HERBICIDE RESISTANCE MANAGEMENT

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General Information

Weed resistance to herbicides is an important weed control topic for producers. The development and implementation of weed management programs that do not repeatedly use similar herbicide mode of action (MOA) is essential. A herbicide's MOA describes how it inhibits plant growth. A herbicide's site of action (SOA) is the location within the plant where the herbicide acts to inhibit plant growth. The Herbicide Resistance Action Committee (HRAC) has provided guidelines to the Pest Management Regulatory Agency (PMRA) to introduced a voluntary pesticide resistance management labelling initiative for herbicides grouped according to their primary sites of action. Classification of herbicides by these guidelines is provided on the following pages.

If the primary weed control program for an area relies on the same herbicide or use of herbicides with the same SOA , one resistant weed can turn into a large population of resistant weeds in a few years. South Carolina is familiar with annual grass species that are resistant to dinitroanaline herbicides (yellow herbicides), and acetolactate-synthase (ALS) resistant pigweeds. The most recent example is the development of glyphosate-resistant horseweed (mare's-tail) that now is a problem in most of the cotton belt. The main cause of this is that weed control programs on well over 90% of the soybean and cotton acres relied exclusively on glyphosate over the past several years. Resistant weed biotypes may dominate the weed population. Other resistance mechanisms that are not linked to site of action, but specific for individual chemicals, such as enhanced metabolism, may also exist. Appropriate resistance-management strategies should be followed.

Remember that weed escapes are common. Herbicides rarely provide 100% control, and new flushes of weeds or re-growth can occur. Mis-application of products and the weather can play a factor in weed control, just because some weeds survive does not mean that they are resistant to particular herbicides.

Resistance Management Guidelines

To delay herbicide resistance the following guidelines should be followed.

1. When possible rotate the use classes of herbicides that control the same in weed in a particular field.

2. Use tank mixtures with herbicides from different groups when possible.

3. Use herbicides based on an Integrated Pest management (IPM) program that includes scouting, historical information related to herbicide use and crop rotation, and considers tillage (or other mechanical), cultural, biological and other chemical control practices.
4. Monitor fields for weed escapes and manage these escapes with alternate herbicide or cultural practices **before they set seed.** Notify your county extension agent of the problem.

5. Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment before moving to a new field.

Herbicide Site of Action, Grouping and Symbols.

To ensure consistency in pesticide grouping and labelling, and to contribute to the management of the pesticide-resistance problem, the following guidelines have been developed for agricultural uses of herbicides. The following classification schemes are based on target site of action. The site of action identification symbol should be shown on all end-use product labels (except products for homeowner/residential uses) in a standard format as outlined below, and should:

1. be located on the front panel (preferably at the upper right corner), surrounded by a black rectangle;

2. be in black on a white background except the site of action number(s), which is to be white on a black background with a clear white gap between the site of action number(s); and

3. include the words “GROUP” and “HERBICIDE” in capital letters, and between these words the number(s) representing the site of action group(s) of each active ingredient(s). Where a product has two or more active ingredients, and these are represented by two or more sites of action, then two or more appropriate site of action identifier numbers should be used. For products containing an active ingredient that has multiple sites of action, the letter “M” should be used to represent the site of action group. Alternatively, if sites of action are known, specify each site of action by the appropriate number.

Example 1: A herbicide containing one or more ingredients with the same site of action.

Example 2: A herbicide containing one or more ingredients with the same site of action.

Herbicide Groups Based on Site of Action.

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT (trade name)
1	Inhibitors of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy propionates	diclofop-methyl (Hoelon)
			fluazifop-p-butyl (Fusilade)
			quizalofop-p-ethyl (Assure II)
		Cyclohexanediones	clethodim (Select)
			sethoxydim (Poast)

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT (trade name)
2	Inhibitors of acetolactate synthase (ALS)	Sulfonylureas	chlorimuron (Classic)
			foramsulfuron (Option)
			metsulfuron-methyl (Ally)
			nicosulfuron (Accent)
			primisulfuron (Beacon)
		Sulfonamides	chloransulam-methyl (FirstRate)
			trifloxysulfuron (Envoke)
		Imidazolinones	imazamox (Raptor)
			imazapyr (Arsenal)
			imazethapyr (Pursuit)
		Pyrimidinylthio-benzoate	pyrithiobac (Staple)
		Triazolopyrimidine	flumetsulam (Python)
3	Microtubule assembly inhibitors	Dinitroanilines	ethalfluralin (Sonolan)
			pendimethalin (Prowl)
			trifluralin (Treflan)
4	Synthetic auxins	Phenoxys	2,4-D
			2,4-DB
		Benzoic acids	dicamba (Clarity)
		Carboxylic acids	clopyralid (Stinger)
			picloram (Tordon)
			triclopyr (Garlon)
5	Inhibitiors of photosynthesis at photosystem II Site A	Triazines	atrazine (Aatrex)
			prometryn (Caparol)
			simazine (Princep)
		Triazinones	metribuzin (Sencor)
6	Similar to group 5, but display different binding behavior	Nitriles	bromoxynil (Buctril)
		Benzothiadiazoles	bentazon (Basagran)
		Phenyl-pyridazine	pyridate (Tough)
7	Inhibitiors of photosynthesis at photosystem II Site B	Ureas	diuron (Direx)
			linuron (Linex)
		Amide	propanil (Stam)
8	Inhibitors of lipid synthesis non-ACCase	Thiocarbamates	EPTC (Eptam)

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT (trade name)
9	Inhibitors of 5-enoylpyruvalshikimate-3-phosphate (EPSP) syntahse	None	glyphosate
10	Inhibitors of glutamine synthase	None	glufosinate (Ignite)
11	Inhibitors of carotnoid synthesis	Triazoles	amitrole
12	Inhibitors of carotnoid synthesis at phytoene desaturase	Pyridazinones	norflurazon (Zorial)
13	Inhibitor of all diterpenes	Isoxazolidione	clomazone (Command)
14	Inhibitors of protoporphyrinogen oxidase (PPO)	Diphenylethers	acifluorfen (Ultra Blazer)
			fomesafen (Reflex)
			oxyfluorfen (Goal)
		Triazolinine	sulfentrazone (Spartan)
			carfentrazone (Aim)
			flumioxazin (Valor)
15	Unknown	Chloroacetamides	metolachlor (Dual)
			S-metolachlor (Dual Magnum)
			dimethenamid (Frontier)
16	Unknown	Benzofuran	ethofumesate
17	Unknown	Organoarsenicals	DSMA
			MSMA
18	Inhibitor dihydropteroate synthase	Carbamate	asulam (Asulox)
19	Inhibitor of indoleacetic acid	Phthalamate	naptalam
20	Inhibitor of cell wall synthesis Site A	Nitrile	dichlobenil
21	Inhibitor of cell wall synthesis Site B	Benzamide	isoxaben
22	Photo-system I electron diverters	Bipyridyliums	diquat (Reward)
			paraquat (Gramoxone Max)
23	Inhibitor of mitosis	Carbamates	chlorpropham
24	Uncoupling membrane disruptors	Dinitrophenol	dinoseb

GROUP	SITE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT (trade name)
25	Unknown	Arylaminopropionic acid	flamprop-methyl
26	Unknown	Various	trichloroacetic acid (TCA)
27		Various	cinmethylin
28	Inhibitors of 4hydroxy-phenyl-pyruvate-dioxygenase	Isoxazole	Isosaflutole (Balance Pro)
		Pyrazole	
		Triketone	mesotrione (Callisto)

Description of Herbicide Modes of Action

AMINO ACID SYNTHESIS INHIBITORS

Herbicides with this mode of action reduce or block the production of amino acids, the building blocks of proteins. They inhibit a key enzyme necessary for production of the particular amino acid(s). **Roundup Weather Max, Touchdown and other glyphosate products** are amino acid derivatives, and they inhibit **EPSP synthase**, an enzyme responsible for production of aromatic amino acids.

The **ALS inhibitors** inhibit **ALS** (acetolactate synthase), an enzyme necessary for production of three amino acids. These herbicides are absorbed readily and move throughout the plant.

The **Glutamine synthetase** inhibitor **glufosinate** (Liberty, Ignite) inhibits the conversion of glutamic acid and ammonia to glutamine. Ammonia accumulates and glutamine, glutamate and aspartate decrease. This interruption of important nitrogen metabolism and indirect inhibition of electron flow in photosynthesis causes a disruption of membranes.

CELL MEMBRANE DISRUPTORS

These herbicides, composed of the diphenylethers **(Ultra Blazer, Cobra, Reflex, others)** and the bipyridiliums **(Gramoxone Max and Reward),** work quickly as contact herbicides to disrupt plant cell membranes. Light is required for herbicide activity.

GROWTH REGULATION

The benzoics **(Banvel/Clarity/Distinct** and **Marksman)** and the phenoxys **(Butyrac 200** and **2,4-D)** work as auxin-like growth regulators in plants, producing the characteristic twisting, curling and cupping in broadleaved plants. They move freely within most plants.

RESPIRATION INHIBITORS

Inhibitors of respiration (the arsenical herbicides **DSMA** and **MSMA**) interfere with the production of ATP, the major source of energy in plants. Also, the arsenicals may act by interfering with enzyme activity and by disrupting cell membranes.

PHOTOSYNTHETIC INHIBITORS

The triazines **(AAtrex, Princep, Sencor and others)**, ureas **(Cotoran, Linex/Lorox, and others),** nitriles **(Buctril),** and **Basagran** inhibit the process of photosynthesis in plants. Soil applications of the triazines and ureas move with transpiration water upward in plants, but foliar applications of these same herbicides show little to very limited movement in plants. Likewise, foliar applications of **Buctril, Basagran, or Storm** act mainly on contact.

LIPID BIOSYNTHESIS INHIBITORS

There are two families of chemistry, the **"DIMS" (Achieve, Poast/Poast Plus and Select)** and the **"FOPS" (Fusilade, Fusion, Assure II and Hoelon)** comprise the postemergence grass herbicides. These herbicides all have the same mode of action. They inhibit an enzyme ACC'ase which is crucial for the formation of lipids in plants. These herbicides are quickly absorbed and they move throughout the plant. Effected plants die in 14 days.

MICOTUBLE ASSEMBLY INHIBITORS

The dinitroaniline or herbicides **(Treflan, Prowl and others)** inhibit lateral root development in plants by interfering with the process of cell division.

SHOOT GROWTH INHIBITORS

There are two chemical families of soil-applied herbicides, the substituted amides **(Dual II Magnum, Lasso, Surpass and others)** and the carbamothioates **(Eptam, Sutan + and others)** that are thought to work by inhibiting the synthesis of very-long-chain-fatty-acids, and in turn, growth of shoots in weeds immediately following germination. Herbicides in both chemical families tend to move readily from the roots, upward in the plant.

PIGMENT SYNTHESIS INHIBITORS

Four herbicides, **Balance, Command, Callisto and Zorial**, inhibit pigment synthesis in plants, hence the characteristic bleached appearance of susceptible weeds. Of these herbicides, only Callisto is applied postemergence.