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Introduction

With the current changes in weed management and the onset of glyphosate resistant weed species, soybean farmers are using both additional herbicide modes and action and more preplant herbicide options to supplement glyphosate in their weed management programs. In years with conditions favorable for seedling disease and other disease there are typically concerns and inquiries about the cause(s) of symptoms in agronomic plants. Many of the questions focus on differentiating between plant injuries potentially caused by recent herbicide applications versus symptoms caused by plant pathogens. Chemical injury in row crops is caused by chemicals such as herbicides, fertilizers, fungicides, insecticides, growth regulators, and crop oils when they are applied individually, as a mixture, or together with adjuvants. If chemicals are applied incorrectly, plants may be damaged at any point during the growing season. Chemical injury can result from carryover in the soil, contamination of the spray tank, spray drift, or misapplication. Damage may even be realized with chemical applications when recommended application guidelines are followed if other environmental conditions are adverse, including low soil temperatures, high soil moisture levels, or if young plants are exposed to high levels of various fertilizers. Factors such as the mode of action of the chemical, application rate, growing conditions, and growth stage of the crop determine the extent of injury and symptom expression. Symptoms of chemical damage are diverse and include leaf lesions with burned, necrotic patches, wilting, damping off, and sometimes death of mature plants. These symptoms could easily be confused with those caused by various common plant pathogens. In most instances management actions cannot be taken during the year of injury once you are past the replant timing. Therefore, you will want to correctly identify what is causing any stand problems to aid with future management actions.

Scouting – Determine symptom distribution

Field Distribution:

Symptom distribution in the field and on the plants can be the most valuable clues to the cause of the problem. Diseased plants can be identified by their overall wilting and discoloration of leaves. They will have rotted, decaying roots and/or lower stems. Because some organisms that cause disease survive in the soil, their diseases usually occur in patches in the field — randomly scattered or often associated with low, wet areas (Figure 1). Typically, when chemical injury is the cause, a high percentage of the plants will exhibit symptoms and the distribution will be more uniform across a field or in patterns that may be associated with applications (Figure 2.). Injury is not likely to be concentrated in pockets. Diseased plants also may be randomly scattered among otherwise healthy plants in the field. Field topography will be key in distribution factors. In very flat fields it is possible to have plants with seedling disease scattered across the field but this is rare. In the event that a high percentage of the plants are affected across the entire field, typically another stress or injury is triggering the plant response. Depending on the chemical history, it may be the result of an underlying chemical injury.

Figure 1. Patchy distribution of symptoms in the field often associated with plant disease.

Figure 2. Uniform distribution of symptoms in the field associated with chemical injury.

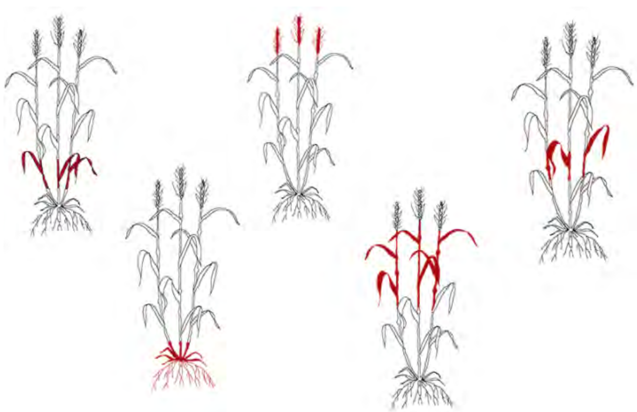

Figure 3. Symptom distribution on the plant level showing various plant parts affected.

Plant distribution

After the distribution of symptoms has been identified in the field, the next level to evaluate is the symptom distribution on individual plants (Figure 3). The actual plant part affected can give critical clues to differentiating the cause of the problem. Most seedling diseases caused by a pathogen will result in root symptoms. Conversely, the roots of a plant displaying herbicide injury on the aboveground parts may be completely healthy.

Plant part distribution

Distribution patterns on the individual plant part (root, stem, leaf) can offer clues as to the pathogen involved. For example, soybean damage at the lower portion of the root system can often be associated with Fusarium, while lesions near the soil line are often due to Rhizoctonia.

Early crop development symptoms and injury

Seedling diseases are common in both soybean and corn. The most common seedling diseases have been those caused by Pythium species. These organisms require wet conditions so that their swimming spores can move toward and infect plant roots. Frequent and/or heavy rainfall events and cool temperatures are very conducive for infection by Pythium species.

Seedling diseases are often difficult to diagnose because their symptoms are very similar among several seedling diseases and may also be easily confused with other problems. Seedling diseases can be confused with insect injury, herbicide damage, planting problems, or environmental stresses that often have similar symptoms. Some of the possible symptoms of seedling diseases are:

- Rotted seed prior to germination
- Rotted or discolored seedlings after germination prior to emergence
- Post-emergence seedling damping off
- Stunting
- Root decay

Carefully dig up symptomatic plants/roots, as any rotted roots may be broken off more easily and lost in the soil. Distribution patterns on the individual plant root systems can offer clues as to the pathogen involved.

Soybeans and preemergence PPO herbicide injury

Three PPO herbicides are predominantly used for pre-emergence weed control in soybeans. These are:

- flumioxazin (in Valor®, Valor XLT®, Gangster®, Enlite®, and Envive®),
- saflufenacil (in Sharpen®, Optill®, Optill® PRO, and Verdict®), and
- sulfentrazone (in Authority First®, Authority Assist®, Authority® MTZ, Authority® XL, Authority® Elite®, Spartan®, and Sonic®).

These active ingredients provide residual control of many important annual broadleaf weeds in soybeans. These products also can be effective in preplant burndown situations – depending upon the rate and weed species — because of their postemergence activity. They can be applied from early preplant to shortly after soybean planting; however, severe injury can occur if they're applied as the soybean is cracking through the soil surface. (All labels of these products warn against applications at this point.)

From a weed management perspective, using these products in a diversified herbicide weed control program is beneficial and can help manage the progression of glyphosate-resistant weed development.

However, if these products are not used properly, as with most herbicides, crop injury can occur. In general, injury potential increases

- as the use rate increases, and/or
- as soil organic matter decreases, and/or
- the closer the application is to planting.

Additionally, there is a variable injury response among soybean varieties, ranging from highly tolerant to fairly susceptible. This variable response has been documented in several areas including research with breeder plant introductions (Taylor-Lovell et al., 2001) and some companies publish list of variety sensitivity. In the future, informing your seed dealer of your planned herbicide program is an important step to avoid pairing a susceptible variety with a preemergence PPO-based soybean herbicide program. Prolonged cool and wet weather conditions are ideal for adverse crop response to these products. Frequent or heavy rains as the hypocotyl arch is cracking through the soil surface or shortly after the cotyledons emerge can cause excessive herbicide uptake and subsequent injury. Cool temperatures reduce the rate at which the plant can metabolize (break down) the herbicide.

Injury will commonly display as reddish to purplish to brownish spots leading to necrotic tissue on the cotyledons and possible whittling of the stem at or near the soil surface. The potential to see injury often remains through the first few vegetative stages. Rain can splash soil with herbicide onto the unifoliates and first trifoliates, causing necrotic spotting and a crinkled appearance to some of the early developing trifoliates. In some instances it is difficult to assign specific levels of stand reduction to suspected causes such as herbicide injury, a soil-borne seedling disease, or cultural problems such as improper planting depth and soil crusting/compaction. Tissue injury from an excessive concentration or uptake of a PPO herbicide could cause points of infection for seedling diseases, while lack of vigor from seedling diseases could reduce a plant's ability to metabolize the PPO herbicide fast enough to prevent injury. Therefore, in many cases it can be difficult to identify the main cause of the injury.

Can herbicide injury result in more disease?

In many instances when an herbicide is applied, even at the labeled rate, there can be some injury to the plant. Even glyphosate on Roundup Ready varieties affects flow in the shikimate pathway that has downstream effects on plant susceptibility. Most studies to date have focused on Rhizoctonia and Fusarium and have not been conclusive at the field level, but pretty consistently show increased disease levels with different modes of action under controlled conditions. The vast majority of publications are related to soybean, but there are a few in corn and other crops. This section will focus on soybean and is a brief summary of some of the key literature related to soybean pathogens.

Fusarium Studies

The application of glyphosate and imazethapyr resulted in an increase in disease severity and isolation frequency of *F. solani* f. sp. *glycines* (SDS pathogen) under controlled conditions (Sanogo et al., 2000). This same publication also showed that glyphosate reduced fungal growth and sporulation in culture. In a combined study across the north central region it was found that there were no consistent effects of glyphosate on SDS severity. One publication focusing on trifluralin concluded that the "hypothesis that the primary effect of trifluralin on the host-pathogen interaction is to predispose soybean seedlings to infection by *F. oxysporum* was supported by their data" (Carson et al., 1991). In 2007, Powell and Swanton reviewed all the Fusarium related studies with glyphosate effects and concluded: "At this time, there is insufficient evidence to prove or disprove a link between glyphosate and crop diseases associate with *Fusarium* spp. and this area should receive high research priority given the rapid and widespread increase in glyphosate use."

Rhizoctonia Stuides

Under controlled conditions, imazethapyr, dimethenamid+metribuzin, pendimethalin, and aciflorfen were found to increase Rhizoctonia root and hypocotyl rot severity (Bradley et al., 2002). These did not all result in significant increases in the field, but different ones resulted in more disease at different locations. In another study when glyphosate tolerant soybeans were treated with pendamethalin or pendamethalin + imazethapyr the combination resulted in more Rhizoctonia infection (Harikrishnan and Yang, 2002). These researchers also noted differences between field and greenhouse studies and identified more disease in pendimthalin treated soybeans, which is in the same chemical class as trifluralin which has also been shown to increase Rhizoctonia (Wiley and Ross, 1974) and Fusarium infection (Carson et al., 1991). The effect of trifluralin was demonstrated again to increase susceptibility to Rhizoctonia in greenhouse seedlings in 2005 (Montazeri and Hamdollah-Zedeh).

Management

The best strategy for avoiding chemical injury is to follow label instructions and restrictions when applying an herbicide or any crop protection product. Application equipment should be correctly calibrated to avoid misapplication and applications should be avoided during extreme environmental conditions, such as gusty winds and high or low temperatures. Several products being added to the glyphosate weed management program have the potential to injure soybeans, and growers must be prepared for this with the application. The level of injury will vary with herbicide choice, rate of use, application timing, current weather, and soybean variety.

Herbicide application is a benefit to crop production overall and manages plant competition of the weeds to the crop as well as potential interaction of weed species as reservoirs or alternative hosts for many soil borne pathogens. If a disease interaction is proven to exist, the key to avoid more injury will be to avoid certain modes of action that have been demonstrated to affect disease development in the specific crop. As more information is derived and conclusions are made this could alter future weed management plans in fields with consistent problems related to specific diseases.

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