

How the agribusiness industry can respond to herbicide resistance in weeds

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Summary The number of herbicide resistant cases is continuously increasing worldwide both in terms of the number of biotypes and mode of action (MoA) (<http://www.weedscience.org/in.asp>). A reaction to herbicide resistance in the field by farmers or advisors usually involves selecting a 'different' herbicide, sometimes unknowingly with the same MoA or mode of degradation (MoD). However, there are many ways of reacting to herbicide resistance and the agribusiness industry is more concerned with the long-term issues in order to:

- (a) minimise the further increase and spread of herbicide resistance
- (b) minimise the selection of resistance to new MoA herbicides
- (c) understand the management of target site and metabolic resistance.

Keywords Herbicide resistance, agribusiness industry.

DISCOVERY OF HERBICIDES WITH NEW MODES OF ACTION

The discovery of herbicides with new modes of action that control existing resistant weed species is of high priority. Unfortunately, the diversity of current commercial herbicides is small, with most herbicides having one of three modes of action:

1. inhibition of photosynthesis at Photosystem II (PS II)
2. inhibition of acetolactate synthase (ALS)
3. inhibition of acetyl CoA carboxylase (ACCase).

As a result of herbicide resistance to PS II, ALS or ACCase inhibiting herbicides, there is little interest to discover new analogs from these herbicide classes. For this reason, the agribusiness industry is placing considerable effort into discovering herbicides with new MoA.

Discovering a herbicide with a new MoA that controls existing resistant weed biotypes would be welcomed by the farming community. Such new herbicides are however, rare. Fortunately this has not discouraged the agribusiness industry, and in fact, has stimulated research into identifying new herbicides that act on different target sites using modern techniques. Such techniques include identifying genetic targets that could be potential herbicide targets. Knowledge

of the structure of herbicide target sites enables compounds to 'fit' in these sites by using techniques such as combinatorial chemistry. Such compounds are subsequently screened using high-throughput *in vivo* and *in vitro* methods. Identifying herbicides that have multiple target sites in plants is of high priority because they are less likely to be prone to resistance. Furthermore, a new herbicide should ideally not be prone to degradative metabolism by existing metabolic resistant weeds.

Once a herbicide advances into the development phase, modelling studies incorporating biological information from *in vitro* and *in vivo* studies are valuable in designing models to investigate the resistance risk. Ideally the resistance risk for a new herbicide should be classed as 'low'. In some cases however, even if the resistance risk is not low, a new molecule may have other favourable features that request its development. In such cases establishing scientifically sound strategies to manage resistance should not deter registration.

HOW TO MAINTAIN EFFICACY OF CURRENT COMMERCIALY AVAILABLE HERBICIDES THREATENED BY RESISTANCE

A proportion of the research conducted by the agribusiness industry is focused in ensuring that existing herbicides remain as effective as possible. This involves identifying strategies to avoid or overcome resistance. In situations where resistance occurs there is growing information on methods to combat the problem. However, the cost to the farmer is often higher than previous methods of weed control.

Developing strategies to fight herbicide resistance involves utilising experts. Collaboration with academic and advisory institutions is beneficial to maximise the effort. One approach is to conduct greenhouse trials with resistant biotypes and subsequently evaluate with trials in fields where resistance occurs. Greenhouse trials enable extensive testing reliably and efficiently to identify potential leads that can be successful treatments in the field. Field testing is important to confirm greenhouse observations and furthermore allows these to be tested with non-herbicide methods to identify potential resistance breaking weed control programs.

Herbicide mixtures, sequences and rotations with different modes of action aid in resistance management, particularly if they have the following features:

Herbicide mixtures Mixture partners must target the same weed species considered for resistance management and the dose of each partner must be at the recommended field rate. Such mixtures have been denoted ‘Smart Mixtures’ and assume that the probability of finding target site resistance to two herbicides with different modes of action is extremely rare. Mixtures have the added benefit that they only require a single application, unlike sequences, but could favour resistance by metabolism.

Herbicide sequences Occasionally mixtures are not possible because of chemical instability (antagonism) or the components are active on different growth stages. Costs are usually increased with sequences because multiple applications are required but have added benefits such as allowing weeds to be controlled at different timings:

- a. Before the crop emerges.
 - i. Using non-selective herbicides such as Spray-seed or glyphosate.
 - ii. Using selective herbicides e.g. trifluralin.
- b. After the crop emerges – using in crop-selective herbicides.

A ‘Smart Sequence’ should aim in reducing the initial weed density with the first application. The second application with a different mode of action herbicide (ideally one that has a low propensity to be metabolised) should further reduce the target density to acceptable levels. An area worth further investigation is in identifying herbicides that sensitise resistant weeds and therefore increase the efficacy of subsequent herbicides.

Herbicide rotations Rotating herbicide MoA and MoD in the cropping system can minimise resistance if cross-resistance is not present. However, rotations are not always as effective as mixtures or sequences because exposure is not on the same generation of

weeds. Rotations however, currently play an important role in resistance management.

Weed control techniques not involving selective herbicides Cultivation, use of higher crop seeding rates and competitive varieties, the ‘early tickle’ to stimulate germination and follow up with non selective herbicides (e.g. Spray.Seed, glyphosate), crop-topping, pasture-topping, seed catching, stubble burning, grazing etc. all act by reducing weed densities. All these techniques are examples that can diversify weed control practices. Combination of herbicide mixtures and/or sequences with non-herbicide weed control is the only effective method in controlling resistant weed species.

COMMUNICATION

In order for the agribusiness industry to play its full part in combating resistance, good communication is essential.

Syngenta has formed a dedicated resistance research group. In addition, a central task team comprising of representatives from different sectors has been created to investigate herbicide resistance. Resistance monitoring and regional resistance information is forwarded periodically to the central task force by a global Syngenta network.

Communication between companies and the industry occurs through the Herbicide Resistance Action Committee (HRAC) that meets at least yearly. The committee consists of representatives from agribusiness companies that meet to discuss recent issues and actions. The mission of HRAC is to facilitate the effective management of herbicide resistance by fostering understanding, co-operation and communication between industry, government and farmers. Dissemination of information occurs via literature publications, Internet (<http://www.plantprotection.org/HRAC/>) and within countries, by aiding in the establishment of country resistance groups. HRAC also contributes towards funding selected projects involved in resistance, including sponsoring of a global database (<http://www.weedscience.org/in.asp>).