Utility of Future Herbicide Tolerance Traits for Corn and Soybeans

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Glyphosate-based weed management programs continue to be very effective for many corn and soybean growers. Inadequate control with glyphosate has occurred in an increasing number of fields, over the past 6 years or so. This has occurred primarily with several broadleaf weed species, including horseweed (marestail), giant and common ragweed, common lambsquarters, and waterhemp. Populations of these weeds have developed resistance to glyphosate, and are in some instances resistant to both glyphosate and ALS inhibitors. Research conducted by Purdue University and Ohio State University shows that glyphosate resistance in these populations can range from low to high. The presence of low-level resistance, when weeds are not completely controlled but show injury symptoms, can explain the opinion of many growers and agronomists that glyphosate has become generally less effective after 12 years of use in Roundup Ready crops. This has led to the need to integrate glyphosate with other herbicides in many fields, a practice that was promoted by university weed scientists from the start. Integration has so far taken the form of preplant applications of residual herbicides, or mixing other herbicides with glyphosate in postemergence applications.

Herbicides currently available for corn and soybeans can resolve many of the issues with glyphosate-based herbicide programs. For example, lambsquarters control issues are readily resolved with residual herbicides, many of which provide seasonlong control. The addition of 2,4-D ester to spring burndown treatments resolves at least some of the issues with marestail control. Mixtures of glyphosate with Status can resolve many postemergence broadleaf control issues in corn. Problems with control tend to occur more in soybeans, where options can be limited if weeds are resistant to both glyphosate and ALS inhibitors. Situations where new herbicide-tolerant crop technology could have a role include:

1. Marestail (horseweed). While 2,4-D ester is an important component of preplant burndown programs for control of emerged glyphosate-resistant marestail, it must be applied at least 7 days before planting. Technology that allows use of 2,4-D or other effective herbicides at the time of planting or shortly thereafter could greatly improve control. We also need additional postemergence options for control of late-emerging marestail or those that are not killed by burndown treatments. ALS inhibitors are ineffective in many fields due to the presence of ALS-resistant plants, and herbicides such as FirstRate and Classic are effective primarily on small plants anyway.

2. Giant ragweed. Research shows that 50% or more of the season's giant ragweed population has often emerged by early May, so technology that allows use of 2,4-D or other effective herbicides at the time of planting or shortly thereafter could

improve control. We also need additional options for postemergence control of populations that are not well controlled by glyphosate. ALS resistance limits the effectiveness of ALS inhibitors such as FirstRate and Classic. Flexstar and Cobra control primarily small plants, and control with these products has always been somewhat variable.

3. Common ragweed. Needs are similar to those listed for giant ragweed. One difference is that Flexstar and Cobra often effectively control common ragweed. However, some populations have developed resistance to PPO inhibitors, and reliance on these herbicides is likely to result in an increased frequency of these populations.

4. Waterhemp. While waterhemp is less of a problem in Ohio and Indiana than farther west, some waterhemp populations have developed resistance to essentially all of the postemergence herbicides that normally have activity. Preemergence herbicides can control waterhemp for the first part of the growing season, but waterhemp can germinate into midsummer. New postemergence herbicide options are needed.

5. Volunteer glyphosate-resistant corn. The main problem is trying to control volunteer glyphosate-resistant corn in continuous corn fields.   Glufosinate can be somewhat variable for control of volunteer glyphosate-resistant corn. There are no options for control of volunteer corn where the previous year's corn had both glyphosate resistance and Liberty Link traits.

Liberty Link soybeans

Liberty Link corn has been available for a number of years, and Liberty Link soybeans will be available for planting starting in 2009. Unlike corn, the Liberty Link trait is not likely to occur in conjunction with the glyphosate resistance trait in soybeans, at least not at first. Liberty Link crops are resistant to glufosinate, for which Ignite 280SL is the latest formulation. Glufosinate is a broad-spectrum herbicide that can control many the annual grass and broadleaf weeds that occur in soybean fields. However, it is most effective on weeds that are less than 4 to 6 inches tall, and there is the risk of inadequate control where growers assume that glufosinate is capable of controlling large weeds. As a result, the most consistently effective control will occur where Ignite is applied postemergence following the preemergence application of a broad-spectrum residual herbicide. Glufosinate has primarily contact activity on plants, so spray volume and nozzle selection can be more critical than for glyphosate and other systemic herbicides.

Does it resolve current issues?

Glufosinate can be an effective tool for control of common and giant ragweed and waterhemp populations that have developed resistance to glyphosate and/or ALS inhibitors. Multiple postemergence applications, or a combination of preemergence residual herbicides and postemergence glufosinate applications are likely to be needed in moderate to dense giant ragweed infestations. Glufosinate can control small marestail plants that emerge after soybean planting, but often does not adequately control large plants. Common lambsquarters is one of the weeds that glufosinate can be generally weak on (plants must be very small to be consistently controlled), and this weed should be controlled by residual herbicides applied at planting in Liberty Link soybeans.

Optimum GAT

Optimum GAT is new technology that combines resistance to glyphosate and ALS-inhibiting herbicides. This technology was developed by DuPont and will appear in Pioneer corn hybrids and soybean varieties within the next several years. The technology combines a new glyphosate metabolic inactivation mechanism with an ALS enzyme that is insensitive to all five classes of ALS herbicides, including sulfonylurea and imidazolinone herbicides. The Optimum GAT trait can allow for higher glyphosate application rates and a wider application window than other products currently available. The ALS resistance should broaden the window of application of ALS inhibitors in corn, and generally results in less risk of injury and yield loss from postemergence applications to large corn. It also allows for the expanded use of certain ALS inhibitors that previously were too injurious (e.g., use of chlorimuron or imazpyr on corn), or novel ALS herbicides.

Does it resolve current issues?

Whether there is considerable benefit to technology that allows the use of higher glyphosate rates or application to crops more advanced in growth stage is debatable. Weed populations with tolerance or a low level of resistance to glyphosate can respond to higher glyphosate rates, but this will often be a less successful strategy than mixing glyphosate with other herbicides. The ALS resistance trait may result in the use of more effective ALS herbicides, which could certainly improve control of certain weeds. However, the overall utility of ALS inhibitors in soybeans for control of glyphosate-resistant ragweeds and marestail has been variable due to widespread ALS resistance, and most waterhemp populations do not respond to ALS inhibitors.

Dow Herbicide Tolerance (DHT)

Dow Herbicide Tolerance (DHT) confers resistance to 2,4-D in corn and soybeans, and may be available within the next 4 to 5 years. DHT corn is also resistant to foliar-applied aryloxyphenoxypropionate grass herbicides (“fops” - Fusion, Fusilade, Assure II/Targa). 2,4-D, a broad-spectrum systemic herbicide, remains an extremely important component of no-till herbicide programs for corn and soybeans. It controls or helps control most broadleaf weeds, and has a history of working well in mixtures with glyphosate. The development of weed populations with resistance to 2,4-D has been relatively rare, but does occur in wild carrot populations in Ohio and Michigan (and most likely Indiana).

Does it resolve current issues?

Combinations of 2,4-D with glyphosate have effectively controlled glyphosate-resistant ragweeds, marestail, and lambsquarters in preplant burndown treatments. Crop tolerance that allows preemergence (at planting) and postemergence use of 2,4-D in soybeans would help resolve many glyphosate and ALS resistance issues. Postemergence use of

2,4-D in corn has been limited to early growth stages to avoid injury, and DHT technology would allow a wider window of application and increased utility.

Dicamba-resistant soybeans

Soybeans with resistance to dicamba are being developed by Monsanto, and could be available within the next 5 years. Dicamba resistance would be available only in conjunction with glyphosate resistance, presumably the Roundup Ready 2 Yield trait or a successor. Dicamba, a broad-spectrum systemic herbicide with activity on most broadleaf weeds, has a history of working well in combinations with glyphosate. The substantial utility of dicamba in corn herbicide programs indicates that it would help resolve broadleaf control issues in soybeans. It has been used in the south for preplant control of marestail in soybeans, but preplant applications have been limited in the Midwest due to greater risk of crop injury. The development of weed populations with resistance to dicamba has been extremely rare.

Does it resolve current issues?

Crop tolerance that allows preemergence and postemergence use of dicamba could help resolve many glyphosate and ALS resistance issues. Dicamba has substantial activity on the broadleaf weeds that are currently problematic in glyphosate-resistant crops. Dicamba applications might have to be limited to early stages of soybean growth, due to volatility issues that become more likely as temperatures increase in the summer.

HPPD-resistant soybeans

Bayer has developed a trait that confers resistance to HPPD inhibitors in soybeans, which would apparently be used in conjunction with a trait for glyphosate resistance (and also glufosinate resistance?). It is unclear at this time whether the HPPD resistance trait confers resistance to all currently available HPPD inhibitors: Callisto, Balance, and Impact.

Does it resolve current issues?

It depends on which HPPD inhibitors could be used in soybeans, and how they could be applied. Balance lacks substantial foliar activity, but could provide residual weed control when applied at the time of soybean planting or in early postemergence treatments. Balance has substantial residual activity on waterhemp, common ragweed, and lambsquarters (and marestail?), and partially controls giant ragweed. Impact and Callisto could have considerable utility in postemergence applications to soybeans for control of these same weeds, especially when used in combination with glyphosate.

Are there downsides to new herbicide tolerance traits?

The introduction of these traits should help resolve some of the weed control issues that have developed in glyphosate-resistant crops, and help prolong the utility of glyphosate. However, the eventual availability of all of these traits presents some new challenges, and the herbicides they are associated with are not without their own issues. Some examples of these challenges:

- Herbicide-tolerant crop technology in the Midwest has to this point consisted primarily of glyphosate resistance in corn and soybeans, and on glufosinate resistance in corn. Still, fields of corn and soybeans have been sprayed with glyphosate or glufosinate erroneously, and crops severely injured or killed. Problems of this nature can only become more frequent when all of the potential herbicide tolerance traits discussed here are available. Not only will applicators have to track whether the crop in a field is glyphosate-resistant, but which of the other herbicides it has resistance to: 2,4-D, dicamba, or glufosinate. Growers have the same issue to contend with – do they plant several different types of herbicide-resistant crops, or just one in order to simplify herbicide application? Sprayer cleanout also becomes more important as a sprayer moves from one field to another that is planted with a different type of herbicide-resistant crop.

- Dicamba has an inherently high vapor pressure, and a tendency to volatilize in high temperatures and under inversion conditions. Use may have to be limited to spring and early summer to avoid problems with off-target movement. A related issue is whether we will observe a higher frequency of dicamba injury to soybean fields that are not planted to dicamba-resistant soybeans. The same issues pertain to 2,4-D, but to a lesser extent because low-volatile amine formulations greatly reduce volatility and off-target movement.
- These herbicide tolerance traits enable the use of herbicides that can resolve many of the current glyphosate-resistant weed problems. However, currently available herbicides can already solve at least some of these issues, and possibly at a lower cost than a new herbicide-tolerant trait/herbicide system. While we tend to focus on the value of these traits for resolving glyphosate-resistant weed problems, many growers have yet to experience these problems due to their effective stewardship of glyphosate. Forcing these growers to pay a higher price for seed that contains a trait that fails to benefit them only reduces their profitability. There also appears to be an assumption that stacking many herbicide tolerance traits in the same seed is always beneficial, but the benefits of multiple traits may not justify a high seed price for many growers.
- None of these traits really resolves the problems with control of volunteer corn in continuous corn systems. Use of DHT corn in continuous corn systems would allow application of Assure II, Fusion, or Fusilade for control of volunteer glyphosate-resistant corn in a given year. However, control of volunteer DHT corn the following year would be problematic, since the volunteers would carry resistance to glyphosate and "fops," and glufosinate for BT hybrids. Stacking herbicide resistance traits only makes the problem worse, and leaves no options for control of volunteer corn in continuous corn, or control of a failed initial corn stand where replanting is necessary. It is possible to come up with a plan where glufosinate-resistant corn is planted the first year, glyphosate-resistant corn the second year, and DHT corn the third year, which would result in viable options for control of volunteer corn in years two and three. The field would then have to be rotated to soybeans, however, and this three-year planting sequence assumes that a grower can find the desirable genetics to do so.

Avoiding the mistakes of the past

With the exception of Liberty Link soybeans, current plans are that all of these traits would be marketed only in combination with glyphosate resistance. Herbicide programs for these crops are likely to still include postemergence applications of glyphosate in combination with dicamba, 2,4-D, or other herbicides that are enabled by the herbicide tolerance trait. The effectiveness of these herbicides does not alter the need for a sound weed management program to maximize control and prolong their utility. More than 10 years of experience with glyphosate-resistant crops indicates that this program should include the following:

1. Ensure a weed-free start at planting through the use of preplant burndown herbicides or tillage.
2. Use residual herbicides to protect crop yields from early season weed interference, improve control of weeds that have extended emergence patterns, and reduce selection for herbicide resistance.
3. Make initial postemergence treatment when weeds are less than 4 to 6 inches tall.
4. Make a second postemergence treatment as necessary to control late-emerging weeds or weeds that survive the initial postemergence treatment.
5. Use as many different sites of action within and among seasons as is economically feasible.