Opportunities and Threats with Roundup Ready® Flex and Liberty Link® cotton, the next generation of herbicide tolerant cotton varieties

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Summary

Roundup Ready® cotton has been commercially available to Australian cotton growers for five years and has been widely adopted by the industry with approximately 77% of the area planted to Roundup Ready cotton in the 2005/06 season. The next generation of herbicide tolerant cotton varieties; Roundup Ready® Flex and Liberty Link®, are likely to become commercially available over the next couple of years. These traits will allow the cotton industry to further develop in-crop weed management systems that may rely almost exclusively on the use of one or other of these technologies. The widespread adoption of these technologies is likely to result in a further decrease in the use of residual herbicides, inter-row cultivation and hand-hoeing in cotton fields. Adoption of these systems should reduce crop establishment problems, allow better yields and reduce problems of environmental contamination currently occurring with residual herbicides. However, their use is also likely to further exacerbate problems with species shift, herbicide spray drift and the control of volunteer crop plants, as well as increasing the risk of weeds developing herbicide resistance.

Introduction

Australian agriculture has rapidly embraced most new technologies, but for various reasons, has been slow to adopt genetically modified crops. The Australian cotton industry has been the exception to this rule, using transgenic, insect tolerant cotton varieties for the last decade and transgenic herbicide tolerance for the last six seasons. Approximately 80% of the Australian cotton crop was transgenic insect tolerant Bollgard II® (a stack of two genes) and 77% was glyphosate tolerant, Roundup Ready® cotton in the 2005/06 season, with the combination of all three genes employed on 70% of the crop area (about 210 000 ha).

The rapid uptake of herbicide tolerant cotton can be attributed partly to the value of the technology for managing some of the more problematic weeds that are difficult to control in the traditional system, such as nutgrass, cowvine (peachvine) and bellvine. However, Roundup Ready cotton is also being grown in many fields that do not have major weed problems, as additional benefits have been gained through using the technology. These benefits include broad-spectrum post-emergence weed control through the use of Roundup Ready Herbicide in crop, the ability to easily control weeds in cotton planted into standing crop stubble and narrow-row configurations, the ability to replace less favored components of the system, such as hand-hoeing and inter-row cultivation, a reduction in seedling establishment problems where the technology has replaced pre-planting and at-planting residual herbicide applications, and as drift protection against the possibility of glyphosate drift occurring. The use of Roundup Ready cotton has lead to a large increase in the use of glyphosate in the crop, to a reduction in the use of pre-planting herbicides, and to small

reductions in the use of inter-row cultivation and hand-hoeing. There has also been an increase in the use of lay-by residual herbicides. Roundup Ready cotton allows more timely targeted management inputs, with the ability to control weeds that emerge with or soon after the crop. The crop safety of shielded glyphosate applications later in the season is greatly improved compared to conventional cotton, allowing this herbicide to be used to manage some of the more problematic weeds in cotton later in the season. These changes have contributed to improved productivity in the cotton system, with more timely weed management and reductions in crop damage from herbicides and cultivation.

The value of the Roundup Ready technology, however, has been limited by relatively poor expression of the gene in the reproductive parts of the cotton plant, effectively limiting the broadcast application window for glyphosate to the emergence to 4-node stage of plant growth, before the reproductive plant parts are initiated. This limitation has ensured that glyphosate has not replaced the other management tools in the integrated weed management system used in the cotton system, but has been a valuable additional tool in the system. The problem of poor gene expression has been overcome in Roundup Ready Flex® cotton, the second generation of herbicide tolerant cotton that is set to become commercially available in Australia in the 2006/7 season and beyond. Roundup Ready Flex cotton varieties have much high levels of tolerance to glyphosate in both vegetative and reproductive phases, with an extended over-the-top Roundup application window.

A second new technology, Liberty Link® cotton, with a high level of tolerance to glufosinate-ammonium may also become commercially available in the near future. This technology will bring a new herbicide into the cotton farming system, with good efficacy on some of the weeds that are difficult to control in conventional and Roundup Ready systems. However, the introduction of these technologies may challenge the integrity of the integrated weed management system now in use.

Managing weeds with Roundup Ready® cotton

The development of a new weed management system was one of the challenges faced with the introduction of Roundup Ready cotton. Prior to the commercial release of Roundup Ready cotton it was anticipated that a weed management system relying heavily on glyphosate might develop, potentially leading to species shifts and herbicide resistance developing. To address this threat a crop management plan was developed that emphasized the continuing need for an integrated approach to weed management, and included assessment of the weed threat, scouting for weed escapes after a glyphosate application, and treatment of any escapes with an alternative weed management tool to prevent seed-set. This management plan has proven to be effective, although a shift towards glyphosate tolerant weed species is already apparent in the cotton industry, as shown by results of a series of in-crop weed surveys. This shift has not been primarily caused by the introduction of Roundup Ready cotton, but has been a response to a general change in the farming system to using glyphosate as the primary weed management tool in place of cultivation, especially in fallow weed control. The species shift is being managed with a range of alternative weed management tools and has not caused major problems to date.

A number of other problems have, however, occurred subsequent to the introduction of Roundup Ready cotton. Problems with the management of volunteer Roundup Ready cotton plants were

anticipated, but were not expected to be a major issue. However, adoption of Roundup Ready cotton has led to significant problems with the management of volunteer plants, to increasing problems with herbicide (glyphosate) drift, and to problems with the management of weeds in the areas around cotton fields, particularly in irrigation structures.

Problems with the control of volunteer cotton plants have highlighted the heavy reliance on glyphosate for weed control in fallows over the summer period in the cotton farming system, particularly in zero-till systems where standing crop stubble is retained. Seedling volunteers can be controlled with alternative chemistry such as Spray.Seed® (paraquat+diquat) or Hammer® (carfentrazone-ethyl), but there are few options other than cultivation for the removal of these weedy plants once they are well established. Maintaining good fallow hygiene and controlling seedling volunteers with non-glyphosate options has become an essential component of the transgenic farming system. Problems with volunteer Roundup Ready cotton plants also occur in back-to-back cotton and are much worse where reduced rates of residual herbicides are used at planting. Where no residual herbicides are used prior to or at planting far higher numbers of volunteer cotton plants may establish than is normally the case where standard rates of residual herbicides are used. Three or four inter-row cultivation passes may be required to manage these volunteers, reducing the value of the technology, and potentially still leaving an excessive population of cotton in the plant-line, particularly problematic when there has been a change in the cotton variety. This problem is most readily overcome by rotating cotton with a winter crop and ensuring that crop volunteers are managed in the summer fallow.

Far too many instances of herbicide drift from broadcast applications of glyphosate to Roundup Ready cotton have occurred, with damage reported on surrounding crops including conventional cotton and sorghum. Problems with glyphosate drift from Roundup Ready cotton have been accentuated by the necessity of making a broadcast glyphosate application no later than the 4-node stage of crop development. This application is often delayed as late as possible to ensure maximum effectiveness is achieved with the spray. However, when wet and windy conditions then occur it has on some occasions become necessary to apply the herbicide under less than ideal conditions, increasing the risk of spray drift.

Where the adoption of Roundup Ready cotton has led to large reductions in the use of pre-emergent residual herbicides in fields, problems have developed with weeds in irrigation channels and surrounding areas. It has become apparent that many of these weeds were largely controlled in the traditional system by residual herbicides that moved out of the crop area in irrigation tail water. With a reduction in the use of these herbicides, volunteer cotton, weeds and particularly grass weeds, have become more problematic, potentially creating a seed source for re-infesting the fields. This problem has been exacerbated by the tendency to use glyphosate as the primary weed control tool in these areas and is necessitating the use of residual herbicides, cultivation and alternative herbicides such as Amitrole T (amitrole+ammonium thiocyanate ®) and Spray.Seed to manage these areas.

Opportunities and threats with Roundup Ready Flex® cotton

The introduction of Roundup Ready Flex will allow cotton growers to develop weed management systems that are much less reliant on traditional inputs, and to manage some problematic weeds

with improved crop safety. On cotton fields that have relatively low weed pressure, it is likely that Roundup Ready Flex systems will develop that rely almost solely on glyphosate, with no pre-emergence or at-planting residual herbicides, little or no hand-hoeing, and no inter-row cultivation for weed control. Some inter-row cultivation may still be necessary to incorporate a lay-by residual herbicide and to facilitate the movement of irrigation water. Such a system will be conducive to optimal crop yields but will inevitably lead to problems with species shifts to glyphosate tolerant species and may lead to the development of herbicide resistance. Modeling undertaken by Jeff Werth has shown that resistance is unlikely to occur in the short-term in the irrigated cotton system, but is more likely with rain-fed cotton where cotton is a less significant component of the whole system. Nevertheless, Roundup Ready Flex cotton will give growers the opportunity to develop a weed management system which is more environmentally friendly (with less cultivation and residual herbicide) and is consistent with good crop management. Regular cropping rotations will provide opportunities to manage weeds with other technologies and can decrease the selection pressure on weeds. Where species shift does lead to problematic levels of glyphosate tolerant weeds, cotton growers will have the opportunity to rotate to an alternate crop and use different herbicide chemistry, or to re-introduce some conventional weed management tools. In an extreme case, a cotton grower may opt to use a conventional weed management program to manage glyphosate tolerant weeds.

In high weed pressure fields and where problem weeds such as nutgrass are common, glyphosate will continue to be a valuable tool in a Roundup Ready Flex system that continues to incorporate many of the more conventional weed management tools in an integrated weed management system.

Problems with glyphosate drift should decline with Roundup Ready Flex cotton due to the much extended window for broadcast applications with this technology allowing applications to be delayed until conditions are favorable for ground-rig application.

Problems with the management of glyphosate tolerant weeds and crop volunteers are likely to be increased with Roundup Ready Flex cotton. While these problems can be addressed using an integrated approach with cultivation, residual and alternative herbicides, this will increase the cost of the overall system, reducing its value. Over time, cotton growers should be able to reduce weed pressure and the weed seed bank on most cotton fields, and may then have the opportunity to return to a more traditional weed management system using lower herbicide rates. This decision will be driven by a range of factors including the cost of the technology.

Opportunities and threats with Liberty Link® cotton

The introduction of Liberty Link cotton brings the opportunity to introduce a new herbicide to the cotton farming system, with very good crop safety. Liberty® (glufosinate-ammonium) is effective on a wide range of broad-leaf weeds, some of which are not well controlled by glyphosate, but has poorer efficacy on the grasses. It is weakly translocated and has no efficacy on the nutgrasses, one of the strengths of glyphosate.

A cropping system for Liberty Link cotton could develop that is similar to the Roundup Ready Flex system, with reduced inputs of residual herbicides, inter-row cultivation and hand-hoeing, but

it is likely that a Liberty system would need to retain a pre-emergence residual grass herbicide due to the poor efficacy of this product on grasses.

Such a system would have similar advantages to a Roundup Ready Flex system, but also have many of the same disadvantages. Liberty Link cotton plants will be no different to conventional plants in their tolerance to the herbicides normally used in fallows and rotation crops and will be controlled by glyphosate. Consequently, their management in fallows and rotation crops should raise no additional difficulties over that of conventional cotton. However, back-to-back Liberty Link crops will see significant problems with crop volunteers. Problems with herbicide drift will also be similar to those with Roundup Ready Flex cotton, although the consequences of drift may be less severe, as glufosinate-ammonium is only weakly translocated in the plant and will have a more transitory effect. Problems with weeds in irrigation structures and surrounding areas will be similar to the problems with Roundup Ready Flex cotton where weed problems are accentuated by a reduction in the use of residual herbicides in crop.

However, it may be that a cropping system with Liberty Link cotton may be more like the traditional cotton system. The relative costs of the Liberty Link cotton technology and Liberty herbicide will have a large influence on the use of this technology. Glufosinate-ammonium has traditionally been a relatively expensive herbicide and one possible scenario is a lower price for the technology license fee, combined with a higher product cost when compared to Roundup Ready Flex cotton. In this scenario, it is likely that Liberty Link cotton may be grown using a more traditional weed management system, with most weeds controlled by conventional means and Liberty used as a directed spray to manage problem weeds. In this scenario Liberty Link cotton would be grown within an integrated weed management framework and would have few associated problems other than the control of crop volunteers in back-to-back Liberty Link crops.

A herbicide tolerant farming system

The best outcome from herbicide tolerant cotton varieties will be achieved by continuing to use these technologies in an integrated weed management system, where weeds are prevented from setting seed, reducing the size of the weed seed-bank and weed pressure over time. As the weed seed-back declines, it may be economically desirable to return to a more traditional weed management approach using non-herbicide tolerant cotton varieties.

Where possible, these technologies should be used in a rotational cropping system, where problems with volunteer crop plants can be managed in a rotation crop or fallow. Alternatively, rotation of the two technologies may give the best outcome in a continuous cotton system.

Conclusions

- Continuing adoption of a crop management plan based on the premise of preventing weed escapes setting seed should maintain the viability of the herbicide tolerant systems.
- The management of herbicide drift, volunteer crop plants and weeds around cotton fields will continue to be important issues, with different issues faced in back-to-back cotton compared to systems that include a cropping rotation.
- It seems likely that the value of these technologies will decline over time as weed densities decline in-field, and species shifts reduces the effectiveness of herbicide applications.

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