The "wicked" problem that is herbicide resistance of weeds©

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INTRODUCTION

Sociologists define a "wicked" problem as one without clear causes or solutions, and thus difficult or impossible to solve. According to Jussaume and Ervin (2016), herbicide resistance meets the requirements of a wicked problem because the causes of resistance are obscured by a complex mix of biological and technological factors, and are fundamentally driven by the whims of human decision-making.

Human influence on not only plants called "weeds", but vegetation of all types, is an important factor contributing to the shaping of plant communities in various environments, both natural and man-made. The tools and technologies that humans employ for the management of growth and development of plants are diverse but usually of either chemical (herbicides, plant growth regulators, etc.) or physical (implements, machinery, structures, etc.) nature.

Even though this discussion focuses on a chemical means of manipulating plant growth and development, namely herbicides, weeds have the ability to adapt to, and survive, other practices employed for their control. Domination of specific weed species in a weed community could develop in response to any control method, irrespective of whether it is of chemical (herbicide), physical, or mechanical nature, in particular when the method is not effective on those species, but successfully controls other species in the same community. Such "species shifts", and domination of one or more species, evolves over time and usually takes a few years to become obvious and economically debilitating.

HERBICIDE RESISTANCE IN CROP PRODUCTION SYSTEMS

From the scientific-technical viewpoint, we know a lot about herbicide resistance, arguably enough to deal successfully with the challenge, and yet, the problem is running away at an alarming rate. The problem is especially rife in the field of agriculture, in particular in crop production, where herbicide resistance is arguably the most critical risk factor, outside of natural factors, facing producers and the herbicide industry. A study conducted in the USA estimated the economic impacts of glyphosate-resistant *Erigeron canadensis* (syn. *Conyza canadensis*) (horseweed), which is closely related to *E. bonariensis* (syn. *C. bonariensis*) (hairy fleabane), that has proven resistance to both glyphosate and paraquat in South Africa (Frisvold and Reeves, 2010). The conclusion of that study is that, across a 20-year horizon period, the estimated annual profit margin benefit attributable to resistance management of horseweed was R2,370 per hectare for maize (calculation based on $158 per hectare, $1 = R15). For soybean the increase in profit margin was R825 per hectare, and R2,055 per hectare in the case of maize-soya bean rotation system.

There is virtually no data available in South Africa on the scale of economic impacts that herbicide resistance has on the crop production and crop protection industries. Considering the direct growth and yield reductions caused by weed interference in all types of crop production, together with additional costs of managing herbicide-resistant weeds, the Rand-value of losses probably runs into many hundreds of millions on an annual basis.

Currently, based on information compiled by Dr. Ian Heap (http://www.weedscience.org/), 470 unique cases of herbicide resistant weeds have been reported globally, involving 250 plant species (145 dicots and 105 monocots). A most disturbing factor is that weeds have evolved resistance to 23 of the 26 known herbicide sites of action

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and to 160 different herbicides. Herbicide resistant weeds have been reported in 86 crops in 66 countries.

In South Africa, there are nine weed species for which confirmed resistance to one or the other herbicide was recorded over the years, and alarmingly, some of these weeds have developed multiple-resistance, i.e. resistance to more than one herbicide mechanism-of-action (Pieterse, 2010). Nine species locally, when seen in the global context of 250 species, may not seem like much to worry about, but considering these weed types represent some of South Africa's worst weeds that occur in major crops, the magnitude of the problem hits home.

Consider the case of glyphosate-resistant weeds, where globally 34 species have been recorded to date. Of the 34, three also occur in South Africa, namely: hairy fleabane (*Conyza bonariensis*), narrow-leaved ribwort (*Plantago lanceolata*), and the complex of ryegrasses (*Lolium multiflorum, L. perenne, L. multiflorum* × *L. perenne*, *L. rigidum*). Three out of 34 may not appear significant, but mere numbers discount the prominent weed status of the afore-mentioned three species. Moreover, 16 other weeds among the 34 for which glyphosate resistance have been proven in some or other part of the world are well-established weeds in South Africa. In light of the doomsday scenario of 19 out of 34 species evolving glyphosate resistance in a single country, lax approaches to herbicide resistance management is simply unaffordable.

Equally perplexing is that, the world over, there exists little understanding of the "wicked" problem of herbicide resistance. Moreover, there generally is poor implementation of resistance management strategies. A survey conducted in the USA among more than 1,000 maize, cotton, and soya bean growers showed that only 39% "always or often" used herbicides with more than one mechanism-of-action, whilst 28% employed this best practice "seldom or never". Even in a country like Australia where there is tremendous hype plus action on best practices for resistance management, there is disappointingly low uptake of, and low consistency in adherence to, these practices. Similar information for South Africa either does not exist or is not available in the public domain.

Confounding factors in explaining low adoption of resistance management practices are generally accepted to be two-fold, firstly, because gains from managing resistance only accrue in the future there is uncertainty attached to it, and secondly, there are real short-term costs associated with resistance management which represent unwanted increases in already high input costs. Therefore, the conundrum is that it is expected of crop producers to spend money, time and effort on a problem that may not yet exist, or are still evolving and therefore uncertain. Ask anybody doing research or providing advice on herbicide resistance, it is a tough sell to generate hype around a problem that may or may not develop at an unfixed time in the future. However, reality check tells us that herbicide resistance is real, with us already, and day by day creeping steadily ahead.

Strategies and tactics with which to successfully manage resistance are well-documented and well-proven; therefore, why the despondency in certain quarters over an apparently lost battle? Shaw (2016) believes that "doing something different" is key to successful resistance management. There is powerful truth locked up in the simple understanding voiced by Amy Asmus, who isn't a scientist but works in agriculture, at the 20th Annual Conference of the International Consortium on Applied Bioeconomy Research (July 2016, Italy): "My advice for successful resistance management is to regard any herbicide-resistant weed as a brand-new weed". This approach would at least force a rethink on weed management options for combating the resistance problem, and would be tantamount to "out of the box" thinking, which we desperately need for tackling herbicide resistance head-on (Asmus and Schroeder, 2016).

According to Shaw (2016), the rethinking of herbicide resistance management strategies should include greater emphasis on IWM (integrated weed management that incorporates mechanical, biological, and chemical tools), as well as a multi-disciplinary approach that brings together in team context agronomists, weed scientists, economists, sociologists, extension advisors, consultants, and farmers. Surely, this is the new way to go!

RESISTANCE RISK IN NURSERIES

Many herbicides registered for use in nursery environments are associated with weed resistance because the same herbicides often find use in agricultural crop production. Moreover, many weed species are ubiquitous and occur across a wide spectrum of plant production systems. Exactly the same principles and practices for avoidance of herbicide-resistant weeds apply to nurseries and any other plant/crop production system. Combinations of weed/herbicide for which resistance have been recorded globally are posted on the website managed by Dr. Ian Heap, http://www.weedscience.org/

Overuse of any single herbicide product, and therefore, failure to rotate herbicide modes-of-action, is likely to promote the evolvement of resistance in one of more weed species occurring in the area targeted for weed control. In addition to rotating different types of herbicides, avoidance of dependence on any single method of control, whether it be hand-weeding or mowing, is key for ensuring that one or more weed species do not become dominant, especially if such a species has some or other harmful characteristic.

Plants of economic value produced in containers, especially those distributed widely, can be a means for bringing new weeds into an area where they did not occur before. Even more serious a problem would be the inadvertent distribution of weeds that have evolved resistance to an herbicide in the nursery. Nurseries therefore have the heavy responsibility to employ best management practices as far as weed management is concerned.

In most areas in life, including herbicide resistance management, we should take heed of these eternally wise words:

> "Insanity: Doing the same thing over and over again and expecting different results"—credited to Albert Einstein

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