Herbicide Resistance: Prevention and Detention

Selective herbicide use began in the 1940s with the discover of 2,4-D. This new compound killed many broadleaf weeds without damage to grassy plants, adding a new dimension to crop production. Producers could easily and economically control broadleaf weeds in grass crops that previously required mechanical or hand removal. Use of these materials spread rapidly and has continued to grow with the discovery and registration of new herbicides.

Weeds vary in susceptibility to herbicides. Some weeds tolerate herbicides and others do not. For example, morningglory and other broadleaf plants tolerate Fusilade DX, while annual and perennial grasses do not. Herbicide labels and weed response tables provide growers with this information, but there is also variation in control within a particular genus or species. Selected plants of a species normally controlled by a herbicide may require slightly higher application rates for an acceptable level of control. For example, in a particular field or year, Treflan may not control smooth pigweed as well as it does in other fields or years. Similarly, spiny amaranth (also known as spiny pigweed) may be not be controlled as well as smooth pigweed. You rarely get 100 percent control of any weed species with any herbicide.

A number of factors influence weed control: target coverage, application method, herbicide rate, environmental conditions, and weed size and development at application time.

Lack of control also may be due to the genetic ability of a weed to tolerate or resist the herbicidal properties of the pesticide. The Weed Science Society of America has defined resistant weeds as "species or a biotype of a species that originally was controlled by a specific herbicide that is no longer controlled."

Resistance may not be detected for many years, until a high percentage of the targeted species survives the herbicide treatment. The resistant-weed biotypes survive to produce seed, and the population grows. As the population of resistant weeds increases in relation to susceptible plants, you may suspect resistance, especially if this observation is made more than one year. Factors such as seed production and longevity, seed survival, germination rate, seedling hardiness, growth rate, and competitiveness of the susceptible and resistant biotypes influence the speed at which the resistant population grows.

Herbicide resistance has become an issue in Mississippi. The following cases have been found and confirmed:

- Annual bluegrass resistant to the traizines [simazine (Princep, Simazine) and atrazine (several)]
- Johnsongrass resistant to the acetyl-coenzyme A carboxylase (ACCase) herbicides [fluazifop-P (Fusilade DX and quizalofop-P (Assure II)]
- Common cocklebur resistant to imidazolinone herbicies [imazaquin (Scepter) and imazethapyr (Pursuit)]
- Common cocklebur resistant to organo arsenical herbicides [DSMA (several) and MSMA (several)]
- Goosegrass and johnsongrass resistant to dinitroaniline herbicides [trifluralin (Treflan, Tri-4, Trilin, etc.) and pendimethalin (Prowl)]
- Ryegrass resistant to the sulfonylurea herbicide [sulfometuron (Oust)]
- Horseweed [glyphosate (several)].

Confirming herbicide resistance in a low population is a slow process. Seed or other propagation material must be collected, plants grown to treatment size in a controlled environment, treatments applied and results evaluated. Collected seeds may require an after-ripening period or storage at freezing temperatures before germination occurs. Seedlings from a susceptible parent (preferably one that has never been exposed to the suspected herbicide) must be grown and treated along with the resistant seedlings for comparison purposes. This

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process can require from several months to one year after the initial collection. Fortunately there is an ongoing effort to develop techniques for quicker resistance detection.

Often, you must evaluate the situation in the field to determine the reason for lack of control. If several weed species that should have been controlled by the herbicide are detected, resistance probably is not the cause for lack of control. Likewise, if a pattern of no control can be detected, or if adverse environmental conditions existed at the time of application, the control failure was probably not caused by herbicide resistance. If, however, all weeds except one susceptible species were controlled, herbicide resistance might be suspected. When resistance is suspected, contact your county Extension agent to initiate resistance testing.

Proper herbicide selection and use can delay the development of a resistant-weed population. Crop rotation may not be necessary, however, if several alternative herbicides are available so you can use a herbicide with a different mode of action in that crop. For example, imidazolinone-resistant cocklebur can be controlled in soybeans with other herbicides such as bentazon (Basagran) that have a different mode of action. Although ACCase-resistant johnsongrass can be controlled with clethodim (Select) in cotton or soybeans, no one can determine if or when resistance to Select will occur. It would be wise to use glyphosate (Roundup) as a wiper treatment, spot treatment, or after harvest for johnsongrass control in conventional cotton or soybeans rather than continued use of clethodim (Select) on those resistant populations. Another alternative would be rotating to Roundup Ready cotton or soybean, where Roundup could be applied for postemergence johnsongrass control.

The availability of Roundup Ready crops has made glyphosate an additional option, with a different mode of action, for postemergence weed control in Roundup Ready corn, cotton, and soybean. Acceptance, spectrum of weed control, and cost associated with Roundup Ready weed control systems, particularly in cotton and soybean, have resulted of many acres of cropland in Mississippi receiving applications of glyphosate. Grower should try to avoid only utilizing glyphosate products for weed control on a given piece of land over several consecutive years. If Roundup Ready crops are grown in a field over several consecutive years, tank-mixing glyphosate with herbicides with different modes of action may aid in managing resistance development.

Crop rotation will not delay weed resistance if herbicides with similar modes of action are used in the rotation crop. In the example just mentioned, rotation from cotton to soybeans would not help resistant johnsongrass because many of the same herbicides are used in both crops for post grass control. Rotation to corn and use of nicosulfuron (Accent) or primisulfuron (Beacon) for johnsongrass control alternates the herbicide modes of action.

Use of herbicides that contain more than one active ingredient in the formulation, or premixes, may help control certain herbicide-resistant weeds. This will be an effective treatment alternative only if both ingredients were initially effective on that particular weed.

If you have detected a resistant-weed population, use all available control methods to avoid seed deposition in the field. Hand-removal following cultivation may be economical if the end result is to avoid spread of a herbicide-resistant weed population.

The table contains many of the herbicides routinely used in Mississippi, along with the modes of action of these herbicides. This information can be useful to plan weed control tactics that include herbicide rotation so herbicides with similar modes of action or in the same families are not repeatedly used year after year.

Table 1. Mode of action, site of action, and family of commonly used herbicides.

General Mode of Action	Specific Mode of Action	Family	Herbicide Common Name	Herbicide Trade Name(s)[a]
Amino acid synthesis inhibitors	Inhibition of (ALS[b]), also known as (AHAS)	Imidazolinone	imazamox	Beyond, Raptor
			imazapic	Cadre
			imazapyr	Various
			imazaquin	Scepter, Image
			imazethapyr	Pursuit, Newpath
		Pyrimidinylthio-benzoate	pyrithiobac	Staple
			bispyribac-sodium	Regiment
		Sulfonylurea	bensulfuron	Londax
			chlorimuron	Classic
			chlorsulfuron	Glean, Telar, Corsair
			foramsulfuron	Option, Revolver
			halosulfuron	Permit, Manage, Sandea
			metsulfuron	Various
			nicosulfuron	Accent
			primisulfuron	Beacon
			prosulfuron	Peak
			rimsulfuron	TranXit
			sulfometuron	Oust
			sulfosulfuron	Maverick, Outrider
			thifensulfuron	Pinnacle, Harmony GT
			trifloxysulfuron-soduim	Envoke, Monument
		Triazolopyrimidine	cloransulam-methyl	First Rate, Amplify
			diclosulam	Strongarm
			flumetsulam	Python

Table 1. continued

General Mode of Action	Specific Mode of Action	Family	Herbicide Common Name	Herbicide Trade Name(s)
	Inhibition of (EPSP) synthase	None[c]	glyphosate	Various
Nitrogen metabolism disrupters	Inhibition of glutamine synthetase	None	glufosinate	Various
Cell membrane disrupters	(PS) I electron diverters	Bypyridylium	diquat	Various
			paraquat	Gramoxone Max, Boa
	(Protox) Inhibition	Diphenylether	acifluorfen	Ultra Blazer
			fomesafen	Reflex, Flexstar
			lactofen	Cobra
			oxyfluorfen	Goal, Delta Goal
		N-phenylphthalimide	flumiclorac	Resource
			flumioxazin	Valor
		Oxadiazole	oxadiazon	Ronstar
		Triazolinone	carfentrazone	Aim
			sulfentrazone	Authority, Spartan
	Inhibition of protein sulfation	None	sodium chlorate	Various
	Unknown	Fatty acid	pelargonic acid	Scythe
Lipid biosynthesis inhibitors	Inhibition of acetyl CoA carboxylase	Aryloxyphenoxy proprianate	cyhalofop-butyl	Clincher
			diclofop	Hoelon, Illoxan
			fenoxaprop	Acclaim, Ricestar, Whip
			fluazifop	Fusilade, Ornamec
			quizalofop	Assure II
		Cyclohexanedione	clethodim	Select, Prism, Envoy
			sethoxydim	Various
			tralkoxydim	Achieve
Photosynthesis inhibitors	Inhibition at (PS) II site A1	Triazine	ametryn	Evik
			atrazine	Various
			prometon	Pramitol
			prometryn	Caparol, CottonPro
			simazine	Princep, Simazine
		Triazinone	hexazinone	Velpar
			metribuzin	Sencor
		Uracil	bromacil	Various
			terbacil	Sinbar
	Inhibition at (PS) II site A2	Amide	propanil	Various
		Urea	diuron	Karmex, Direx
			fluometuron	Various
			linuron	Lorox, Linex
			siduron	Tupersan
			tebuthiuron	Spike
	Inhibition at (PS) II site B	Benzothiadiazole	bentazon	Basagran
		Nitrile	bromoxynil	Various
Pigment inhibitors	Inhibition of phytoene desaturase	Pyridiazinone	norflurazon	Zorial, Solicam`
		None	fluridone	Sonar
	Inhibition of (DOXP) synthase	Isoxazolidinone	clomazone	Command
	Inhibition of (HPPD)	Triketone	mesotrione	Callisto
Respiration inhibitors	Unknown[d]	Organoarsenical		
			DSMA	Various
			MSMA	Various
Root inhibitors	Inhibition of microtubule assembly	Amide	pronamide	Kerb

Table 1. continued

General Mode of Action	Specific Mode of Action	Family	Herbicide Common Name	Herbicide Trade Name(s)
		Dinitroanaline	benefin	Balan
			ethalfluralin	Sonalan, Curbit
			oryzalin	Surflan, Oryzalin
			pendimethalin	Various
			prodiamine	Barricade
			trifluralin	Various
		Pyridine	dithiopyr	Dimension
		None	DCPA	Dacthal
Shoot inhibitors	Inhibition of lipid synthesis	Thiocarbamate	EPTC	Eptam, Eradicane
			molinate	Ordram
			thiobencarb	Bolero
		None	bensulide	Prefar, Betasan
	Inhibition of very long-chain fatty acid biosynthesis	Acetamide	napropamide	Devrinol
		Chloracetamide	acetochlor	Harness, Surpass
			alachlor	Lasso, Micro-Tech
			dimethenamid	Outlook, Frontier
			metolachlor	Dual, Pennant
		Oxyacetamide	flufenacet	Define
	Inhibitors of (DHP)	Carbamate	asulam	Asulox, Asulam
	Inhibition of cell wall biosynthesis site B	Benzamide	isoxaben	Gallery
Synthetic Auxins	Unknown	Phenoxy	2,4-D	Various
			2,4-DB	Butoxone, Butyrac
			2,4-DP, dichloroprop	Various
			MCPA	Various
			MCPP, mecoprop	Mecomec
		Benzoic acid	dicamba	Various
		Carboxylic acid	clorpyralid	Various
			picloram	Tordon
			triclopyr	Various
		Quinalinecarboxylic acid	quinclorac	Facet, Drive
	Inhibition of (IAA) transport	Phthalamate	naptalam	Alanap

[a] Listing a specific product does not represent support for that product over another, nor does not listing a product represent non-support.

[b] Abbreviations: ALS, acetolactate synthase; AHAS, acetohydroxyacid synthase; EPSP, 5-enolpyruvyl-shikimate-3-phosphate synthase; PROTX, protopor phyringen oxidase; PS, photosystem; DOXP, 1-deoxy-D-xyulose 5–phosphate synthatase; DPPD, 4-hydroxyphenyl-pyruvate dioxygenase; DHP, 7,8-dihydro-pteroate synthetase; IAA, indolacetic acid.

[c] Herbicide does not belong to an accepted herbicide family.

[d] The specific site(s) of action is not yet completely understood.

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