub-lethal dose of herbicide is applied to cause weeds to abort seed or to set non-viable seed. Defoliants or Roundup applied at or prior to defoliation may also help to reduce seed set. Further research is needed to confirm the value of these options.

**Weaknesses of the critical period for weed control concept**

It needs to be recognised that weed management in and around cotton field is conducted for a variety of reasons other than for yield maximisation. These include for managing insect pest species such as rough bollworm, aphids and whitefly, to minimise disease carryover and more recently for bio-security reasons. Weed control decisions may also be justified for irrigation and harvesting efficiency, to prevent lint contamination, and to prevent weed seed set, reducing future weed burdens. The critical period for weed control does not take these other factors into consideration and therefore needs to be used as apart of an integrated weed management strategy not as the sole basis. The critical period for weed control also assumes that weeds are equally easily controlled at all growth stages, that the cotton grower has the capacity to control all weeds at the required time, and that the weeds have no negative impact except on crop yields. These weaknesses need understood and accounted for when developing a weed management plan for a farm.

**References**