How ammonium sulphate enhances weed control efficacy of herbicides

By Dr Charlie Reinhardt

Weed control with herbicides is generally accepted to be a rapid, relatively cheap and highly effective way of preventing unacceptable crop yield losses caused by weed interference. However, variable success with the use of herbicides is often encountered because of the unpredictability of climatic factors, the natural herbicide tolerance of certain weeds, and herbicide-resistant weeds.

In response, the agrochemical industry is constantly striving to find ways to increase the efficacy (effectiveness) of herbicides by, among others, reducing the variability (or lack of predictability) in herbicide product performance.

Not only is there the constant quest for novel chemistry in the form of new herbicide modes-of-action but also for the development of companion, non-herbicidal chemical compounds (adjuvants) that act as enhancers of herbicide biological activity; in other words, adjuvants can boost herbicidal effects on weeds, thus improving reliability of herbicide performance.

Leaf surfaces are typically not compatible with water, and the latter carries herbicide molecules to the plant in spray droplets. Thereafter, molecules must overcome several obstacles to penetrate into leaves, from where they are translocated to those plant parts where the site-of-action is located.

(Photograph by Dr Charlie Reinhardt)

Development of adjuvants

Given the slow-down (ongoing for longer than 20 years) in unique herbicides reaching the market, any extra tool for making chemical weed control more effective is of critical importance – development of adjuvants for herbicides is a case in point.

Simultaneous with the lag in novel herbicide modes-of-action reaching the market, herbicide resistance has escalated and presents huge challenges for effective weed control that must rely on the current 'old' range of modes-of-action. The herbicide market in the foreseeable future is, arguably, likely to benefit more from the entry of novel chemistry in the form of adjuvants than is the case for herbicides.

Enhanced herbicide activity with the aid of adjuvants is largely dependent on increased contact and compatibility of spray (water) droplets with the target organism (weed plants), and increased uptake of herbicides by weeds.

The use of ammonium sulphate as an adjuvant in herbicide application is common practice, because of its well-proven ability to improve herbicide efficacy or biological activity. In the broadest context the term 'adjuvant' refers to all those compounds added to spray mixtures with the intention to improve the biological activity (efficacy) of pesticides.

Neutralising water-borne cations

Research has revealed that ammonium sulphate (AMS) has an important function in the neutralisation or inactivation of cations such as Ca^{2+}, Mg^{2+}, Na^{+}, etc., which are known to reduce glyphosate activity when the cation and herbicide molecule reacts chemically to produce biologically inactive molecules, for example Ca-glyphosate or Mg-glyphosate.

Calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations typically occur in high concentration in so-called 'hard' water, which when used as carrier for spraying glyphosate can reduce the effectiveness of this herbicide and others that are susceptible to chemical reactions with cations.

The sulphate (SO_4^-) component of ammonium sulphate (NH_4SO_4) reacts with cations such as Ca^{2+} and Mg^{2+} present in water used as herbicide carrier in sprays to form inert (inactive) $CaSO_4$ (calcium sulphate) and $MgSO_4$ (magnesium sulphate), which does not interfere with herbicide activity.

Because cations such as Ca^{2+} and Mg^{2+} usually occur in variable concentration in all water sources, it is sound practice to use ammonium sulphate as adjuvant irrespective of the cation types and concentration of water used as herbicide carrier in spray mixtures. The ammonium cation (NH_4^+) is not competitive with glyphosate and many scientific studies report its role in enhancing glyphosate efficacy.

Enhancing herbicide entry

Plant-uptake and transfer of herbicides to the target site (e.g. a susceptible enzyme) within the plant system, where it exerts herbicidal (plant-killing or phytotoxic) activity, is a complex process and consists of several stages (*Figure 1*).

Herbicide mode-of-action comprises several processes, and all are equally important in determining effective weed control – ultimately, it is the critical (threshold) amount of herbicide that reaches the site-of-action which determines whether weeds are controlled effectively, i.e. killed, or not.

The biological activity of every herbicide is affected and can be manipulated in product formulation for the optimisation of herbicide action. Besides herbicide product formulation, adjuvants are instrumental for the optimisation of herbicide delivery, uptake by plants, and transfer in the plant system.

Most studies on the role of AMS in herbicide efficacy confirm its beneficial effect on the improvement of weed control. However, differences in AMS effect have been reported among glyphosate formulations and weed species.

In South Africa, Dr Brian de Villiers of Villa Crop Protection has conducted significant research on the effects of formulation and adjuvants on glyphosate activity. In the case of glyphosate, AMS not only protects the integrity of this herbicide in the spray tank but also increases its uptake and translocation to its site-of-action (the EPSPS enzyme in the case of glyphosate).

Increase droplet drying time

AMS is a member of the group of adjuvants that increase spray droplet drying time on leaf surfaces. A substance that increases the drying time of a spray droplet is called a humectant. Humectants are typically water-soluble compounds that resist drying even after the water component of droplets has evaporated. Increased drying time is achieved by the humectant drawing water from the atmosphere.

Because uptake into leaves can occur only when the herbicide is in solution, slowing the rate at which droplets dry will allow more time for uptake (absorption). Theoretically, a humectant should improve herbicide performance under hot, dry conditions. However, herbicide performance rarely increases with the addition of a spray adjuvant if weeds are under severe moisture stress.

The ammonium (NH_4^+) ion reportedly enhances the movement or transfer of certain herbicides from one cell to another in plant tissue. The transfer mechanism involves pH changes and pH differences in different parts of cells, and pH-regulated electric charge that is induced on herbicide molecules.

Gronwald *et al*. (1993) demonstrated that ammonium is taken up (absorbed) by leaves and induces acidification of cell walls (lowered to a pH of approximately 4,5 to 5), while the cytoplasm is at pH 7. They found that imazethapyr herbicide molecules are negatively charged at pH 7 in the cytoplasm and that they undergo protonation in the cell wall, which is relatively acidic at about pH 5.

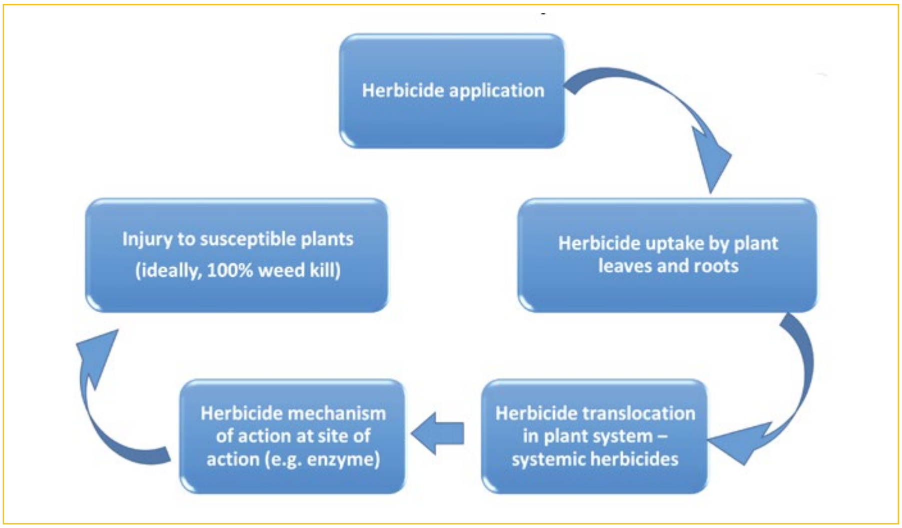
Neutral molecule

During protonation, protons (H^+) are attracted to the negative charge on the imazethapyr molecule, thus rendering the molecule neutral (carries no electric charge). It is only in this state (neutral) that the imazethapyr molecules can move through the plasmalemma (cell membrane), which acts like a filter to prevent movement of foreign substances through the plant system.

Once in the cytoplasm (pH 7) neutral imazethapyr molecules lose protons (H^+) and negative charge is restored. This process is repeated from cell to cell; hence, molecules of a systemic, weak-acid herbicide such as imazethapyr can move between plant cells on their way to the site-of-action which, in this case, is the enzyme acetolactate synthase (ALS).

The same mechanism is probably also involved in the transfer of other systemic, weak-acid herbicides such as glyphosate. It is generally accepted that AMS can increase weed control efficacy of both imazethapyr and glyphosate.

Figure 1: The processes of herbicide mode-of-action.



Cautionary note: Only AMS products that are registered for use with herbicides must be considered and not fertiliser grade AMS, because impurities in the latter could antagonise herbicide activity.

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