Using mimic weeds to determine the critical period for weed control for more effective weed management

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Summary

The introduction of Roundup Ready® cotton and the future release of other herbicide tolerant cotton varieties will allow more flexible weed management with greater emphasis on post-emergence herbicides for weed control. To optimize the use of these herbicides and to minimize the risks associated with herbicide resistance and species shift, these technologies need to be introduced as part of an integrated weed management (IWM) program. The critical period for weed control is an important component of IWM and provides growers with information on when weeds are likely to interfere with crop growth, and when weed management strategies should be targeted to avoid yield reductions. Mimic weeds are plants that have similar biomass and leaf area to actual weeds encountered in the field and allow the development of critical periods for weed control that are applicable to a range of species, based on their competitive impact on cotton. The critical period for weed control allows for more flexible and effective management packages to be developed for a range of weeds and is similar conceptually to that already established for insect control using IPM in the Australian cotton industry.

Introduction

The last five years have seen some exciting and new developments in integrated weed management (IWM) in the Australian cotton industry. The introduction of post-emergence herbicide technologies that afford better control of some of the more difficult to control weeds and the introduction of Roundup Ready® cotton have allowed growers to develop more effective and flexible weed management programs. These new systems have retained some reliance on broad-spectrum residual herbicides and other management strategies (Charles *et al.* 2004), but have begun to integrate and substitute these new technologies to maximise weed control and to minimise costs. The role of research in the development of IWM systems is to examine how these systems are evolving, test possible outcomes and provide industry with some guidance as to possible benefits and pitfalls of the new systems. For example, Taylor and Charles (2002) highlighted the necessity to develop and maintain an IWM approach to minimise the impact of species shift and herbicide resistance in irrigated production systems relying more heavily on glyphosate for weed control. Additionally, Taylor *et al.* (2003) reported on the cost benefits of being able to reduce dependence on residual herbicides for weed control in fields that have low weed densities.

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 may be particularly useful in systems into which herbicide tolerant crops have been introduced Knezevic *et al.* (2002). This paper discusses the use of mimic weeds that have similar biomass and leaf area to actual weed species, to determine the critical period for weed control for use in cotton systems using Roundup Ready cotton or in the future using the new herbicide tolerant cotton varieties.

The critical period for weed control

Changes in the weed spectrum to glyphosate tolerant weeds and the potential threat of herbicide resistance are two of the main reasons why IWM should be adopted in the Australian cotton industry Charles *et al.* (2004 in these proceedings). The critical period for weed control (CPWC) is an important component of IWM and has been defined by Knezevic *et al.* (2002) as "the window in the crop growth cycle during which weeds must be controlled to prevent unacceptable yield losses."

The widespread adoption of Roundup Ready cotton within the Australian cotton industry estimated at approximately 60% for 2003/04 season, demonstrates the importance of having a flexible weed management package as well as providing some indication of the impact of weeds in the cotton farming system. 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 need to be made with an understanding of the CPWC. This will result in more cost effective weed management and the judicious use of post-emergence herbicides will decrease selection pressure and reduce the likelihood of herbicide resistance or species shift.

Currently, with Roundup Ready® cotton, over the top post-emergence control is limited to the four leaf stage although the control of some specific weeds can be enhanced with the use of existing post-emergence herbicides such as Staple® and Envoke®. The future introduction of Roundup Ready Flex® and Liberty® cotton varieties will provide a wider envelope during which herbicides can be applied over the top of cotton. To maximise the potential of these herbicide technologies, but still retain an IWM approach for reasons of resistance and species shift, weed management decisions need to be made on the basis of potential yield impacts and not on the presence/absence of weeds. In many ways this concept is similar to that of IPM, which revolves around pest complex thresholds. Weed management decisions should also be based around weed thresholds. These weed thresholds need to take into account the competitive impact of weeds on the crop and between the weeds themselves, because an increase in weed numbers does not necessarily result in increased yield loss.

Critical time for weed removal

Timing of application is critical when using post-emergence herbicides to achieve a good result. Herbicides need to be applied when weeds are small, when there is adequate soil moisture, within temperature parameters and prior to weeds causing any irreversible reduction in yield. Germination of weed seeds is mainly dependant on temperature and moisture and successive germination of weed cohorts will be influenced by the dormancy of those seeds at the time. Thus, it is likely that there will be a multitude of weed flushes due to rainfall or irrigation throughout a season. Growers then are trying to balance a number of variables such as the number of germination events, the cost of weed control, the capacity to cover a number of fields with the application equipment available, and possible yield reductions due to weed pressure. Given that there are likely to be a number of germination events in any given season, it is important to know whether those germinating weeds will compete with the cotton plants resulting in a yield reduction or whether they will add to the seed bank, creating a problem for the next season. The critical time for weed removal (CTWR) is the period during crop growth that the crop can tolerate weed competition before the crop suffers an irreversible yield reduction (Knezevic 2002). The CTWR varies for each species and for the density of the weed.

Mimic weeds to model the competitive impacts of cotton weeds

Currently there are over two hundred weed species that are problematic in Australian cotton production systems. It would be impractical and an inefficient use of research funding to attempt to develop a CTWR for each species at the varying densities that these weeds are present in cotton fields. Instead, other plants can be used to model the competitive impacts of weeds on cotton and weeds can then be grouped by their competitive impact on cotton, allowing more general guidelines to be developed that are applicable to a range of species rather than to just one. The use of mimic weeds also overcomes some of the other inherent problems typically associated with using weeds in experiments, such as staggered germination due to dormancy characteristics, environmental considerations when planting weeds in large field areas and so-on. Kim *et al.* (2000) state, that weed competitivity is dependent on weed leaf area, and that weed leaf area is dependent on weed biomass. Therefore weed biomass is a good indicator of weed competitiveness. By using a crop plant with similar biomass and leaf area to the weed, the competitive impact on desired crop yield can be estimated. Biomass and leaf area measurements were taken for a range of weed and crop species to determine crop species that may be suitable alternatives to weeds. Sunflowers and mungbeans were similar in their biomass to thornapple (*Datura stramonium*) and bladder ketmia (*Hibiscus trionum* var. *trionum*) (Fig. 1) and therefore were used as mimic weeds to determine the critical time for weed removal.

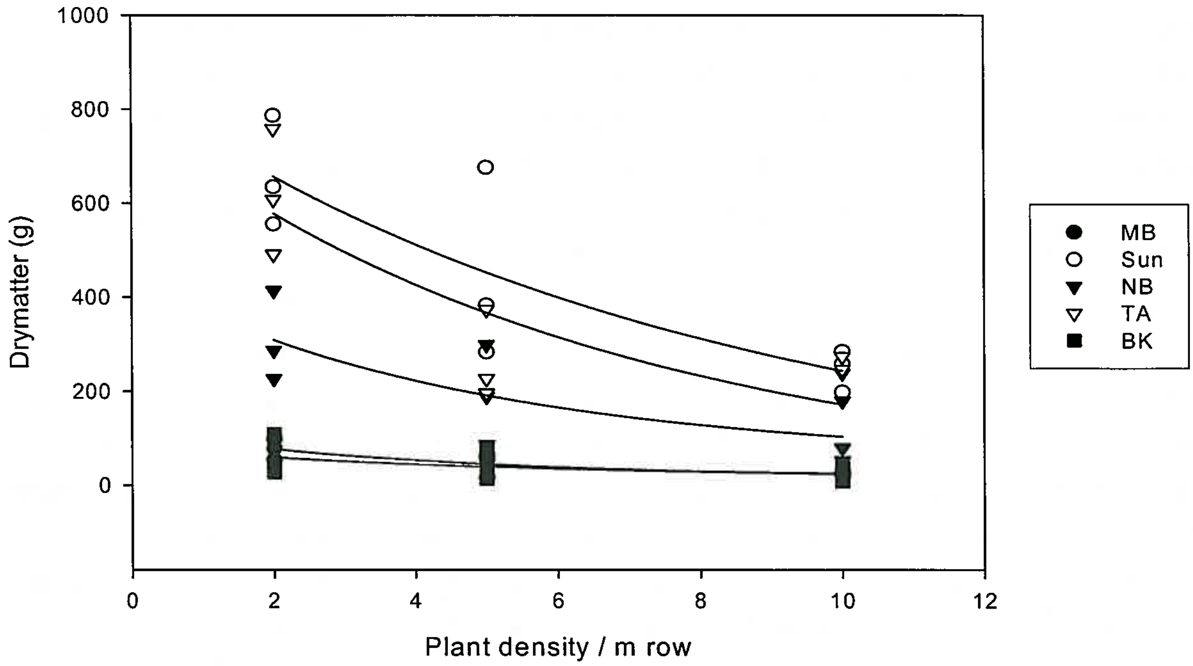

Fig. 1. The mean biomass of mungbean, (MB) sunflower (Sun) noogoora burr (NB) thornapple (TA) and bladder ketmia (BK) in grams per plant over a range of densities. Sunflower and thornapple were not significantly different nor were bladder ketmia and mung bean..

The competitive impact of sunflowers and mungbeans as mimic weeds on cotton.

To be able to deduce the critical time for weed removal, it is necessary to establish when the particular weed begins to interfere with the crop growth and subsequently yield, and how increasing densities also impact on yield. Figure 2 illustrates the relationship between weed density and weed removal time on cotton yield for sunflower and mungbeans as mimic weeds for thornapple and bladder ketmia, respectively. Yield losses were particularly high for sunflower even at a density of one weed per meter of row. At densities of 5, 10 and 20 weeds per meter of row, the impact of sunflowers on cotton yield is similar, indicating the competitive effects that the weeds have on each other. Mungbeans, however, do not have the same effect on cotton yield. At densities between 1 and 5 weeds per meter, if the weeds are removed within 40 days after emergence there is relatively little impact on yield. At higher densities of 10 and 20 weeds per meter yields are reduced at approximately 30 days after emergence, but yield declines become quite large if the weeds are not removed until day 93.

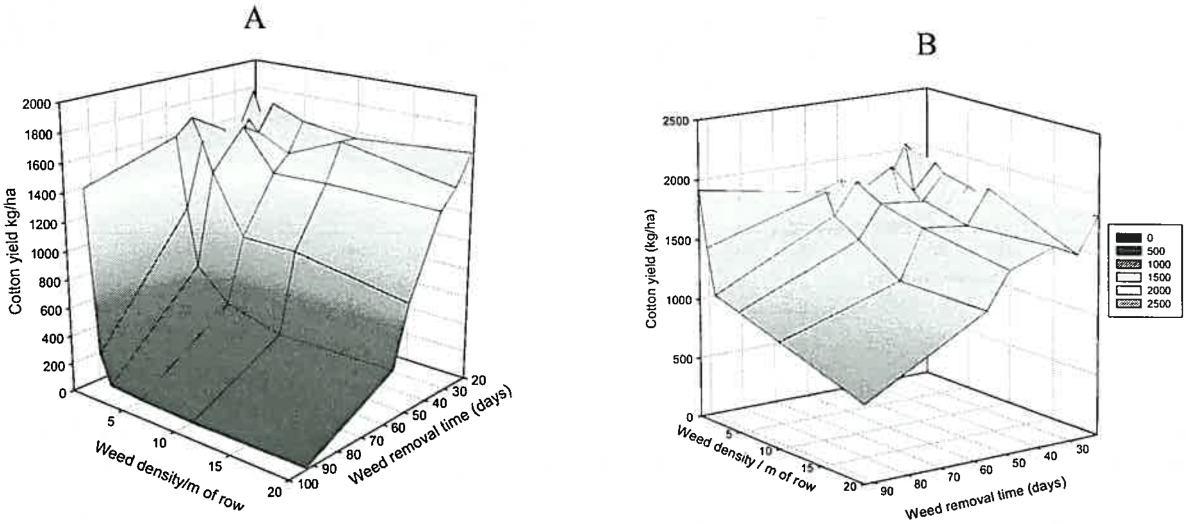

Fig.2. The impact on cotton yield (kg/ha) of sunflowers (A) and mungbeans (B) as mimic weeds planted at 0, 1,2,5,10 and 20 weeds per meter and then removed at 21, 28, 35, 49, 56 or 93 days after emergence.

Determining the economic threshold for weed control.

The point at which a grower will decide to spray will be determined by the weather, access and availability of equipment as well financial aspect such as lint price, and the cost of herbicides. The decision to spray should also take into account the a yield loss threshold and as such will be a personal choice reflecting what a grower will tolerate before deciding to spray. For example at a bale price of $550, a grower expecting a yield of 12 bales ha^{-1} may decide that he would apply a Roundup Ready herbicide application when there was a potential yield loss of around 2.5%, that is in dollar terms a loss of around $165 ha^{-1}. The herbicide application including licensing fee and operator costs may be in the vicinity of around $50 ha^{-1}. It is not worthwhile spraying more often than this because the returns on investment for the application cost becomes too low for example it is not worth spending a dollar on control to receive a dollar back in yield. Additionally the frequent application of herbicides results in increased selection pressure on the weeds hastening species shift and the likelihood of resistance developing.

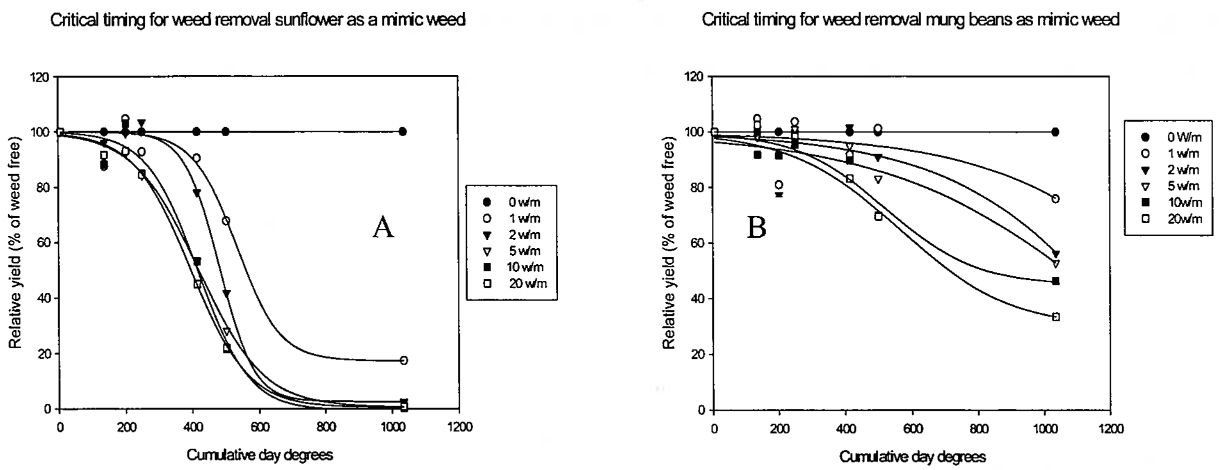

Fig 3. The impact of sunflowers (A) and mungbeans (B) as mimic weeds at densities of 0, 1, 2 5, 10 and 20 weeds per meter on cotton yield expressed relative to the weed free yield and related to crop thermal time

The critical weed free period

As mentioned earlier, the critical period for weed control is the window during which weeds must be controlled to prevent yield losses. We have so far defined when weed control measures should be commenced but we now need to define the point when it is no longer necessary to continue control practices from a yield loss point of view. The critical weed free period (CWFP) is the period after which emerging weeds no longer significantly compete with the crop and therefore reduce yields. In cotton, this stage is likely to occur prior to canopy closure, but like the CTWR, will be depend on weed growth rate, weed density and other agronomic factors such as planting configuration or the cotton variety. The CWFP is illustrated in Fig. 4 for a sunflower density of 1 weed per meter of row. The critical period for weed control is the period between the CTWR and the CWFR and is determined by the nominated economic yield loss. The CPWC in this example uses a yield loss threshold of 2.5% to define the beginning and the end of the control envelope. A weed density of 1 weed (sunflower) per meter of row is used as survey data, Charles *et al.* (2004) suggest that weed densities on a number of cotton farms have ranged from 1.84 to 0.51 weeds m^{-2} during the last 10 years. Relating the critical period for weed control to crop day degrees allows growers to determine the cotton growth stage for a particular season and therefore time their applications to cotton growth stage. The critical period for weed control appears to be approximately 1250 day degrees for a density of 1 thornapple per meter of row. However, this needs to be further validated through field experiments over the next two years. Additionally, more work needs to be completed to provide guidance on densities that are less than 1 weed per meter of row.

Determination of critical period for weed control

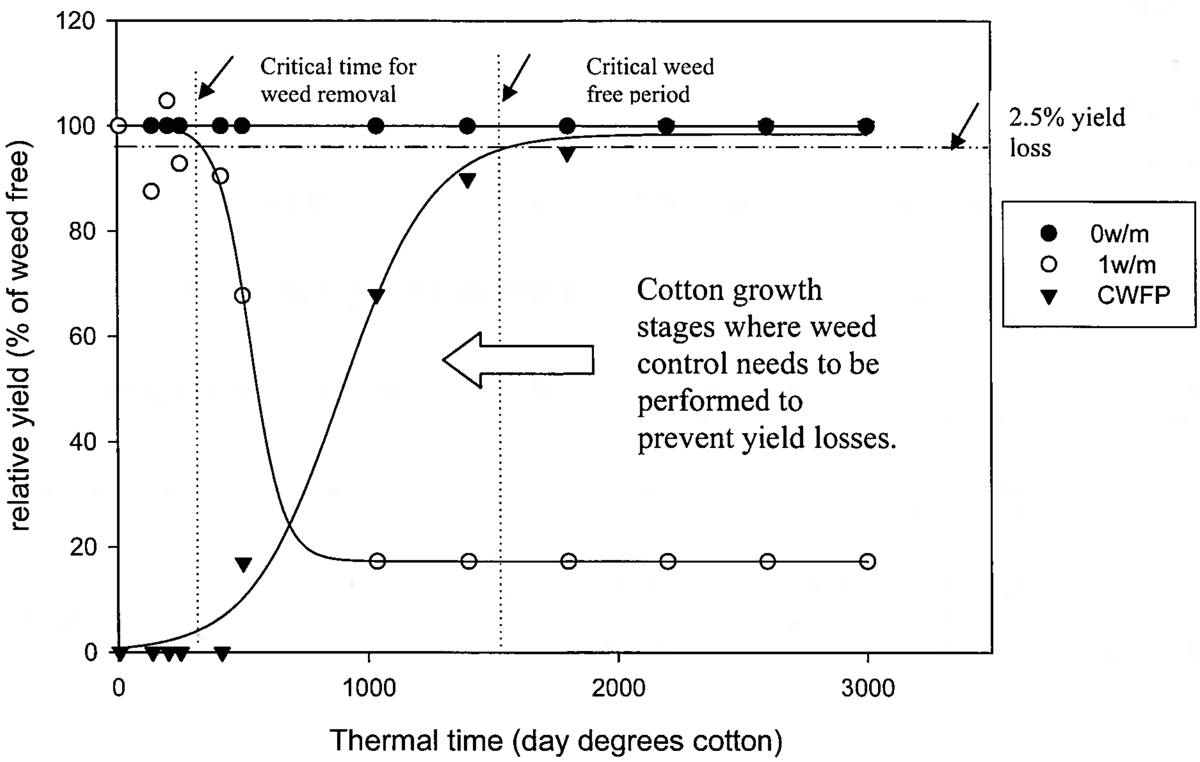

Fig. 4. Determination of the critical period for weed control for thornapple (using sunflower as a mimic weed). The critical period for weed control is based on a weed density of 1 weed per meter of row

Weed management strategies

While much of this paper has been devoted to weed control to prevent yield loss, the aim of weed management is to prevent weeds from setting seeds and thus adding to the existing weed problem. Weed management strategies need to be continued past the critical period for weed control. However, rather than focussing on just controlling the weeds, emphasis needs to be placed on also preventing those weeds from setting seed. In winter cereals, a technique known as selective spray topping has been employed successfully and focuses on using sub-lethal doses of specific herbicides to cause weeds to abort seed. A similar tactic can be used by the cotton industry or a lay-by herbicide program s can be used to prevent key weeds from emerging or setting seed.

The continued development and adoption of this concept requires input from a number of other key researchers, particularly for managing difficult to control weeds and to better understand the population dynamics, biology and ecology of the weeds to ensure management options are planed at critical times in the weeds life cycle. Graham Charles is currently developing a number of packages for weeds such as polymeria take-all, peach vine and nutgrass. Stephen Johnson is currently researching the population dynamics, biology and ecology of key weeds such as bladder ketmia. Their input and valuable knowledge is recognised and I thank them for their input in developing this concept for Australian cotton systems.

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