FACTORS INFLUENCING CROP TOLERANCE TO HERBICIDES

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Herbicides are amazing chemicals. Ideally, we expect herbicides to kill weeds and protect our crops from weed competition, without harming the crop. Fortunately, this is the typical case, but herbicides can damage our crops on occasion. To minimize the risk of herbicide-injured crops, we need to understand how herbicides function and factors that affect their activity. We can use this information to make better decisions regarding the risk of crop injury when selecting or applying herbicides.

Herbicide Selectivity

Most field crop herbicides are selective, which means that the herbicide controls certain weeds without harming the crop. For most herbicides, this selectivity is based on the crop's natural ability to metabolize or breakdown the herbicide into non-toxic chemicals before it damages the plant. There are other cases where herbicide selectivity is based on placement. One example of selective placement is when Prowl is applied preemergence in corn. Prowl is sprayed on the soil surface so it is positioned above the level where the corn roots develop. This protects the corn roots from Prowl damage. Occasionally, herbicide selectivity is obtained because the herbicide does not bind to the target site in the plant. For instance, the postemergence grass herbicides like Assure II bind to and inhibit the ACCase enzyme in grasses, which kills them. However, these same herbicides do not bind to the insensitive form of the ACCase enzyme that exists in soybeans and other broadleaf plants. As a result, soybeans are rarely affected by these postemergence grass herbicides. Discovering herbicides with the desired selectivity (one that controls many major weeds without injuring one or more crops) is done by testing hundreds of thousands of chemicals. Fortunately, the chemical companies have discovered many herbicides that our crops can naturally tolerate with only a slight risk of injury.

Until recently, if a good herbicide was available, but the crop could not tolerate the herbicide, there was little hope for using the herbicide in that crop. Now, scientists can use biotechnology to make crops resistant to the herbicide of choice. Resistant crops have been created by using four different techniques:

1. Using chemicals to cause mutations in seeds or pollen and selecting the resulting plants for resistance. STS soybeans were selected using seed mutation and one imidazolinone tolerant corn line was selected using pollen mutation.
2. Selecting herbicide resistant plants from tissue culture. Tissue culture is the technique of growing plant cells in the laboratory. Resistant cells are selected and regrown into resistant plants. Sethoxydim- (Poast Protected) and imidazolinone- (Clearfield) resistant corn lines were selected from tissue culture.
3. Inserting a new gene into the plant that produces a target site enzyme that is insensitive to the herbicide. This new enzyme will produce the needed products even though the herbicide blocks the activity of the natural enzyme in the plant. Glyphosate resistant (Roundup Ready) soybeans and corn were created this way. Because a gene from another species was inserted into these crops, these crops are classified as genetically modified organisms (GMO).

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4. Inserting a new gene into the plant that produces an enzyme that metabolizes the

herbicide. Glufosinate resistance (Liberty Link) in corn and soybeans was created by inserting a metabolism gene. These crops are also classified as GMOs.

Risk of Crop Injury

In general, the risk of crop injury differs and depends upon the type of selectivity. For the herbicide resistant crops, there is a very low risk of injury from the designated herbicide on Roundup Ready, Liberty Link, STS, and Poast Protected crops. Crops with naturally insensitive enzymes such as soybeans to the postemergence grass herbicides (ACCase inhibitors) have a near zero risk of injury. Some injury can occur on Clearfield corn and may be more similar to the risk of injury that exists with herbicides that have metabolism-based selectivity.

There is a greater risk of herbicide injury with herbicides that have metabolism- or placement-based selectivity. For either type of selectivity, we must understand the environmental conditions that affect the herbicide's activity. For metabolism-based selectivity, the herbicide's potential for injuring the crop increases when more herbicide is taken into the plant (this uptake process is also called absorption) or when the crop's metabolism is slowed. Environmental conditions that increase herbicide absorption depend on if the herbicide is soil- or postemergence-applied. For preemergence applications, a germinating crop seedling absorbs more herbicide when more herbicide is available and availability increases when soils have coarser textures or less organic matter. With either coarse textured soils or low organic matter, less herbicide is adsorbed to soil particles, leaving more herbicide available for uptake by the crop seedling compared to soils with either higher organic matter levels or finer-textures. Greater soil moisture also increases the amount of herbicide that is available in the soil water compared to dry soils where more herbicide is bound to the soil particles.

For postemergence applications, greater herbicide absorption occurs when it is easier for the herbicide to penetrate through the waxy coating on the leaf. This waxy layer is called the cuticle. For instance, the thin cuticle on a young seedling is an easier barrier for a herbicide to cross than a thick cuticle on a older plant. Weather conditions also affect the ease of absorption. A cuticle that is swelled with water because of good soil moisture and high humidity has more "water channels" for a herbicide to diffuse through compared to a drought stressed plant with a dried out cuticle. Higher air temperatures will also increase postemergence herbicide absorption. Of course, adjuvants also have a large effect on postemergence herbicide absorption. In general, the order that adjuvants increase absorption from least to greatest are ammonium fertilizer, nonionic surfactant, crop oil concentrate, and methylated seed oil.

After the herbicide is absorbed, the rate at which a herbicide is metabolized or broken down into non-toxic chemicals is the next step in determining if crop injury will occur for metabolism-based selectivity. The metabolism rate depends on the herbicide, crop, and temperature. Most herbicides are metabolized by plant enzymes and the rate of these reactions increases with higher temperatures. At lower temperatures, these enzymes may not metabolize enough herbicide before some crop injury occurs. Some herbicides labels note when these weather conditions can result in crop injury. For example, the Raptor label recommends delaying applications for 48 hours if the air temperature has been below 50° for 10 or more hours to reduce crop response.

Other variables that can affect the risk of crop injury include the stage of crop growth, genetic differences, and insecticide or herbicide interactions. In most cases, earlier postemergence applications offer greater crop safety than later applications. A very dramatic example of this exists with postemergence applications of Accent to corn in the V7 or V8 growth stage. When applications are made during this late growth stage, the corn plant is developing the number of

rows on the ears and the stress from Accent can cause the ears to become pinched. Crops with certain genetic backgrounds can also be sensitive to injury. Specific corn hybrids or soybean varieties have been noted by seed companies and on herbicide labels as being sensitive to specific herbicides. Several herbicides, especially the ALS-inhibitors, can interact with insecticides to cause injury. For the ALS-inhibiting herbicides, the organophosphate insecticides can slow the rate that the herbicides are metabolized and cause herbicide injury. This can happen with either soil- or postemergence-applied ALS herbicides. Generally, soil type does not affect the risk of crop injury from postemergence-applied herbicides.

Managing the Risk of Crop Injury

Crop injury can range from minor cosmetic symptoms such as leaf burn from a contact herbicide to more severe injury such as damage to the growing point from a translocating herbicide. Assessing the risk and potential severity of this injury is the first step in its management. The risk can be based on information such as the risk of crop injury ratings from the *Pest Management in Wisconsin Field Crops* bulletin (Table 1), knowledge of the factors that affect the specific herbicide's activity, and knowing the field conditions and the weather conditions that are likely to occur.

After you have assessed the risk, select herbicide programs that have low or acceptable risks. Consider the cost if injury occurs (lost yield) versus the cost of other herbicides that may be safer, but higher priced or the additional cost of splitting the application. For instance, a preemergence application of Outlook plus Marksman to corn can provide good broad spectrum weed control. However, if this treatment is followed by a heavy rain in field with low organic matter soil, injury may occur and result in yield loss. The risk of injury from these same herbicides can be greatly reduced by applying the Outlook preemergence and the Marksman early postemergence. Splitting this treatment into two applications will increase the cost, but by avoiding the risk of injury and maintaining the potential for high corn yield, a farmer's net return may be increased.

Other management practices may also lessen the risk of crop injury. For preemergence herbicide applications, it may be possible to lessen the risk of injury by following the specific precautions on the herbicide label (eg. planting corn at least 1.5 inches deep), not using the herbicide on soil types that are at high risk of injury (eg. coarse soils with less than 2% organic matter), and using the lower end of the recommended rate range. For postemergence herbicides that are at risk of causing injury under poor weather conditions, there may be a few options to lessen the risk of injury. If cold, wet conditions often trigger injury with the planned postemergence herbicide and a week of cold, wet weather is forecast, what can be done? If the farmer is relying on a custom applicator, there may be three options: 1) switch to a less risky herbicide if that option exists; 2) switch to a less active adjuvant such as from crop oil to surfactant (if allowed by the label); or 3) delay the herbicide application until warmer weather arrives. The option of delaying the application may be a difficult option for the custom applicator because 1) custom applicators need to keep spraying to stay on schedule and 2) applications need to be made before the weeds exceed the size where they become difficult to control or begin competing with the crop. If a farmer has his own sprayer, he would have greater flexibility to delay the application until better weather conditions arrive and still make the application on time.

Table 1. Risk of crop injury to selected corn and soybean herbicides[a].

Herbicide	Risk of corn injury[b]	Herbicide	Risk of soybean injury
Preplant/Preemergence		Preplant/Preemergence	

Atrazine	N	Alachlor (Lasso/Partner)	VS
Acetamides + atrazine premixes	VS	Authority	S
Acetochlor (Degree, Harness, Surpass, or TopNotch)	VS	Dimethenamid (Frontier, Outlook)	VS
Alachlor (Lasso, Partner, Microtech)	VS	Dual II Magnum	VS
Axiom	S	Boundary	M
Broadstrike+Dual	S/M	Broadstrike+Dual	S
Dimethenamid (Frontier, Outlook)	VS	Command	VS
DoublePlay	VS	Domain	S/M
Dual II Magnum	VS	FirstRate	S
Hornet	S	Pendimax, Prowl	VS
Marksman	S	Pursuit	VS
Pendimax, Prowl	S	Pursuit Plus	VS
Pursuit Plus	S	Sencor	M
Python	S	Python	VS
		Treflan	VS

Postemergence		Postemergence	
Accent	S	Assure II	N
Accent Gold	S/M	Basagran	S
Aim	S	Classic	VS
Atrazine	VS	Cobra	H
Basagran	VS	Extreme	S
Basis	S/M	FirstRate	S
Basis Gold	S/M	Flexstar	M/H
Beacon	S	Fusion	N
Bromoxynil (Buctril, Connect)	S	Glyphosate	N
Celebrity Plus	S/M	Harmony GT	M
Dicamba (Banvel, Clarity)	S/M	Poast Plus	N
Distinct	S/M	Pursuit	S
Glyphosate	VS	Raptor	M
Hornet WDG	S	Resource	M
Liberty	VS	Select	N
Liberty ATZ	VS	Stellar	H

Lightning	S	Synchrony	M
Marksman	S/M	Ultra Blazer	H
NorthStar	S/M		
Permit	VS		
Ready Master ATZ	VS		
Resource	S		
Stinger	VS		
Tough	VS		
2,4-D	M		

[a] Adapted from *Pest Management in Wisconsin Field Crops 2001*, A3646, p. 20-21 and 83-84.
[b] H = high, M = moderate, S = slight, VS = very slight; N = none.

I will make one final comment in regards to new herbicides and crop injury. The introduction of new herbicides invariably creates a lot of dealer and grower interest and high expectations. You are encouraged to try new products that appear to fit your weed situation and soil conditions. However, I suggest that new herbicides are tested on a relatively small scale during the first year because it is likely that much will be learned about crop safety and weed control during the first year of commercial use. If there is crop injury in the first year of use, it would be wise to gain this knowledge on a few hundred acres rather than several thousand acres.