IOWA SOYBEAN ASSOCIATION RESEARCH UPDATE

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Herbicides:

Beginning with the Green Revolution, many agricultural advances during the past 80 years, including crop hybridization and other developments in classical and molecular breeding, synthetic fertilizers, improved equipment and precision agriculture, biotechnology, and pesticides for the control of yield-robbing insects, diseases and weeds have increased our ability to feed, clothe and fuel a constantly growing world population. Specific to weed control, the convergence of chemistry and biology facilitated the development of herbicides with different mechanisms of action to non-selectively and selectively kill weedy plant species that otherwise rob crop plants of water, nutrients and solar radiation, as well as contaminate crop harvests with seeds that negatively impact quality and value. Modern chemical herbicides really got their start in the 1930's and 1940's with the introduction of 2,4-D (2,4-Dichlorophenoxyacetic acid), a synthetic auxin hormone-like plant growth regulator that kills most broadleaf weeds by causing uncontrolled growth (growing point and vascular tissue cell division, protein production and ethylene production). Following the success of 2,4-D and through the application of plant physiology and biochemistry, many herbicides with unique and effective mechanisms of action have been developed and commercialized.

Herbicide Classification and Function:

Herbicides are classified by their site of action (SOA) or mechanism of action (MOA). There are approximately 25 different mechanisms of action for commercial herbicides and often several different active ingredients, formulations and trade names for herbicides in each mechanism of action group. Several sources of information and tables listing mechanisms of action, chemistries, active ingredients, trade names, target plants and resistant weeds exist. One excellent reference is the "*Take Action: Pesticide-Resistance Management*" website developed by the United Soybean Board (www.iwilltakeaction.com).

It is important to use herbicides with multiple mechanisms of action in order to control weeds and delay the development of herbicide resistant weed populations. Knowing a little bit about the biochemistry and physiology of herbicides and plants will help with management decisions about what, when, how and where to use (and not use) various herbicides.

Herbicides work at the cellular level so they need to be taken up through roots, leaves and/or stems and moved into cells throughout the plant. This means that, in addition to the active ingredients, herbicide formulations commonly include surfactants and other chemicals to facilitate and enhance uptake and movement in the plant.

Herbicide mechanisms of action include the inhibition or disruption of seed germination, seedling growth and development, amino acid/protein, nucleic acid or lipid/fatty acid synthesis, cell division, cell elongation or growth, nutrient, water or chemical transport, photosynthesis, nitrogen metabolism or pigment production (Figure 1).

Some herbicides can be applied to the soil (pre-emergent) because they prevent weed seed germination and/or early growth and development. Others must be applied to the leaves and stems of young plants after they have emerged from the ground (post-emergent). Most herbicides are systemic, having the ability to move throughout the plant, while some are contact herbicides and only kill the parts of plants where they are applied. Because grasses and broadleaf plants have differences in their physiology and biochemistry, some herbicides may kill one type of plant and not another. These differences enable the development and use of selective vs. non-selective herbicides. Furthermore, by creating stable crop mutants or by using biotechnology to express specific proteins, many crop plants have been rendered tolerant to certain herbicides, allowing selective or non-selective herbicides to be applied to the soil or applied over the top of these crop plants in order to kill the weeds while not harming the crops. Finally, there are herbicides that are termed organic (e.g. vinegar or corn gluten meal) and non-organic (most corn and soybean herbicides).

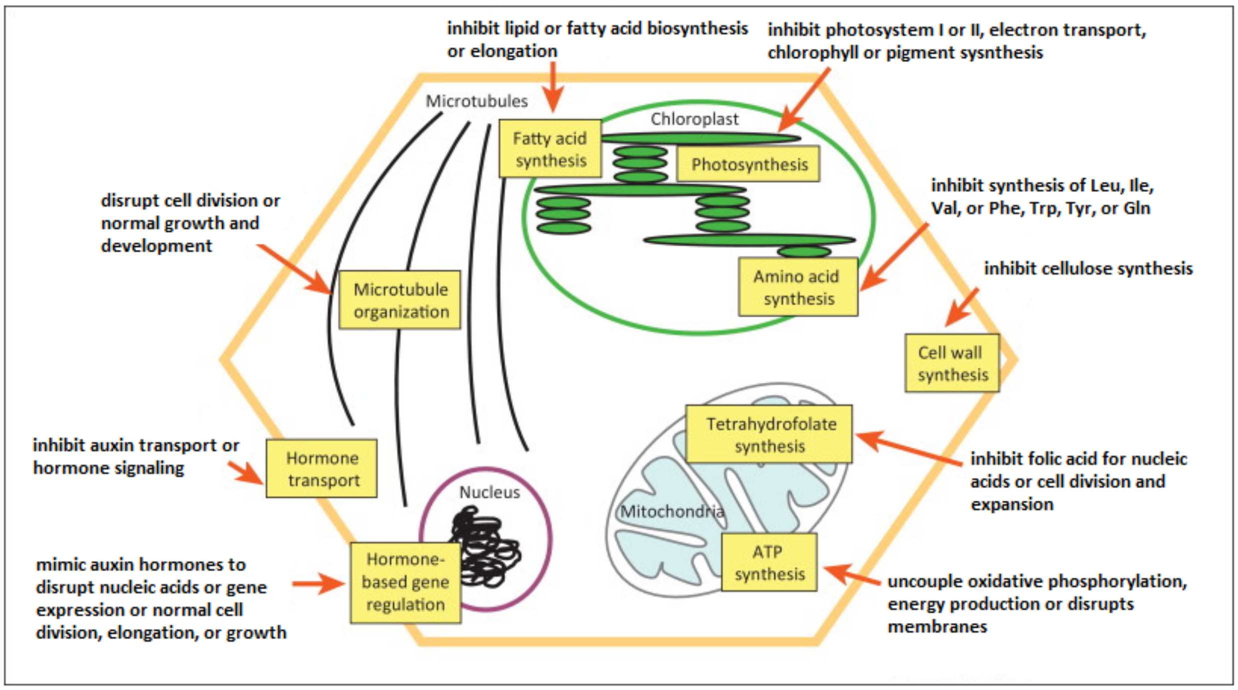

Figure 1: Simple illustration of the key modes of action for most of the herbicide MOA groups. While more than one group of herbicides may affect each of these targets, they may inhibit or disrupt different components of these systems. While not obvious in the illustration, lipids and fatty acids are necessary for cell membranes, photosynthesis components are essential for fixing carbon dioxide into sugars and other carbon-containing compounds, Leu, Ile, Val, Phe, Trp, Tyr and Gln represent amino acids that are essential protein building blocks. *Adapted from Delye et al. Trends in Genetics 29(11):649-658 (2013).*

Herbicide Advantages:

Herbicides have enabled farmers to produce higher yielding and higher quality crops more cost-effectively and more simply. Some of the advantages of herbicides include: reduced tillage for less soil loss, better soil health and more efficient water and nutrient management, earlier planting dates, better-growing and higher-yielding crops due to less competition for water, nutrients and sunlight, reduced labor and costs for manual and mechanized weed removal, more sustainable crop production via reduced greenhouse gas emissions, fewer passes over the field, lower fuel use, and reduced equipment costs.

Herbicide Risks and Watch-Outs:
Like any technology or practice, the use of herbicides requires clear understanding of the cropping system and weed pressures, combined with some detailed knowledge of available chemistries and function. Some risks associated with herbicides include selection of the wrong herbicide for the target weed and crop system, over-use of the same mechanisms of action that result in the selection and build-up of herbicide-resistant weed populations, inappropriate preparation and mixing that may result in too little or too much application of the active ingredients or combinations of chemistries that do not work well together, application of herbicides at the wrong times or in the wrong places which can include incorrect crop or weed growth stages, inappropriate soil types or soil conditions, poor current or forecasted weather or wind conditions, inadequate distance from off-target plants, insects, animals, humans or water sources, all resulting in unintended damage, death or environmental pollution.

The Dicamba and 2,4-D Example, What's Old Is New:
Over-use and long-term use of any herbicide results in the selection of herbicide-resistant weeds in a population. In the most recent and wide-spread example, glyphosate herbicide has been effectively used almost ubiquitously for non-selective weed control in non-biotech and biotech-derived glyphosate-tolerant crop systems for approximately 20 years. In part due to the success and ease of the glyphosate and glyphosate-tolerant crop system, essentially no new herbicide mechanisms of action have been developed for many years. Over the past several years, a number of glyphosate-resistant weed populations have emerged, causing significant problems where only glyphosate and glyphosate-tolerant crops are used. Recently, a few seed and chemical herbicide technology companies have produced biotech crops with tolerance to new and improved formulations of old auxin hormone-like herbicides 2,4-D and dicamba. Furthermore, the crops engendered with auxin-like herbicide resistance have genetic stacks containing one or more of glyphosate-tolerance and glufosinate-tolerance. Advantages of these new biotech crops and weed management solutions include: better weed control in situations where multiple herbicides are needed to control resistance weeds, continued ease of use in an over-the-top herbicide application system, and reintroduction of more integrated weed management strategies with multiple mechanisms of action. There are risks and potential pitfalls of this new technology as well. The auxin-like herbicides, especially dicamba, tend to drift and volatilize under certain wind and temperature conditions. Because these herbicides tend to cause symptoms and damage at very low doses, drift and volatilization may lead to off-target impacts and require farmers and herbicide applicators to be very careful when using these herbicides.

In Summary:
Herbicides can be used as safe and efficacious components of crop production systems. When deciding to integrate herbicides into a cropping system, the farmer should consider many things related to their agronomic and cultural practices, weed pressures, crops, surrounding plant species and ag and urban settings, soil types, environmental conditions, the available herbicide mechanisms of action, the herbicide formulations and their compatibility with other chemicals, application timing, the equipment that must be used and the potential for the herbicide to provide maximum control of target weedy plants and minimum risk to off-target plants, animals and humans. As described in the Iowa Pest

Resistant Management Program (www.ipm.iastate.edu/about-the-iprmp), the sustained efficacious and economic use of herbicides is dependent on an integrated approach that includes cultural and agronomic practices, genetics, biotechnology, and a diverse tool set of chemical herbicides, especially different mechanisms of action and those that can be applied pre- and post-emergence. Finally, farmers and herbicide applicators should always be in communication with their neighbors in order to consider and mitigate the risks of off-target exposure.

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