THE ROLE OF ROUNDUP READY™ FIELD CROPS IN AUSTRALIAN CROPPING SYSTEMS

Andrew J. Somervaille
Monsanto Australia Limited, PO Box 884, Toowoomba, Queensland 4350, Australia

Summary Field crops genetically engineered to withstand topical applications of Roundup® herbicide have the potential to contribute positively to weed management practices in dryland and irrigated cropping systems in Australia. The introduction of Roundup Ready™ crops will enhance the sustainability of intensive cropping systems reliant on the use of herbicides. The opportunity to utilize Roundup herbicide selectively in certain field crops will enhance the sustainability of cropping systems by complementing existing integrated weed management practices and specifically by substituting for herbicides reliant on mechanical incorporation and those having an extended life in soil.

INTRODUCTION

Herbicide resistance was the first agriculturally useful trait to be introduced into plants by genetic engineering (Comai *et al.* 1985) and a number of herbicide tolerant crops have been developed. Genes conferring tolerance to Roundup® herbicide (Roundup Ready™ by Monsanto) have been introduced to various field crops including cotton, soybean, corn, sugar beets, oilseed rape and canola. Also of significance have been the evaluation of crop cultivars with herbicide resistance obtained through conventional plant breeding utilizing protoplast fusion (e.g. use of triazine resistant *Brassica campestris* to develop triazine resistant cultivars of canola), seed mutagenesis (e.g. to develop sulfonyl resistance in soybean) or in vitro cell selection (e.g. imidazolinone tolerant maize).

The aim of this paper is to discuss the benefits which may accrue from the introduction of Roundup Ready crops, and address the major concerns which have been raised about transgenic herbicide tolerant crops with particular reference to the Roundup Ready gene. These concerns include:

- the risks of transferring resistance genes to wild crop relatives through out-crossing (Darmency 1994)
- the control of herbicide tolerant crop volunteers (Medd *et al.* 1995)
- the concern at increasing the likelihood of producing weed populations with an acquired resistance to a herbicide and thus reducing the utility of the herbicide in other use situations (Pratley *et al.* 1995)
- the concern at increased herbicide use or dependence on herbicide use for weed control and the accompanying concern of increasing residues of herbicides in food (Phelps 1995).

In addition, concern has been expressed that farmers will be required to pay for technology whether they want it or not and that chemical manufacturers may push the adoption of herbicide tolerant cultivars regardless of the consequences for sustainable agriculture (Pratley *et al.* 1995).

It is the contention of this paper that the introduction of Roundup Ready crops in a carefully considered approach will enhance the sustainability of cropping systems when integrated with other methods of weed control.

DISCUSSION

Out-crossing of field crops with weedy relatives Both the likelihood and potential consequences of out-crossing of transgenic crops with wild relatives, are fundamental issues which are considered by the developer of herbicide tolerance technology before proceeding with any crop and again in the context of a specific proposed crop release.

If the introduced gene were to confer a survival advantage to a wild relative, then this could have flow-on effects in the ecosystem. If there were no selective advantage, then the presence of the gene would not have significant impact on the ecosystems and its frequency would remain at a low and stable level.

For a herbicide tolerance gene, provided there are no incidental selective advantages associated with the gene, then its transfer to a wild relative should not alter the species' abundance or place in a natural ecosystem. However, a particular concern which must be addressed, arises in relation to potential transfer of herbicide tolerance to a weedy relative which normally is controlled by that herbicide.

These issues have been considered by Monsanto in making the decision to progress development in Australia of cotton containing the Roundup Ready gene. Reproductive and geographic barriers provide effective and practically insurmountable barriers to out-crossing. In any case, cultivated cotton has no weedy relatives.

Herbicide resistant crop volunteers The prospect of controlling herbicide resistant crop volunteers is an issue which must be considered where the herbicide is

normally used for control of volunteer plants. Alternative methods of weed control which do not result in economic or environmental disadvantages must be available.

The issue is of particular significance where conservation tillage is practiced using Roundup herbicide as the primary means of weed control in the fallow. Roundup herbicide is used widely, for example for the control of volunteer cereals and alternative cost-effective treatments for their control would have to be available if Roundup tolerant cereal cultivars were to be developed. In farming systems where Roundup Ready cotton, soybeans, sugarbeets and canola might be grown however, Roundup would rarely be used alone to control volunteer plants and therefore current methods of control would be unaltered.

Nevertheless, the prospect of reducing the utility of glyphosate in conservation tillage systems is a significant criterion for evaluating opportunities for Roundup Ready crops both from an economic and environmental perspective.

Weed resistance Herbicide-resistant weeds threaten the continuing success of herbicide technology to contribute to world crop production (Powles *et al.* 1996) and the occurrence of herbicide resistant weeds in southern Australia has become the most significant issue for sustainability of weed control systems in winter crops in southern Australia. This has particularly affected the control of annual ryegrass (*Lolium rigidum* Gaudin) where resistance has occurred to herbicides with various modes of action.

Weed resistance has apparently developed in plant species with wide genetic variability, out-crossing capability and those in which the primary method of control over a period of time has been the use of a highly effective herbicide or herbicides sharing a common mode of action. Thus, the situation must be avoided where weed management in herbicide tolerant crops is based solely on a particular herbicide. In accordance with this principle, a total approach is being made to weed management in Roundup Ready cotton in Australia and will be factored into any Roundup Ready crop development by Monsanto.

It has been argued that the availability of cultivars with tolerance to Roundup herbicide will necessarily compromise adoption of no-tillage technology (Medd *et al.* 1995) due to the dependence of this system on the effectiveness of glyphosate herbicides.

It should be pointed out that the introduction of the Roundup Ready gene to cultivars of certain crops e.g. canola will only have a small incremental impact on the number of 'exposures' to the herbicide glyphosate in a cropping system and will indeed enhance the long term utility of alternate herbicides used for weed control. This would be particularly the case in northern Australia where multiple applications of this herbicide are currently utilized in the fallow between successive crops.

Estimates based on modelling (Gill and Diggle 1995), indicate that the introduction of a non-selective herbicide at the very least will contribute to some extension of the usefulness of existing herbicides. When used in combination with other management techniques such as rotations with grazed pastures and strategic use of tillage, it will contribute to a greater sustainability of current weed management systems.

It should be pointed out that it is both in the interest of farmers and manufacturers of Roundup herbicide to develop weed management systems which deliver sustainable production and income.

Changes in weed spectrum Changes in weed flora have been a continuing feature of changes in cropping practices over the period of agricultural development. For example, the shift away from a rotation of continuous winter crops on the central Darling Downs of Queensland has seen a decline in the significance of wild oats. The expansion in cropping of hybrid grain sorghum in northern NSW and the use of atrazine as an in-crop herbicide have resulted in the decline of mintweed as a significant weed.

The prospective introduction of Roundup Ready crops should therefore be viewed no differently to any other change in weed management practice. In considering the possible impacts it will clearly be helpful to identify strategies or practices which will overcome any shift in weed spectra. This is already accommodated with fallow management where a range of herbicide and non-herbicide practices are employed to provide effective weed control.

Implications of transgenic herbicide resistant crops on herbicide use Application of selective herbicides for weed control in field crops has become a feature of extensive crop production in the latter part of the 20th century. While there is continuing research into weed control practices which reduce the dependence on synthetic inputs, an immediate goal which can be realised without loss of productivity is the reduction in the total amount of material applied and a shift toward materials with more benign environmental characteristic and reduced crop residues.

It is to this end that the introduction of Roundup Ready crop technology may have a significant impact. In their analysis of current and future weed control practices in cotton utilizing transgenic herbicide resistant cultivars, Charles *et al.* (1995) estimated that the annual

industry-wide use of residual herbicides could drop from 855 000 kg a.i. currently to 257 000 kg a.i. utilizing Roundup Ready cotton. The scope for reduction in the total use of herbicides associated with the sugar industry has also been highlighted in a recent survey conducted by the Queensland Department of Industries (G. McMahon personal communication) which shows the estimated current total use of residual herbicides in catchments where sugar cane is grown to be over 631 000 kg a.i.

We argue therefore that the prospects for herbicide use in Roundup Ready crops are likely to produce a decrease in total herbicide use in crops where there is a current dependence on certain soil applied residual herbicides.

Implications of transgenic crops on residues in crops and food Strict regulations set limits on the permitted pesticide residue levels in foodstuff and animal feeds. These limits are set with wide safety margins to protect health over a lifetime of consumption. Despite this, a desirable community goal is that residues be reduced or eliminated. A feature of many herbicide tolerant crops, is that herbicide residues are extremely low or undetectable in food.

In the case of applications of Roundup herbicide to tolerant crops, the presence of detoxification enzymes generally results in extremely low levels of the unchanged parent material and low levels of metabolites in various crop fractions, even following multiple herbicide applications at exaggerated use rates.

Costs of transgenic crop technology to the farmer Technology development in the agricultural sector is supported directly by the farmer in the cost of goods (e.g. pesticides, seed) or by way of levies on production (supporting specific industry related research or extension programmes) or otherwise is indirectly funded by the taxpayer (in funding for research and services). In the case of transgenic crop technology, developments will only take place where there is a benefit for the farmer and acceptable return on investment to the technology provider, a commercial entity. It is envisaged in most situations that only farmers utilizing Roundup Ready crop technology and benefiting directly from it will contribute to the cost of technology development either by way of royalty, license fee or through purchase of Roundup herbicide for use on tolerant crops.

CONCLUSION

Roundup Ready technology will contribute positively to weed management practices in cropping systems in Australia. Concerns arising from potential out-crossing will be avoided by restriction of the crop types or use-situations, where appropriate. The need to control Roundup tolerant volunteer crop plants will be a primary consideration in the prospective introduction of Roundup Ready crop cultivars. Introduction of Roundup Ready technology is unlikely to result in increased herbicide use. Rather, it will result in:

- reduction in the total amount of herbicide applied in some situations
- less reliance on soil applied residual herbicides
- provide an extended portfolio of options for weed control with a new herbicide mode of action in certain field crops complementing existing weed control practices.

Roundup Ready technology will contribute to sustainable crop production through careful selection of the crops to be introduced and the concomitant development of appropriate weed management strategies where use of Roundup herbicide is integrated with other weed management options.

ACKNOWLEDGMENTS

I wish to acknowledge the helpful comments of Marion Sheers in preparing this paper.

REFERENCES

Comai, L., Facciottie, D., Hiatt, W.R., Thompson, G., Rose, R.E. and Stalker, D.M. (1985). Expression in plants of a mutant aroA gene from *Salmonella typhimurium* confers tolerance to glyphosate. *Nature* 317, 741-4.

Charles, G.W., Constable, G.A. and Kennedy, I.R. (1995). Current and Future Weed Control Practices in Cotton: the Potential Use of Transgenic Herbicide Resistance. *In* 'Herbicide-Resistant Crops and Pastures in Australian Cropping Systems'. Proceedings of a GRDC, CRDC, British Council, RIRDC and BRS Workshop, Canberra, 15–16 March 1995, eds. G.D. McLean and G. Evans. (Bureau of Resource Sciences, Canberra).

Darmency, (1994). The impact of hybrids between genetically modified crop plants and their related species: introgression and weediness. *Mol. Ecol.* 3, 37-40

Gill, G.S. and Diggle, A.J. (1995). Implications of Growing Herbicide-resistant Crops for the Development of Reistance in Weeds-A Simulation Study. *In* 'Herbicide-Resistant Crops and Pastures in Australian Cropping Systems'. Proceedings of a GRDC, CRDC, British Council, RIRDC and BRS Workshop, Canberra, 15–16 March 1995, eds. G.D.

McLean and G. Evans. (Bureau of Resource Sciences, Canberra).

Medd, R.W., Martin, R.J. and Felton, W.L. (1995). Herbicide Tolerant Crops: Opportunities and Concerns for the summer rainfall Grain Belt in Australia. *In* 'Herbicide-Resistant Crops and Pastures in Australian Cropping Systems'. Proceedings of a GRDC, CRDC, British Council, RIRDC and BRS Workshop, Canberra, 15–16 March 1995, eds. G.D. McLean and G. Evans. (Bureau of Resource Sciences, Canberra).

Phelps, Bob (1995). Industry Plans to Entrench Herbicide use with Genetically Engineered Herbicide-tolerant Plants: Unsustainable, Unsafe, Unwanted. *In* 'Herbicide-Resistant Crops and Pastures in Australian Cropping Systems'. Proceedings of a GRDC, CRDC, British Council, RIRDC and BRS Workshop, Canberra, 15–16 March 1995, eds. G.D. McLean and G. Evans. (Bureau of Resource Sciences, Canberra).

Powles, S.B., Preston, C., Bryan, I.B. and Jutsum, A.R. (1996). Herbicide Resistance: Impact and Management Advances in Agronomy Volume 58. (In press).

Pratley, J.E., Lemerle, D.J., Luckett, J.P., Brennan, J.P. and Cornish, P.S. (1995). The Role of Herbicide-resistant Crops in the Winter Rainfall Farming System of South-eastern Australia. *In* 'Herbicide-Resistant Crops and Pastures in Australian Cropping Systems'. Proceedings of a GRDC, CRDC, British Council, RIRDC and BRS Workshop, Canberra, 15-16 March 1995, eds. G.D. McLean and G. Evans. (Bureau of Resource Sciences, Canberra).