MSPB
MISSISSIPPI SOYBEAN PROMOTION BOARD

USING HERBICIDE MOA TO SELECT HERBICIDES

Members of the production agricultural industry are constantly looking for new tools to aid in making management decisions. This is especially so for weed management in today's environment of increasing development of weed resistance to popular herbicides such as glyphosate.

Herbicide-resistant [HR] weed populations generally result from the continuous use of a herbicide or herbicides with the same mechanism [synonymous with mode or site] of action [MOA]. This overuse of these herbicides results in the selection of traits that allow a weed species to withstand herbicide applications that otherwise would kill them.

Subsequent generations of the resistant weed inherit the ability to survive and reproduce following a herbicide application that normally would kill plants of the species. Thus, HR weeds are the product of intensive selection pressure resulting from the continuous use of a herbicide or herbicides that target a specific physiological or biochemical process.

Producers, consultants, and professional crop practitioners should select herbicides that are best suited to manage specific HR weeds, or that can be used in rotation to prevent or delay HR. A system of herbicide labeling that categorizes weed control products by their MOA can be used in the herbicide selection process.

Knowledge of the MOA categories described by the Herbicide Resistance Action Committee [HRAC] will aid in managing weeds that are resistant to herbicides that are now available. Using this additional management tool will reduce, if not prevent, the likelihood of selecting for HR weeds. In fact, in today's conservation production systems that mostly rely on herbicides for weed management, selecting and using herbicides with different MOA's should be a primary tool for preventing and/or managing HR weeds.

Selecting herbicides with different MOA's must be combined with choosing herbicides within those MOA groups that are effective at controlling targeted weeds in individual fields. In other words, merely selecting herbicides from a different MOA Group will do little to reduce selection pressure if those herbicides are not effective at controlling targeted problematic weeds in a field.

The numerical classification system developed by the Weed Science Society of America [WSSA] [see below table] is available on herbicide labels. A box labeled "Group Herbicide" is located near the top of the label, and contains the number or numbers that indicate the MOA of the product's active ingredient(s). Multiple numbers in the box indicate that the herbicide product or herbicide premix has more than one MOA.

Examples are the labels for Roundup WeatherMax [Group 9]

GROUP	9	HERBICIDE

and Valor XLT [Groups 2 and 14].

GROUP	2 + 14	HERBICIDE

The following examples illustrate how to use the herbicide MOA's shown in the below table as a component in weed control decisions. In the examples, level of control of weed species by indicated herbicides is from the latest issue of Weed Control Guidelines for Mississippi that can be accessed here.

Example 1. A producer uses the stale seedbed planting system for his early-planted soybean crop, and relies on a preplant foliar application of herbicide(s) to kill weed vegetation before planting. The producer has used predominantly glyphosate [MOA Group 9] as the burndown herbicide in the past. However, glyphosate-resistant [GR] horseweed and Italian ryegrass are now a problem in the field(s) planned for soybean planting.

Additionally, a majority of the fields contain buttercup, cutleaf evening primrose, annual bluegrass, and henbit. A tank mix of glyphosate and a phenoxy-type herbicide such as 2,4-D [MOA Group 4] may improve control of the broadleaf weeds that are present, but can antagonize glyphosate activity on grass species. Consequently, this would lead to adding other herbicides to the mixture, thus increasing cost and devaluing the utility of glyphosate.

In this example, it is now March 25 and planting is intended to occur around April 5, or about 10 days after application of burndown herbicides.

There are viable alternatives for killing the GR horseweed and Italian ryegrass with burndown herbicide(s). Choices, MOA's, and level of control are:

- Clarity herbicide [MOA Group 4] results in a high level of control of horseweed, buttercup, and cutleaf evening primrose, but only moderate control of henbit. It has no activity on Italian ryegrass and annual bluegrass. Plus, following its application and a minimum accumulation of 1 in. of rainfall or overhead irrigation, there is a 14- to 28-day waiting period [depending on rate] before soybean should be planted.
- Paraquat + 2,4-D [MOA Groups 22 + 4] exhibits good control of all aforementioned species, and an application by mid-March should beat the deadline for aerial application of 2,4-D in Mississippi. However, the 14-28 day waiting period [depending on 2,4-D rate] before planting soybean could cause a delay in planting past the intended April 5 starting time. Planting an Enlist soybean variety will avoid this waiting period.
- Paraquat + metribuzin [MOA Groups 22 + 5] exhibits a high level of control of all aforementioned species. Plus, metribuzin provides residual control of many broadleaf weeds, including pigweed [with higher use rates]. There is no required waiting period before planting soybean when these herbicides are used. However, the intended soybean variety must be tolerant of metribuzin.
- Liberty [MOA Group 10] exhibits a high level of control of horseweed and henbit, but not buttercup and evening primrose. It is not very effective against annual bluegrass and Italian ryegrass. There is no required waiting period before planting soybean.
- Sharpen [MOA Group 14] exhibits a high level of control of only horseweed.

In this example, all of the options have an MOA different from that of glyphosate, and all will control the GR horseweed. However, paraquat + metribuzin appears to be the best choice from the standpoint of controlling all of the target species and not having a required waiting period before planting soybeans. Thus, the criteria of level of control of targeted weed species coupled with MOA's different from that of glyphosate are achieved with this burndown option.

Example 2. A producer uses the stale seedbed planting system with GR soybean varieties, and in the past has relied on glyphosate [MOA Group 9] to control later-emerging annual grasses. The decision is made to change from relying on glyphosate to avoid GR problems. Also, it is decided to forego using a residual grass herbicide in favor of using POST applications of graminicides if needed.

As indicated in Table 1, there are several choices of grass herbicides to use in this program since all of the postemergence [POST] graminicides are in MOA Group 1, which is different from that of glyphosate. In this case, two concerns are 1) choosing the graminicide that exhibits the highest level of control of the grass species that appear after soybean emergence, and 2) recognizing that all of the POST graminicides listed in the table have the same MOA.

For future resistance management, rotating the POST graminicides [all in MOA Group 1] with a preemergence [PRE] herbicide such as Dual or Micro-Tech [MOA Group 15] will be an important consideration. This rotational herbicide system should be monitored closely since the PRE grass herbicides exhibit a low level of control of Johnsongrass, and there is documentation that there are Johnsongrass biotypes that exhibit resistance to POST graminicides.

- If there is no indication of GR grasses presently in these fields, then glyphosate can be entered into the POST grass control rotation. The important points in this example are 1) have a good knowledge of the grass species that are present on an annual basis, and 2) monitor weed escapes that may indicate selection against the herbicides used in this program.
- Rotate herbicide MOA annually to avoid HR weed development.

Example 3. A producer grows soybeans in a 1:1 rotation with rice. Barnyardgrass resistance to Facet herbicide [MOA Group 4], which is used in the rice sequence, is developing and could become a major problem if not addressed.

In the soybean year, Dual [MOA Group 15] could be applied PRE or in-crop followed by one of the graminicides in MOA Group 1 such as Assure or Select to control barnyardgrass. This is an example of crop rotation also serving as an opportunity for herbicide rotation to prevent or delay selecting for HR weed species development.

Important points from the above examples and additional points are:

- Knowing and using herbicide MOA's can be an important component of preventing or delaying development of HR weeds.
- Weed species present in individual fields should be documented each year so that MOA knowledge and level of weed control by individual herbicides can be coupled when making herbicide decisions.
- If GR weed development is not documented in a particular field or fields, then its use is a viable option when used in rotation with other herbicide(s) with a different MOA. In fact, glyphosate used in rotation is an excellent resistance management option if there are no documented GR weeds at the site.
- When tank-mixing herbicides with glyphosate to control GR weeds, it is important that the non-glyphosate herbicide is added at a rate that will control the targeted weed alone or in the absence of glyphosate. Otherwise, the GR weed will not be killed and will continue to live and reproduce.
- Any weed management strategy that is adopted to minimize selection pressure for the development of resistance to a particular herbicide will delay or block the emergence of HR. Thus, the MOA strategy should be viewed as an important management tool that can be used to choose herbicides. This tool should be used in conjunction with other resistance management practices to delay the evolution of HR in weeds.

One of the subjects that is prevalent in the discourse surrounding HR weeds is how the various herbicides work to control weeds. This leads to use of the terms "site-of-action [SOA]" and "mode-of-action [MOA]". These two terms are often used interchangeably, but they in fact refer to two different interactions or processes. Click here for a narrative that will help differentiate between the two processes, and how they relate to herbicide activity.

Herbicide premixes that contain components with different SOA's from each other may contain active ingredients that are different from those of other premixes with the same SOA's. This may result in differences in weeds that are controlled, different required soil qualities, and different plantback/crop rotation restrictions. Click here for examples of this with available premix herbicides.

Remember these final important points.

- **Preventing HR occurrence is an easier, more sustainable, and cheaper option than trying to manage a confirmed population of HR weeds.**
- **The herbicide label should be followed to ensure the lowest risk for HR weed development.**

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Mechanism of action [MOA] classification [Group] of soybean herbicides according to the HRAC. Click CDMS at bottom of table for current labels.

Group*	MOA**	Trade name	Active ingredient(s)	Weeds controlled***
1	ACC-ase inhibitor	Assure II	Quizalofop	Grass
1		Fusilade DX	Fluazifop	Grass
1		Poast	Sethoxydim	Grass
1		Select	Clethodim	Grass
1 + 1		Fusion	Fluazifop + fenoxaprop	Grass
2	ALS inhibitors	Classic	Chlorimuron	Broadleaf
2		FirstRate	Cloransulam-methyl	Broadleaf
2		Pursuit	Imazethapyr	Broadleaf
2		Python	Flumetsulam	Broadleaf
2		Scepter	Imazaquin	Broadleaf
2 + 2		Canopy EX	Chlorimuron + tribenuron	Broadleaf
2 + 2		FirstShot	Tribenuron + thifensulfuron	Broadleaf
2 + 2		Synchrony XP	Chlorimuron + thifensulfuron	Broadleaf
3	Mitosis inhibitors	Prowl H_2O	Pendimethalin	Grass
3		Treflan	Trifluralin	Grass + broadleaf
4	Synthetic auxins	Clarity	Dicamba	Broadleaf
4		Various	2,4-DB	Broadleaf
4		Various	2,4-D	Broadleaf
4		Spitfire	Dicamba + 2,4-D	Broadleaf
4		Elevore	Halauxifen-methyl	Broadleaf
4		Xtendimax (dicamba-DGA salt with Vapor Grip Tech.)		Broadleaf
5	PS-II inhibitor	Metribuzin	Metribuzin	Grass + broadleaf
5		Lorox	Linuron	Grass + broadleaf
5 + 2		Canopy	Metribuzin + chlorimuron	Grass + broadleaf
5 + 4		Metribuzin + 2,4-DB	Metribuzin + 2,4-DB	Grass + broadleaf
5 + 4		Lorox + 2,4-DB	Linuron + 2,4-DB	Grass + broadleaf
6	PS-II inhibitor	Basagran	Bentazon	Broadleaf
9	EPSPS inhibitor	Roundup, Others	Glyphosate	Grass + broadleaf
9		Credit Xtreme	Glyphosate	Grass + broadleaf
9 + 4		Enlist Duo	2,4-D + Glyphosate	Grass + broadleaf
9 + 15		Sequence	Glyphosate + *s*-metolachlor	Grass + broadleaf
10	Glutamine synthetase inh.	Liberty	Glufosinate	Grass + broadleaf
10		Cheetah	Glufosinate	Grass + broadleaf
13	Carotene inhibitor	Command	Clomazone	Grass + broadleaf
14	PPO inhibitors	Cobra	Lactofen	Broadleaf
14		Aim	Carfentrazone-ethyl	Broadleaf
14		Blazer	Acifluorfen	Broadleaf
14		Cadet	Fluthiacet	Broadleaf

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Group*	**MOA****	**Trade name**	**Active ingredient(s)**	**Weeds controlled*****
14		Flexstar, Reflex	Fomesafen	Broadleaf
14		Panther SC	Flumioxazin	Broadleaf
14		Resource	Flumiclorac-pentyl	Broadleaf
14		Sharpen	Saflufenacil	Broadleaf
14		Valor	Flumioxazin	Broadleaf
14		Spartan	Sulfentrazone	Broadleaf
14		Reviton	Tiafenacil	Grass + Broadleaf
14 + 14		Zone Defense	Sulfentrazone + flumioxazin	Grass + Broadleaf
14 + 2		Envive	Chlorimuron + Flumioxazin + Thifensulfuron	Broadleaf
14 + 2		Surveil	Flumioxazin + cloransulam	Broadleaf
14 + 2		Optill	Saflufenacil + imazethapyr	Grass + broadleaf
14 + 2		Valor XLT	Flumioxazin + chlorimuron	Broadleaf
14 + 2		Authority Assist	Sulfentrazone + Imazethapyr	Broadleaf
14 + 2		Zone Assist	Sulfentrazone + Imazethapyr	Broadleaf
14 + 2		Authority First	Sulfentrazone + Cloransulam	Broadleaf
14 + 2		Authority XL Authority Maxx Zone	Sulfentrazone + Chlorimuron	Broadleaf
14 + 2		Afforia	Flumioxazin + thifensulfuron methyl + Tribenuron-methyl	Broadleaf
14 + 5		Authority MTZ Preview 2.1 SC	Sulfentrazone + metribuzin	Broadleaf
14 + 6		Storm	Acifluorfen + bentazon	Broadleaf
14 + 9		Flexstar GT	Fomesafen + glyphosate	Broadleaf
14 + 10		Cheetah Max	Fomesafen + glufosinate	Grass + Broadleaf
14, 2, 5		Trivence	Chlorimuron-ethyl + Metribuzin + Flumioxazin	Broadleaf
15	Mitosis inhibitors	Dual Magnum	*s*-metolachlor	Grass + broadleaf
15		Outlook	Dimethenamid-p	Grass + broadleaf
15		Warrant	Acetochlor	Grass + broadleaf
15		Zidua	Pyroxasulfone	Grass + broadleaf
15 + 5		Axiom	Flufenacet + metribuzin	Grass + broadleaf
15 + 5		Boundary	*s*-metolachlor + metribuzin	Grass + broadleaf
15 + 9		Sequence	Glyphosate + s-Metolachlor	Grass + broadleaf
15 + 14		Prefix	*s*-Metolachlor + Fomesafen	Grass + broadleaf
15 + 14		Warrant Ultra	Acetochlor + Fomesafen	Grass + broadleaf
15 + 14		Authority Elite	Sulfentrazone + *s*-Metolachlor	Grass + broadleaf
15 + 14		Zone Elite	Sulfentrazone + *s*-Metolachlor	Grass + broadleaf
15 + 14		Anthem Maxx	Pyroxasulfone + Fluthiacet-methyl	Grass + broadleaf

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Group*	MOA**	Trade name	Active ingredient(s)	Weeds controlled***
15 + 14		Fierce EZ	Flumioxazin + Pyroxasulfone	Grass + broadleaf
15 + 14		Verdict	Dimethenamid-P + Saflufenacil	Grass + broadleaf
15 + 14		Authority Supreme	Sulfentrazone + pyroxasulfone	Grass + broadleaf
15 + 14		Perpetuo	Flumiclorac pentyl + pyroxasulfone	Grass + broadleaf
15, 5, 2		Matador-S	S-Metolachlor + metribuzin + Imazethapyr	Grass + broadleaf
15, 5, 2		Tendovo	S-Metolachlor + metribuzin + Cloransulam-methyl	Grass + broadleaf
15, 2, 14		Fierce XLT	Chlorimuron + Flumioxazin + Pyroxasulfone	Grass + broadleaf
15, 2, 14		Optill PRO	Imazethapyr + Saflufenacil + Dimethenamid-P	Grass + broadleaf
15, 2, 14		Zidua PRO	Imazethapyr + Saflufenacil + Pyroxasulfone	Grass + broadleaf
15, 5, 14		Fierce MTZ	Flumioxazin + pyroxasulfone + metribuzin	Grass + broadleaf
15, 5, 14		Kyber	Flumioxazin + pyroxasulfone + metribuzin	Grass + broadleaf
22	PS-I inhibitor	Gramoxone	Paraquat	Grass + broadleaf
27	HPPD inhibitor	Alite 27	Isoxaflutole (use only on GT27 varieties)	Grass + broadleaf

*WSSA Group Number.
**See HRAC for detailed description of MOA's.
**Major class(es) of weeds controlled. See label for each herbicide at CDMS for specific weeds controlled, level of control, allowed tank-mix partners, and time of application [preplant-foliar or burndown, preplant-incorporated (PPI), preemergence (PRE), or postemergence (POST)].