Corn Herbicide Mode of Action

What is Herbicide Mode of Action?

Mode of action (MOA) describes the biological process (e.g., photosynthesis) or enzyme (e.g., ALS, or acetolactate synthase) by which an herbicide controls a susceptible plant (weeds). Other examples of MOA might be a description of the injury seen on a susceptible plant. Currently, there are eight modes of action for the commonly used herbicides in field corn production. Within a specific MOA, there may be more than one chemical family, and these can vary slightly in their chemical composition. However, control of susceptible weeds is by the same process, and symptomology may also be similar.[1,2,3]

Understanding Mode of Action vs Site of Action for an Herbicide

Mode of Action and Site of Action (SOA) are often used interchangeably; however, there are differences. As described earlier, **MOA** describes a process or enzyme by which an herbicide works, while **SOA** refers to the specific biochemical or biophysical process in the plant that the herbicide disrupts to interfere with plant growth.[3]

The MOA for an herbicide can be found on the product's label. Often herbicides are described as belonging to a numbered group, which refers to a specific MOA. Table 1 is a summary of the herbicide MOA, SOA, and the numbered classification of common corn herbicides.

*Table 1. Summary of Mode and Site of Action and Classification Group for Common Corn Herbicides.**

Mode of Action	Group	Site of Action
Amino Acid Synthesis Inhibitors	2	ALS Inhibitors (acetolactate synthase)
	9	EPSP Synthase Inhibitor (5-enolpyruvyl-shikimate-3-phosphate)
Growth Regulators (Synthetic Auxins)	4	Various sites
	19	Auxin transport
Photosynthesis Inhibitors	5	Photosystem II Inhibitors
Nitrogen Metabolism	10	Glutamine Synthesis Inhibitor
Pigment Inhibitors	27	HPPD Inhibitors (hydroxyphenylpyruvate dioxygenase)
Cell Membrane Disrupters	14	PPO Inhibitors (protoporphyrinogen oxidase)
Seedling Root Growth Inhibitors	3	Microtubule Assembly Inhibitors
Seedling Shoot Growth Inhibitors	15	Very Long-chain Fatty Acid Inhibitors

*Adapted from Herbicide Mode of Action, Kansas State Research and Extension. Publication C715.

Importance of Multiple Modes of Action in Managing Herbicide Resistance

Knowing and understanding each herbicide's MOA is an important first step in proper herbicide selection, diagnosing injury symptoms, and developing a successful weed management system. Relying on a single herbicide MOA, especially over consecutive years, can place heavy selection pressure on weed populations and can potentially result in reduced herbicide efficacy or resistance. Eventually, individual weeds that are resistant can reproduce and may become the dominate weed species in that field. Rotating MOA herbicides is one strategy that can help prevent or delay the development of weed resistance. Another strategy is to use herbicide products, or a combination of products, with different and overlapping modes of action. One example of a pre-mix herbicide product containing three different modes of action is TriVolt™ herbicide. It contains products from herbicide groups 2, 15, and 27. Overlapping modes of action is the use of two or more products that can control certain weed species; however, they do it through different processes.[1,2]

Corn Herbicide Mode of Action

Mode of Action Details, by Group, for Herbicides Commonly Used in Field Corn

MOA: Amino Acid Synthesis Inhibitors (Groups 2 and 9)

Acetolactate synthase inhibitors comprise a large class of herbicides. There are five chemical families within this group, with three of them having products labeled for field corn (Table 2). They control a broad spectrum of weeds, may be soil-applied or post-emergent, and typically have residual soil activity. By inhibiting the ALS enzyme, the plant cannot synthesize certain amino acids which are the building blocks of proteins and are required for plant metabolism to function properly. Absorption is through the roots and leaves. It can be translocated in both the xylem and phloem to the SOA at the growing point.[3,4]

Glyphosate is the only active ingredient in Group 9 (Table 3). It is readily absorbed by the leaves and translocated via the phloem to the growing point. Glyphosate inhibits the EPSPS (5-enolpyruvylshikimate-3-phosphate synthase) enzyme which is used in the synthesis of three amino acids that are required by the plant for cell wall production. It is a non-selective herbicide with extremely limited soil activity.[3]

Table 2. Group 2, ALS (acetolactate synthase) Inhibitors. (53 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Sulfonylaminocarbonyltriazolinone	thiencarbazone
Sulfonylurea	nicosulfuron, primisulfuron, rimsulfuron
Triazolopyrimidine	flumetsulam

Table 3. Group 9, EPSP Synthase Inhibitor. (17 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Organophosphorus	glyphosate

MOA: Growth Regulators (Groups 4 and 19)

Synthetic auxins are used primarily for broadleaf weed control. There are five chemical families in Group 4 with three having products labeled for field corn (Table 4). They are absorbed through the leaves and roots and can be translocated through both the xylem and phloem. They are called growth regulators because they mimic the natural plant growth hormone auxin, which upsets the normal hormone balance within the susceptible plant.[3,4] Applications can be made pre-plant, pre-emergent, or post-emergent.

Group 19, auxin transport inhibitor, is comprised of one chemical family that disrupts the movement of auxin out of the plant cell at the growing point. When combined with a synthetic auxin such as dicamba, the herbicide can move into the cell but cannot move back out. Diflufenzopyr alone has very little herbicidal activity but enhances auxin containing herbicides when used in combination.[3,4]

Table 4. Group 4, Synthetic Auxins. (10 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Benzoic acid	dicamba
Carboxylic acid	clopyralid
Phenoxy	2,4-D

Table 5. Group 19, Auxin Transport Inhibitor

Chemical Family	Active Ingredient
Semicarbazone	diflufenzopyr

Corn Herbicide Mode of Action

MOA: Photosynthetic Inhibitors (Group 5)

Group 5 consists of five chemical families with one, the triazine family, labeled for use in field corn (Table 6). Triazines are used to control broadleaf and some grass species. Typical application is soil-applied or early post-emergence and can be absorbed by roots or shoots. These herbicides inhibit photosynthesis by binding to a key protein within the plant cell structure which negatively affects processes and products necessary for the transport of chemical energy.[4] Plants must be exposed to sunlight for this process to occur.

Table 6. Group 5, Photosynthetic Inhibitors (28 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Triazine	atrazine, simazine

MOA: Nitrogen Metabolism Inhibitors (Group 10)

Group 10 has one chemical family with the active ingredient glufosinate that has broad spectrum weed control and no soil residual activity (Table 7). It inhibits the activity of the glutamine synthetase enzyme which the plant needs to convert ammonia to other nitrogen compounds. The result is an accumulation of ammonia, which along with decreased glutamine levels destroys plant cells and directly inhibits photosynthetic reactions.[3,4]

Table 7. Group 10, Glutamine Synthetase Inhibitors (3 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Phosphorylated amino acid	glufosinate

MOA: Pigment Inhibitors (Group 27)

Group 27 herbicides inhibit chlorophyll production in the leaves by inhibiting the production of the enzyme 4-hydroxyphenylpyruvate dioxygenase (HPPD). Foliage on susceptible plants turns white, becomes bleached, and eventually die due to a buildup of certain molecules that destroy cell membranes. Three of the four chemical families within group 27 have active ingredients that are labeled for use in field corn (Table 8).[3,4]

Table 8. Group 27, HPPD Inhibitors (5 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Isoxazole	isoxaflutole
Triketone	mesotrione, tembotrione, bicyclopyrone
Pyrazolone	tolpyralate, topramezone

MOA: Cell Membrane Disrupters (Group 14)

Group 14 herbicides inhibit the enzyme protoporphyrinogen oxidase (PPO), which is needed for chlorophyll synthesis. The group consists of three chemical families of which two are labeled for corn (Table 9). PPO inhibitor herbicides quickly form highly reactive compounds in the plants that rupture cell membranes and cause fluid to leak out. They provide selective control of broadleaf weed species. Thorough spray coverage is important for good weed control. These products do not translocate to the roots, so they lack long term control of perennial weed species.[3,4]

Table 9. Group 14, PPO Inhibitors (5 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Triazolinone	carfentrazone
N-Phenylphthalimide	flumiclorac, flumioxazin, saflufenacil

Corn Herbicide Mode of Action

MOA: Seedling Shoot Growth Inhibitors (Group 15)

VLCFA herbicides affect susceptible weeds before emergence but do not inhibit germination or control emerged weeds. The usual application timing is pre-emergence. The primary site of absorption for broadleaf and grass species are the roots and shoots, respectively. Enzymes needed for seedling growth are targeted by these compounds. They are not readily translocated within the plant.[3,4] There are five chemical families in the group with two having labels for corn (Table 10).

Table 10. Group 15, Very Long Chain Fatty Acid Inhibitors (VLCFA) (8 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
α-Chloroacetamide	S-metolachlor, acetochlor, dimethenamid-P
Oxyacetamide	flufenacet

MOA: Seedling Root Growth Inhibitors (Group 3)

Group 3 herbicides consist of three chemical families of which one, the dinitroaniline (DNA) family is labeled for corn (Table 11). Dinitroaniline herbicides are usually applied pre-emergence to control annual grass and some broadleaf weeds. Absorption is through roots and shoots of emerging weed seedlings with germinating shoots being the primary site. Translocation is limited. These herbicides inhibit cell division in meristematic regions such as the growing points of stems and roots. Dinitroaniline herbicides are volatile and require incorporation through light tillage or irrigation.[3,4]

Table 11. Group 3, Microtubule Assembly Inhibitors (6 known resistant weed species in the United States)[4]

Chemical Family	Active Ingredient
Dinitroaniline	pendimethalin, trifluralin

Sources:

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