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 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 resistant weeds, or that can be used in rotation to prevent or delay resistance. 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 Weed Science Society of America (WSSA) and 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 rely mostly on herbicides for weed management, selecting and using herbicides with different MOAs should be a primary tool for preventing and/or managing resistance.

Selecting herbicides with different MOAs 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 important weeds in a field.

The numerical classification system developed by the WSSA (below table) is available on herbicide labels. Near the top of the label, a box labeled "Group Herbicide" 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 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 MOAs 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 Weed Control Guidelines for Mississippi.

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. For the last decade, the producer has used predominantly glyphosate (MOA Group 9) as the burndown herbicide. However, glyphosate-resistant (GR) horseweed and Italian ryegrass are now a problem.

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 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.

According to the Weed Control Guidelines for Mississippi, there are viable alternatives for killing the GR horseweed and Italian ryegrass with a burndown herbicide(s). Choices, MOAs, and level of control are:

- Clarity (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 planting soybean.

- Paraquat + 2,4-D (MOA Groups 22 + 4) exhibits good control of all aforementioned species, and a March 25 application will 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 will cause a delay in planting past the intended April 5 starting time.

- Paraquat + Sencor (MOA Groups 22 + 5) exhibits a high level of control of all aforementioned species. Plus, Sencor provides residual control of many broadleaf weeds, including pigweed (with higher use rates). There is no required waiting period before planting soybean.

- 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 + Sencor 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 target 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 in order to avoid possible future resistance problems. Also, it is decided to forego using a residual grass herbicide in favor of using post-emergence (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 POST graminicides are in MOA Group 1, which is different from that of glyphosate. In this case, there are two concerns: choosing the graminicide that exhibits the highest level of control of the grass species that appear after soybean emergence, and 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 pre-emergence (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:

- Have a good knowledge of the grass species that are present on an annual basis.
- Monitor weed escapes that may indicate selection against the herbicides used in this program.
- Rotate herbicide MOA from year to year to avoid resistance 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 and Select to control barnyardgrass.

This is an example of crop rotation also serving as an opportunity for herbicide rotation to prevent or delay selecting a weed species for resistance to a particular herbicide group.

Important points from the above examples and additional points are:

- Knowing and using herbicide MOAs can be an important component of managing weed resistance to herbicides.
- 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 weed species' resistance to glyphosate 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 is no documented glyphosate resistance.

- 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.

- Crop rotation offers opportunity for herbicide MOA rotation to prevent or delay development of weed resistance to herbicides.

Any weed management strategy that is adopted to minimize selection pressure for resistance will delay or block the emergence of resistance. Thus, the MOA strategy should be viewed as just one of several management tools that can be used to choose herbicides. This tool should be used in conjunction with other resistance management practices to delay the evolution of herbicide resistance in weeds.

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Mechanism of action (MOA) classification (Group) of soybean herbicides according to the WSSA*. Click product name for label.				
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	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
5	PS-II inhibitor(3)	Sencor	Metribuzin	Grass + broadleaf
5 + 2		Canopy	Metribuzin + chlorimuron	Grass + broadleaf
5 + 4		Sencor + 2,4-DB	Metribuzin + 2,4-DB	Grass + broadleaf
6	PS-II inhibitor(3)	Basagran	Bentazon	Broadleaf
7	PS-II inhibitor	Lorox	Linuron	Grass + broadleaf
7 + 4		Lorox + 2,4-DB	Linuron + 2,4-DB	Grass + broadleaf
9	EPSPS inhibitor	Roundup	Glyphosate	Grass + broadleaf
9		Credit Xtreme	Glyphosate	Grass + broadleaf
9 + 2		Extreme	Glyphosate + imazethapyr	Grass + broadleaf
9 + 4		Enlist Duo	2,4-D + Glyphosate	Grass + broadleaf
9 + 15		Sequence	Glyphosate + *s*-metolachlor	Grass + broadleaf

Mechanism of action (MOA) classification (Group) of soybean herbicides according to the WSSA*. Click product name for label.				
Group	**MOA****	**Trade name**	**Active ingredient(s)**	**Weeds controlled#**
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
14		Flexstar, Reflex	Fomesafen	Broadleaf
14		Marvel	Fluthiacet + Fomesafen	Broadleaf
14		Panther SC	Flumioxazin	Broadleaf
14		Resource	Flumiclorac-pentyl	Broadleaf
14		Sharpen	Saflufenacil	Broadleaf
14		Valor	Flumioxazin	Broadleaf
14 + 2		Envive	Chlorimuron + Flumioxazin + Thifensulfuron	Broadleaf
14 + 2		Gangster, 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		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 + 2		Torment	Fomesafen + Imazethapyr	Broadleaf
14 + 5		Authority MTZ	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

Mechanism of action (MOA) classification (Group) of soybean herbicides according to the WSSA*. Click product name for label.				
Group	**MOA****	**Trade name**	**Active ingredient(s)**	**Weeds controlled#**
15	Mitosis inhibitors	Dual Magnum	*s*-metolachlor	Grass + broadleaf
15		Micro-Tech	Alachlor	Grass + broadleaf
15		Outlook	Dimethenamid-p	Grass + broadleaf
15		Warrant	Acetochlor	Grass + broadleaf
15		Zidua	Pyroxasulfone	Grass + broadleaf
15 + 2		Pummel	Metolachlor + Imazethapyr	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		Authority Elite	Sulfentrazone + *s*-Metolachlor	Grass + broadleaf
15 + 14		Anthem	Pyroxasulfone + Fluthiacet-methyl	Grass + broadleaf
15 + 14		Fierce	Flumioxazin + Pyroxasulfone	Grass + broadleaf
15 + 14		Verdict	Dimethenamid-P + Saflufenacil	Grass + broadleaf
15, 2, 14		Fierce XLT	Chlorimuron + Flumioxazin + Pyroxasulfone	Grass + broadleaf
15, 2, 14		Optill Pro	Imazethapyr + Saflufenacil + Dimethenamid-P	Grass + broadleaf
22	PS-I inhibitor	Gramoxone	Paraquat	Grass + broadleaf

*Adapted from Legleiter and Johnson, Corn and Soybean Herbicide Chart, Jordan and Yelverton, and USB's Takeactiononweeds.com.
**See WSSA for detailed description of MOAs.
#Major class(es) of weeds controlled. See the Weed Control Guidelines for Mississippi and individual labels at CDMS for specific weeds controlled, level of control, tank-mix partners, and time of application (preplant-foliar or burndown, preplant-incorporated, pre-emergence, or post-emergence).