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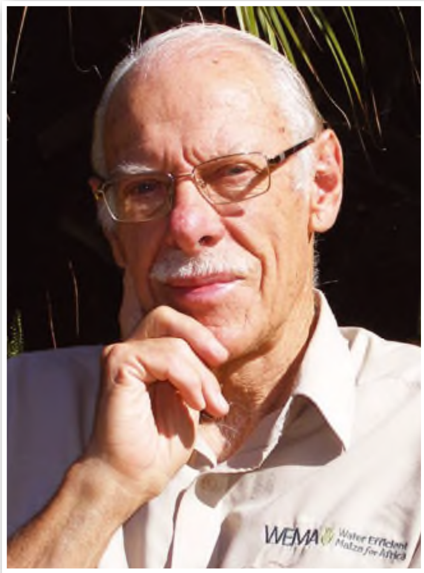
Soya bean: An opportunity to control herbicide resistance in weeds



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Herbicide-tolerant crops have had a major impact on food production. They have reduced the negative impact of weed competition, reduced persistent chemicals in the soil, brought about less mechanical farm operations and have been a driver of conservation agricultural practices to improve soil health.

Impact of GM crop

From 2001 to 2013 the beneficial impact of genetically modified (GM) herbicide-tolerant soya bean in South Africa compared to the conventional crop was US$13 million (R186 million) more farm income, 1,2% less herbicides and 17% less environmental impact measured in environmental impact quotient (EIQ) load (Brookes and Barfoot, 2015).

Yet, continuous application of the same herbicides on the same crops to combat the same weeds will eventually lead to weeds developing tolerance to certain herbicides. Unlike humans and animals, weeds cannot react emotionally to stress, much less walk away from a problem. Nature enables living organisms to maintain ongoing genetic variability through crossbreeding with similar or related species, as well as developing regular mutations, many of which arise by way of miniscule alterations in the genetic code. These variabilities also provide opportunities for tolerance to herbicides.

Scientists, having developed valuable herbicides, have now brought us food crop varieties with tolerance to herbicides so that spraying will only target and eradicate the weeds. The global biotechnology trend is to stack genetic traits, also for crop tolerance to herbicides. This facilitates extending weed control, rotating herbicides and crops, and tank pre-mixing of several herbicides.

A soya bean field in the Bapsfontein district which is almost ready for harvest, and not a single weed thanks to glyphosate herbicide application. (Photograph: Dr Wynand van der Walt)

Stacked herbicide-tolerant traits

This article endeavours to cover stacked traits, relevant herbicides' mode or mechanism of action and types of genetic tolerance to herbicides in soya beans. Here, mode refers to plant symptoms after application. Mechanism signifies the actual biochemical site of herbicide action. The onus remains with producers to obtain technical information and guidance from technology developers and suppliers.

Certain stacked herbicide-tolerant traits are approved internationally for soya beans. Herbicide stacks: Tolerance to gluphosinate + glyphosate + 2,4-dichlorophenoxyacetic acid (2,4-D) in one variety, gluphosinate + 2,4-D, glyphosate + isoxaflutole (IFT), glyphosate + sulphonurea, glyphosate + dicamba and gluphosinate + mesotrione.

Herbicide plus other traits: Glyphosate + sulphonurea + modified oils (just approved in Argentina), gluphosinate + *Bacillus thuringiensis (Bt)* insect resistance, sulphonurea + modified oils, glyphosate + modified oils, glyphosate + enhanced photosynthesis and glyphosate + omega-3 stearidonic acid.

A close-up shot of ripe soya bean in the Delmas district. (Photograph: Dr Wynand van der Walt)

Modes of action

Modes or mechanisms of action of relevant herbicides and GM soya beans' tolerance to certain herbicides are described below. Developing genetic tolerance to herbicides requires different approaches, as herbicide modes of action differ and as soya bean technology developers may employ different genetic routes to obtain the same result. Tolerance to specific herbicides is achieved by inserting into soya bean varieties a novel gene or genes that reduce the herbicidal binding affinity to sites where it is active, or disarming the herbicide's function, or impairing or eliminating herbicidal functions.

2,4-D: This well-known herbicide acts on the plant's growth by mimicking the function of auxins, which are natural plant growth-regulating hormones. The synthetic chemical is absorbed mostly in foliage, little of which is translocated to roots, and results in abnormal above-ground growth. GM soya bean tolerance to 2,4-D: The AAD-12 protein produced by the AAD-12 gene catalyses part of the 2,4-D chain, rendering it ineffective.

Dicamba: This widely used chemical is rapidly absorbed into roots and then translocated to shoot tissue with resultant distortion of leaves, in a similar mode to the 2,4-D effect. GM soya bean tolerance to dicamba: Comparable to 2,4-D tolerance.

Isoxaflutole: It is a synthetic chemical for pre-emergence, soil-applied herbicide. It becomes systemic in roots and leaves to which it is translocated. The chemical affects plant membranes, halting cell division and impairing plant growth. GM soya bean tolerance to isoxaflutole: The hppdPf gene reduces the specificity of the herbicide's bioactive constituent.

Gluphosinate-ammonium: This is another well-known chemical used globally. It affects only the parts of the plant on which it is applied and is effective against a range of annual and perennial weed species. It is a structural analogue of glutamate with the ability to inhibit glutamine synthesis to the detriment of plant growth. GM soya bean tolerance to gluphosinate: Herbicidal activity is eliminated by the N-acetyl transferase enzyme of the bar gene.

Glyphosate: The active ingredient is a glycine (the smallest amino acid) derivative that binds to and blocks 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), which leads to deficiencies in key amino acids that are the building blocks of proteins, thereby starving the plant. GM soya bean tolerance to glyphosate: The CP4 ESPS gene decreases the binding affinity of glyphosate to its action site. Tolerance can also be achieved by way of a double mutant enzyme.

Mesotrione: This active ingredient in the herbicide is part of a class of triketones. Its action is to inhibit synthesis of amino acids and carotenoids. (Beta-carotene is the precursor of Vitamin A.) Mesotrione will eradicate weeds that are tolerant to sulphonurea, acetolactate synthase (ALS) herbicides and triazines. GM soya bean tolerance to mesotrione: An avhppd-03 gene transferred from oats provides tolerance in soya bean to mesotrione by way of p-hydroxyphenylpyruvate.

Sulphonurea: This member of the ALS group was discovered in 1975 and has been sold since 1981. Its herbicidal chemical properties are variable, dependent upon the target weed species. It acts by inhibiting ALS enzymes that control the synthesis of major amino acids. GM soya bean tolerance to sulphonurea: A modified ALS enzyme from a modified csr1-2 gene confers tolerance to the imidazolinone herbicide group which includes sulphonurea.

The above information does not contain reference to technology owners or trade names. Stacked traits may contain genes from different technology owners and some similar stacks may have been developed independently by different companies. Minor genetic alterations may yield the same traits, but with improved efficacy.

Some of the mode and mechanism of action information has been sourced from extension services of the Oklahoma State University, Purdue University, Florida State University and the Weed Science Society of America, with genetic mechanism data obtained from the International Service for the Acquisition of Agri-biotech Applications (ISAAA) database.