

Herbicide resistance: the increasingly important role of the crop protection industry

In this *in focus* section, I have the privilege and honour of providing my perspective in this editorial on the responses of four crop protection companies – Syngenta, Corteva Agriscience, FMC, and Valent U.S.A. LLC (Valent) – on how they are addressing the global problem of herbicide resistance.^{1–4} Additional companies were solicited to provide their perspectives, but unfortunately they were unable to participate. Nevertheless, these four companies reflect the range in corporate size and scope of research, development, and extension (RDE) activities that directly or indirectly impact herbicide resistance.

Since my first introduction to the science of herbicide resistance at the University of Manitoba, Canada in 1988, I have witnessed shifting and evolving attitudes and roles of the crop protection industry (manufacturers, dealers and retailers) with respect to this increasingly complex challenge facing growers and land managers worldwide. Except for those located primarily in the United States corn belt dealing with emerging triazine resistance in the 1970s, the science of herbicide resistance was relatively new and theoretical to many of us living elsewhere – academia and industry alike. At that time and the decade that followed, herbicide resistance RDE were often led by university or other public-sector personnel, with infrequent formal collaborations with industry partners. Today, however, a significant number of research and development personnel in crop protection companies are taking a leading role in both fundamental and applied herbicide resistance RDE nationally and globally.

As expected, there are a number of commonalities in herbicide resistance RDE strategies, goals, and activities of the four crop protection companies represented in this *in focus* section. They all prioritize RDE in optimizing tools and processes for discovery of herbicidal compounds with novel sites of action that are resilient to increasingly complex weed cross-resistance. After about a 30-year drought, we are witnessing renewed industry efforts in this area and consequently some recent commercial successes. At the other end of the spectrum, many crop protection companies provide financial and technical support to the International Weed Genomics Consortium,⁵ which aims to map the genomes of prioritized economically-damaging weed species, provide online analytical tools and training, and facilitate public- and private-sector collaborations.

High priority is similarly given to stewardship of their herbicide product portfolios or herbicide tolerance crop traits through development of best management practices (BMPs), which encompasses regular herbicide resistance monitoring (*e.g.*, conduct or support of baseline surveys in various agroregions, with resistance characterized using developed whole plant or molecular and biochemical diagnostic assays) and diversified herbicide programs involving multiple effective herbicide sites of action (SOA) in mixtures (premixtures or tank mixtures) and sequences/rotations applied pre- and post-emergence. In addition, RDE in the areas of herbicide formulation and application technology

are becoming more important for optimizing delivery and efficacy of their products against target weeds. These RDE activities may be conducted in-house or often in collaboration with external partners such as universities, research institutes, or government departments of agriculture. For example, external collaborations with academia are becoming increasingly common in the areas of weed biology, fitness and resistance mechanisms because of availability of germplasm of weed populations with different cross-resistance profiles, infrastructure and expertise.

In addition, crop protection companies often formally collaborate with external public-sector partners in the area of integrated weed management through research support agreements. To complement their specific herbicide programs and to help sustain their products, they promote or support integration of effective non-chemical practices customized to different agroregions such as crop sequencing, competitive crop cultivars, enhanced crop seeding rates, strategic tillage, cover crops, and harvest weed seed control. Moreover, some companies have led the development and validation of mechanistic models simulating the evolution and population dynamics of herbicide resistance in key annual or perennial weed species to design profitable and sustainable weed management programs.

Crop protection companies now collectively communicate and collaborate with each other *via* memberships or partnerships under the auspices of umbrella groups such as the Herbicide Resistance Action Committee (global and regional), CropLife (International or country-specific), or other industry-led regional initiatives such as Take Action⁶ or WeedSmart⁷ to develop and extend consistent and clear messaging around herbicide resistance BMPs, which can then be tailored to different weed species, cropping systems and environments. The companies also prioritize herbicide stewardship and resistance training, education and communications – internally (both technical and sales personnel) and externally (farmers, advisors, retailers, applicators, *etc.*) – across multiple platforms from smartphone apps, social media, online videos and podcasts to face-to-face field plot tours. Many industry members actively participate and play leadership roles in regional or national weed science or agronomy societies. Moreover, they share methods and findings *via* conferences and scientific publications for the benefit of the weed science community.

Even with continual consolidation and amalgamation within the crop protection industry, I believe that they will play an increasingly important role in herbicide resistance RDE going forward. The pressing issues of food security, climate change, and environment (soil, water, air) protection necessitates increased crop productivity linked with sustainable crop production practices. Although under increasing political, regulatory, and societal scrutiny, herbicides will continue to be the tools favoured by growers for cost-effective weed control in input-intensive agriculture systems. Intensive tillage is not sustainable for a variety of reasons.

The real threat of decreasing global capacity of public-sector RDE in the area of weed science⁸ signifies increasing responsibility and opportunity for crop protection companies in contributing fundamental and applied RDE to mitigating and managing the wicked problem of herbicide resistance. Therefore, strategic collaborations and partnerships with public-sector weed scientists and practitioners as well as agronomists will become even more important in advancing herbicide resistance RDE in the years to come.

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