

ALLELOPATHY – NEW WEED CONTROL OPTIONS FOR MAIZE

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Abstract

New weed management tools are needed to sustain long term maize production in Australia. Current options are in decline and the GM revolution is providing no solutions for Australia.

Consideration needs to be given to the development in Australia of bioherbicides, and the role of allelopathy needs to be explored both for in-field management and in the development and choice of varieties in particular weed species situations.

Industry context

Maize, worldwide, is now predominantly a GM crop. GM status provides improved yield but, more particularly, enables pest and weed control through substantially reduced pesticide inputs. Australian maize growers however, do not participate in the GM revolution because of State government regulations. However, this does not mean that the Australian industry will be able to continue independently from worldwide GM production.

GM crops are dominated by Roundup Ready which increases its share of the market annually. The adoption of Roundup Ready has not been as dramatic in maize (about 18% in the US in 2004) as in other crops (Duke 2005) but it is still significant and can be expected to continue to increase. Table 1 shows the regulatory approval for GM maize varieties. There have been no approvals since 2002.

Table 1. Regulatory approval for growing GM maize (extracted from Duke 2005)

Herbicide	Country	Year approved
glufosinate	Argentina	1998
	Canada	1996
	Japan	1997
	USA	1995
glyphosate	Argentina	1998
	Canada	1998
	Japan	1998
	South Africa	2002
	USA	1997

It is also evident that there is little movement in new herbicide resistant crops and the industry will remain dependent on Roundup Ready. There are some potential consequences or risks of this lack of change. Firstly, there are risks of the industry being dependent on a narrow genetic base. In the event that this germplasm succumbs to disease or pest pressures, the industry at large is affected. The history lesson from the decimation of the US corn crops in the early 1970s by maydis leaf blight (*Drechalera maydis*) due to the industry being based on the Texas cytoplasm or the Australian lucerne industry, based on the variety Hunter River, threatened by the spotted alfalfa aphid (*Therioaphis trifolii*) needs to be recalled.

Secondly, there are risks that the weed population may become increasingly tolerant to the herbicide through evolved resistance or through weed shifts. In North America, there appears to be a weed shift occurring to the Roundup Ready pressures with fleabane (*Conyza* spp) increasing in incidence. Fleabane is relatively tolerant of glyphosate.

Thirdly, the success of glyphosate in its new role of a post-emergent in-crop herbicide through the breeding of Roundup Ready varieties has significantly altered the commercial balance. Increased market share for glyphosate necessarily means reduced market share for other chemicals. This lower market share reduces the capacity and activity for research and development into new herbicides. The outcome, therefore, is no new maize herbicides.

Thus, whilst the Australian maize industry is not participating in the GM revolution, the GM agenda is resulting in little new chemistry research being done to support the non GM sector. The Australian industry is too small for any of the multinationals to be particularly interested in its plight.

What are the options?

There would appear to be at least two courses of action that need to be considered.

- i) Extending the life of the existing armoury – herbicide resistance is an issue for Australian farmers. Whilst its incidence in Australia has been largely confined to winter crop production and to rice weeds, resistance to, for example, the triazines such as atrazine has been relatively common.

Atrazine is an important chemical but does have a negative environmental reputation because of its persistence and for its potential to contaminate ground waters (e.g. Pimental and Gremer 1997, Osteen and Szmedra 1989). In Australia, such instances are uncommon but, in areas where high water tables exist, the risks are ever present especially with sandy soils. Were incidents to occur, pressures would increase to restrict its use.

The application of good management practices remains an imperative to maintain the efficacy and availability of current chemicals.

- ii) Explore new options – there would appear to be at least three options to consider. In each case, the chances of success relate closely to the extent to which the industry is prepared to invest. No longer is it wise to expect that the industry will automatically benefit from overseas developments.

- (a) Producing new modes of action synthetic herbicides – Australia has not traditionally been the home of herbicide development. The infrastructure to do so is not strong and the prospects for this option are also therefore not strong.

- (b) Bioherbicides – there is largely unexplored territory for capitalising on microbes already present in the ecosystems. Augmenting of particular microbe species and applying these as a herbicide offers great promise for an environmentally friendly solution. Bioherbicides are used around the world but Australia does not have any commercial products. Some work has been done (e.g. NSW Department of Primary Industries, Orange, and Charles Sturt University, Wagga Wagga) in Australia but commercialisation remains a challenge. However, this work needs to be carried out in Australia as there are little to no prospects for importing suitable organisms into Australia for this purpose.

- (c) Allelopathy – this is a largely unexplored area in Australia. This is the study of chemicals produced by one plant to influence the growth and production of adjacent plants. The impact may be positive or negative. Acceptance that the concept has much impact in practice has been a debating point for decades. However, strong scientific evidence in the recent past has raised the credibility of this area of study.

In terms of what role allelopathy may play in future crop management, there would appear to be three main opportunities:

- to identify the chemicals involved, isolate them and identify the compounds for consideration as new modes of actions for synthesis as new herbicides. This has been done and recently Syngenta released a new chemical Callisto® for use as a broadleaf herbicide in maize (Cornes, 2005). Its efficacy was identified in a garden where adjacent vegetation was controlled;

- to consider the allelopathic variability in the gene pool of particular crops in order to select new varieties with capability for controlling, perhaps in conjunction with herbicides, particular weed species. It is important to note that it is likely that allelopathic capability has largely been bred out of current varieties because these have usually been evaluated under weed free conditions. Allelopathy has not been the focus of selection.

The good news is that there is considerable allelopathic variability demonstrated, for example, in wheat (Wu et al. 2000, Bertholdsson, 2005) and rice (Olofsdotter, 2001, Gealy, 2005, Seal et al., 2005), but the work has not been done for maize;

- to undertake research to improve the understanding of the allelopathic relationships so that advantage can be taken of the allelopathy or to minimise the negative effects. Such relationships occur between one crop and another in sequence. Alternatively, the dry crop or weed residues carried over from one season to another may interfere with crop establishment or create a weed problem. Examples, although not pertaining to maize, include the work by Leigh et al. 1995 in respect to subclover decline in phalaris pastures, and the difficulties of pasture establishment in *Vulpia* (silvergrass) infested fields (An et al. 1996, 1997).

New understandings

More recent work has demonstrated how allelopathy works in practice. Bais et al. (2003) and Callaway and Vivanco (2005) describe how a relative harmless species, *Centaurea maculosa* or spotted knapweed, in its native Eurasia has become one of North America's worst weeds, invading some 3 Mha. As an exotic, this weed exudes allelopathic agents, particularly catechin, into its new environment where the native population is unable to resist the invasion. The interaction is analogous to an immune reaction – previous exposure as in its native lands builds up a tolerance in other species to its allelopathic chemicals whereas lack of experience of its competitors in the new environment renders the natives highly susceptible to invasion.

Duke et al. (2005) further emphasised that when a plant is challenged by chemicals from another plant (or a herbicide, for example) a defence response is engendered in the receiver plant. Such defence responses may include the induction of genes which are involved in chemical detoxification. The ability of a plant to respond to such challenges will determine the composition of the plant community.

What does all this mean for our weed control efforts in maize, or any other crop? To date, we have taken the simplistic view that weeds occur, they are sprayed and the problem is solved. Herbicide resistance however, is providing a reality check and we need to face the prospect of running out of current chemical options.

We need to recognise that in a crop/weed interaction there are two species, most likely antagonistic to each other. It is likely that each species will excrete allelochemicals and each species will establish a defence response. In most cases in Australian fields the relationship will be between an exotic crop plant and an exotic or native weed species. The crop variety is often changed from year to year and so there will be no co-evolution. This co-existence is most likely to be active rather than passive in respect to antagonism.

It suggests that we need to undertake more research to understand the effects of different varieties on the growth of particular weed species and there needs to be evaluation of the same weed species on the growth of the different crop varieties. We need to recognise that the relationship is bidirectional and a better understanding may lead to improved weed management.

Conclusions

The Australian maize industry has risks which it needs to recognise but which are not within its control. Although not a GM producer, it necessarily is affected by worldwide GM activity. It needs to recognise that herbicide options are finite.

In order to protect its future, the Australian maize industry needs to consider its options and invest wisely in its future by developing new approaches to weed management. These approaches include bioherbicides and allelopathy.

Improved understanding of the interrelationships between crop and weed plants may alter the way in which weeds are managed. Recognition that both parties indulge in chemical challenges and responses represents a new paradigm in addressing weed invasion. Choice of varieties may be a key to future weed management.

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