Herbicide Sites of Action

Herbicides kill plants by binding to a specific protein and inhibiting that protein's function. This protein is referred to as the herbicides site of action. Utilizing herbicide programs that include several different sites of action is a key step in managing herbicide resistant weeds.

A numbering system has been developed that makes it easier to evaluate herbicide program in terms of site of action diversity. Each herbicide site of action is assigned a Group Number (Table 1), and this Group Number is found on the first page of most herbicide labels. Simply including multiple sites of action is not sufficient in fighting herbicide resistance, but rather the different sites of action must be effective against problem weeds (e.g. waterhemp and giant ragweed).

Table 1. Herbicide classification by Group Number and site of action of products commonly used in corn and soybean. Description of the mode of action and herbicide characteristics provided in Table 3.

Group No.	Site of Action	Mode of Action		Group No.	Site of Action	Site of Action (mode of action)
1	ACC-ase	Lipid synthesis		10	GS	Photosynthesis via nitrogen assimilation
2	ALS	Amino acid synthesis		13	DPX	Photosynthesis via carotene synthesis
3	Tubulin	Cell division		14	PPO	Photosynthesis via chlorophyll synthesis
4	Auxin binding site	Synthetic auxin		15	Unknown	Very long chain fatty acid synthesis
5	D1 protein	Photosynthesis via PS II inhibition		19	Unknown	Auxin transport
6 and 7	D1 protein	Photosynthesis via PS II inhibition		22	Unknown	Photosynthesis via PS I inhibition
9	EPSPS	Shikimic acid pathway inhibition		27	HPPD	Photosynthesis via carotene synthesis

Table 2. Active ingredients and Group Numbers of single ingredient products.

Tradename	Group No.	Active Ingredient		Tradename	Group No.	Active Ingredient
2,4-D	4	2,4-D		Lorox	7	linuron
Accent	2	nicosulfuron		Option	2	foramsulfuron
Aim	14	carfentrazone		Outlook	15	dimethenamid
Assure II	1	quizalofop		Peak	2	prosulfuron
atrazine	5	atrazine		Permit	2	halosulfuron
Autumn	2	iodosulfuron		Poast	1	sethoxydim
Balance Flexx	27	isoxaflutole		Prowl	3	pendimethalin
Banvel/Clarity	4	dicamba		Pursuit	2	imazethapyr
Basagran	6	bentazon		Python	2	flumetsulam
Beacon	2	primisulfuron		Raptor	2	imazamox
Buctril	6	bromoxynil		Resolve	2	rimsulfuron
Cadet	14	fluthiacet-ethyl		Resource	14	flumiclorac
Callisto	27	mesotrione		Roundup	9	glyphosate
Classic	2	chorimuron		Scepter	2	imazaquin
Cobra	14	lactofen		Select	1	clethodim
Command	13	clomazone		Sencor	5	metribuzin
Dual	15	metolachlor		Sharpen	14	saflufenacil
Express	2	tribenuron		Sonalan	3	ethalfluralin
FirstRate	2	cloransulam		Spartan/Authority	14	sulfentrazone
FlexStar/Reflex	14	fomasafen		Stinger	4	clopyralid
Fusilade DX	1	fluazifop		Treflan	3	trifluralin
Gramoxone	22	paraquat		UltraBlazer	14	acifluorfen
Harmony	2	thifensulfuron		Valor	14	flumioxazin
Harness/Surpass	15	acetochlor		Warrant	15	acetochlor
Impact/Armezon	27	topramezone		Zidua	15	pyroxasulfone
IntRRo	15	alachlor		*Only sold in premix*	2	thiencarbazone
Laudis	27	tembotrione		*Only sold in premix*	19	diflufenzopyr
Liberty/Ignite	10	glufosinate		*Only sold in premix*	1	fenoxaprop

Table 3. Description of major Herbicide Groups used in Iowa corn and soybean production.

Group	Description
1	The ACCase inhibitors are systemic and disrupt synthesis of lipids, a key component of membranes. At lethal doses, growing points of grasses rot within the whorl. At sub-lethal doses bands of chlorotic, distorted tissue appear on leaves. Large margin of safety occurs with non-grasses due to an insensitive ACC-ase enzyme. These herbicides have little soil activity due to rapid degradation by soil microorganisms. Isolated infestations of Group 1 giant foxtail are found in Iowa.
2	The ALS inhibitors are systemic and disrupt synthesis of branched chain amino acids. Symptoms are variable depending on plant species, dose, and growth stage. Foliar symptoms develop on leaves that emerge following application, and include chlorosis and discoloration of veins on soybean. Corn may develop bands of chlorotic tissue on leaves. Shortening of internodes and inhibition of root growth are additional symptoms. Numerous herbicides are in this class with a wide range of uses; products vary in soil and foliar activity. Group 2 resistance is found in waterhemp, giant ragweed, horseweed and other species in Iowa.
3	The dintroaniline herbicides inhibit root development, resulting in swollen root tips. Soybean may develop swollen hypocotyls, especially with cool, wet soils. The herbicides are used for preemergence control of grasses and small seeded broadleaves. There is little translocation of these herbicides in plants. The DNA herbicides require more rainfall for consistent activity than other preemergence herbicides due to high adsorption to soil colloids and low water solubility.
4	The synthetic auxins (growth regulators) mimic the action of auxin (IAA). A wide range of growth processes are disrupted when sensitive plants are exposed to these herbicides. The most common symptoms are twisting of stems and leaf petioles, and distorted veination of leaves resulting in cupped or elongated leaves. Symptoms on corn include buggy whipping, leaning, brittle stems and malformed brace roots.
5-7	Photosystem II inhibitors interfere with electron transfer, resulting in formation of reactive compounds that disrupt cellular integrity. The different groups bind to different areas of the target site (D1 protein. Symptoms include foliar chlorosis and necrosis. Herbicides vary in soil activity and mobility. Symptoms from soil absorption appear on older leaves, whereas foliar applications result in injury on foliage contacted by the spray. Triazine (HG 5) resistant waterhemp, pigweed, lambsquarter and other weeds are found in Iowa.
9	Glyphosate inhibits an enzyme (EPSPS) involved in the shikimic acid pathway; products of this pathway include amino acids, carotene pigments, phytoalexins and many other compounds. Glyphosate's high level of activity is due to: a) high affinity for target size, b) highly mobile in plant, and c) plants inability to metabolize glyphosate. Symptoms are highly variable depending upon dose, sensitivity of plant and growth stage, but initially appear on new growth. The most common symptom is chlorosis of new growth, but at sublethal doses there can be bleaching and distorted growth. Glyphosate binds tightly to soil colloids, resulting in little soil activity. Glyphosate resistant waterhemp, horseweed (marestail) and giant ragweed is found in Iowa.
10	Glufosinate inhibits glutamine synthetase, an enzyme that incorporates ammonia absorbed by roots into organic compounds. Plant death is due to disruption of photosynthesis caused by the accumulation of ammonia. Symptoms include foliar chlorosis and necrosis due to formation of reactive compounds that disrupt cellular integrity. There is little translocation of glufosinate in plants, and it has no soil activity due to rapid degradation.
14	Group 14 herbicides inhibit PPO, an enzyme involved in the synthesis of chlorophyll. Plant injury and death is due to formation of reactive compounds that disrupt cellular integrity. Foliar applications result in rapid chlorosis and necrosis of foliage of sensitive plants. Since there is little translocation of these herbicides, complete coverage of target plants is required. Tolerant crops often suffer initial burning of contacted tissue, but normally recover quickly. Injury from preemergence applications of flumioxazin or sulfentrazone on soybean may occur if heavy rain occurs when soybean are at cracking stage, resulting in exposure of plumule to high concentrations of herbicide. Group 14 resistant waterhemp is found in Iowa.
15	This group includes chemicals from several different chemical families, but they are often referred to as amides or acetamides. They inhibit enzymes that produce very long chain fatty acids. The exact cause of death is unknown, but the herbicides are used for preemergence control of grasses and small-seeded broadleaves. Symptoms on corn include leafing out underground and improper unfurling of leaves. Use on soybean may result in malformed, heart-shaped leaflets.
19	Status is a package mix of dicamba (HG 4) and diflufenzopyr (HG 19). Diflufenzopyr disrupts the transport of auxin (IAA) within plants, enhancing the activity of dicamba. This allows lower use rates of dicamba.
27	This group inhibits HPPD, an enzyme involved in the synthesis of carotene pigments. One function of the carotenes is to protect chloropyll, thus the Group 27 herbicides cause a loss of chlorophyll and bleaching of sensitive plants. Symptoms also include chlorosis and necrosis, plant death is caused by formation of highly reactive compounds that disrupt cellular integrity (similar to group 5, 6, 7, 10 and 14). Group 13 (clomozone) inhibits carotene synthesis by interfering with a different enzyme in the carotene synthesis pathway. Group 27 resistant waterhemp is found in Iowa.

Table 4. Active ingredients and group numbers of herbicide premixes.

Tradename	Group No.	Active Ingredients
Anthem	14, 15	fluthiacet, pyroxasulfone
Anthem XLT	5, 14, 15	atrazine, fluthiacet, pyroxasulfone
Authority Assist	2, 14	imazethapyr, sulfentrazone
Authority Elite	14, 15	s-metolachlor, sulfentrazone
Authority First	2, 14	cloransulam, sulfentrazone
Authority MTZ	5, 14	metribuzin, sulfentrazone
Authority XL	2, 14	chlorimuron, sulfentrazone
Autumn Super	2, 2	iodosulfuron, thiencarbazone
Basis Blend	2, 2	rimsulfuron, thifensulfuron
Bicep	5, 15	atrazine, metolachlor
Callisto Xtra	5, 27	atrazine, mesotrione
Canopy	2, 5	chloriuron, metrbuzin
Canopy EX	2, 5	chlorimuron, tribenuron
Capreno	2, 27	thiencarbazone, tembotrione
Corvus	2, 27	thiencarbazone, isoxaflutole
Degree Xtra	5, 15	atrazine, acetochlor
Enlite	2, 2, 14	chlorimuron, thifensulfuron, flumioxazin
Envive	2, 2, 14	chloriuron, thifensulfuron, flumioxazin
Expert	5, 9, 15	atrazine, glyphosate, metolachlor
Extreme	2, 9	imazethapyr, glyphosate
Fierce	14, 15	flumioxazin, pyroxasulfone
Fierce XLT	2, 14, 15	chlorimuron, flumioxazin, pyroxasulfone
Flexstar GT	9, 14	glyphosate, fomesafen
FulTime	5, 15	atrazine, acetochlor
Fusion	1, 1	fenoxaprop, fluazifop
Gangster	2, 14	cloransulam, flumioxazin
Guardsman Max	5, 15	atrazine, dimethenamid
Halex GT	9, 15, 27	glyphosate, metolachlor, mesotrione
Harness Xtra	5, 15	atrazine, acetochlor
Instigate	2, 27	rimsulfuron, mesotrione
Keystone	5, 15	atrazine, acetochlor
Lexar	5, 15, 27	atrazine, metolachlor, mesotrione
Lumax	5, 15, 27	atrazine, metolachlor, mesotrione
Marksman	4, 5	dicamba, atrazine
Northstar	2, 4	primisulfuron, dicamba
Optill	2, 14	imazethapyr, saflufenacil
Permit Plus	2, 2	halosulfuron, thifensulfuron
Priority	2, 14	halosulfuron, carfentrazone
Prefix	14, 15	fomesafen, metolachlor
Prequel	2, 27	rimsulfuron, isoxaflutole
Pursuit Plus	2, 3	imazethapyr, pendimethalin
Realm Q	2, 27	rimsulfuron, mesotrione
Resolve Q	2, 2	rimsulfuron, thifensulfuron
Require Q	2, 4	rimsulfuron, dicamba
Sequence	9, 15	glyphosate, metolachlor
Sonic	2, 14	cloransulam, sulfentrazone
Spirit	2, 2	primisulfuron, prosulfuron
Status	4, 19	dicamba, diflufenzopyr
Steadfast Q	2, 2	nicosulfuron, rimsulfuron
Surestart	2, 4, 15	flumetsulam, clopyralid, acetochlor
Synchrony	2, 2	chlorimuron, thifensulfuron
Triple Flex	2, 4, 15	flumetsulam, clopyralid, acetochlor
Valor XLT	2, 14	chlorimuron, flumioxazin
Verdict	14, 15	saflufenacil, dimethenamid
Yukon	2, 4	halosulfuron, dicamba
Zemax	15, 27	metolachlor, mesotrione

Common chemical and trade names are used in this publication. The use of tradenames is for clarity by the reader. Inclusion of a tradename does not imply endorsement of that particular brand of herbicide nor does exclusion imply nonapproval.

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