CAUSES AND MANAGEMENT OF SOYBEAN LEAF PUCKERING

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Each year from mid-June throughout July there is strange phenomenon that materializes across many soybean fields throughout the Midwest. The "unusual" symptoms that appear throughout these fields include soybean plants that have cupped or "puckered" leaves. The most frequently reported scenario is that these symptoms are noticed soon after a soybean field has been sprayed with a postemergence herbicide. These symptoms have appeared as early as 3 days after application up to 3 weeks after application. In fact, in some cases there are entire soybean fields that have not received a postemergence herbicide application that have shown soybean leaf cupping.

Symptoms Affecting Soybeans

The types of symptoms that are frequently reported include: 1) Extreme cupping of trifoliate leaves, usually more pronounced on the upper trifoliates. 2) The veins of affected leaves tend to assume a parallel orientation instead of the usual net venation pattern. 3) The tips of the cupped leaves with parallel veins are often brown in color. 4) Plants are usually stunted as compared with plants not demonstrating the aforementioned symptoms. These plants may remain stunted for the remainder of the season, but this does not always happen.

What Causes This Phenomenon?

The most difficult issue regarding puckered soybean leaves is identifying what the cause or the causal agent(s) are that led to this phenomenon. There are several theories that have been put forth by weed scientists and agronomists to possible causes. It is very unlikely that only one of these possibilities will explain the cause of the puckered soybeans in all instances.

Theory 1: *Somehow, the soybeans were exposed to a growth regulator herbicide used for weed control in corn.*

The growth regulator herbicides tend to mimic the effects of endogenous plant hormones, in particular auxins. Plant hormones control many developmental processes affecting the growth of the plant. These hormones are physiologically active within the plant at extremely low concentrations (parts per million or billion). Exposing a soybean plant to a synthetic type of hormone (i.e., a plant growth regulator herbicide) can induce a wide range of responses within the plant ranging from slight morphological modifications (leaf abnormalities for example) to plant death. The degree or severity of response is partially dependant upon the concentration of herbicide the plant was exposed to as well as environmental conditions and crop stage and variety. The literature has many references to research conducted on the response of various crops to exposure of sub-lethal amounts of various growth regulator herbicides. Many of these studies were conducted more than 20 years ago, but the symptoms of exposure these studies describe are very similar to those encountered during this and previous growing seasons.

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How much (concentration) growth regulator does it take to induce symptoms? Dicotyledonous plants can and do vary in their sensitivity to growth regulator herbicides. In field demonstration studies, leaf cupping/distortion was observed when soybean plants were exposed to Banvel at a rate of 1/10,000 of the field use rate. Stage of plant growth when exposure occurs can also influence the amount of injury induced. Several studies have reported that soybeans were more tolerant to exposure to growth regulators when in early vegetative development as compared with exposure when plants were larger and nearing the reproductive stage.

The herbicide most often discussed or implicated in the cupping response of soybeans is dicamba (Banvel and Clarity) and dicamba-containing products (Distinct, Marksman, NorthStar, and Celebrity Plus). Other herbicides that can cause leaf-cupping symptoms include exposure to 2,4-D and clopyralid-containing products. How would soybeans be exposed to these corn herbicides? There are three possible avenues of exposure.

a) Residues remaining in the spray tank or on the spray equipment from previous applications in corn fields are detached and applied with the soybean herbicide at low concentrations. Labels of products containing dicamba provide techniques for cleaning application equipment to remove residues. The procedure from the label of Banvel states to:

> *1) Hose down thoroughly the inside as well as outside surfaces of equipment while filling the spray tank half full of water. Flush by operating the sprayer until the system is purged of the rinse water.*
> *2) Fill tank with water while adding one quart of household ammonia for every 25 gallons of water. Operate the pump to circulate the ammonia solution through the sprayer system for 15 to 20 minutes and discharge a small amount of the ammonia solution through the boom and nozzles. Let the solution stand for several hours, preferably overnight.*
> *3) Flush the solution out of the spray tank through the boom.*
> *4) Remove the nozzles and screens and flush the system with two full tanks of water.*

If these cleaning procedures are not followed exactly, how much residue would remain in the application equipment and would it be enough to cause injury to soybeans? Many producers and applicators who reported puckered soybeans in the past indicated that the symptoms appeared to follow the spray equipment "to the row". Drift (discussed next) generally does not stop at a selected row in a field. Rather, there is often a feathering effect - symptoms are most severe on the side of the field closest to the source of drift and lessen with increasing distance. Unfortunately, failure to thoroughly clean the application equipment does not appear to explain the reported cases of "...the soybeans sprayed with the first load puckered, those sprayed with the second and third loads are fine but the ones sprayed with the fourth load puckered" when all other factors are held relatively constant.

b) Herbicide vapors on the plant or soil surface move out of the treated area and are absorbed by soybeans (vapor drift). The volatility of a herbicide is a function of several factors: those related to the formulation of the herbicide and those related to prevailing environmental conditions. Vapor pressure is a measure of the tendency of a herbicide to volatilize. As the vapor pressure of a herbicide increases, the potential for volatility also

increases. Ester formulations of 2,4-D are generally significantly more volatile than amine formulations. Banvel is formulated as the dimethylamine salt of dicamba, Clarity as the diglycolamine salt, and Marksman as the potassium salt. Each of these salt formulations differs in their potential to volatilize. With respect to environmental conditions, volatility tends to increase as soil moisture and temperature increase. As soil moisture decreases, the amount of herbicide adsorbed to soil particles can increase and thus reduce the amount of herbicide available to volatilize.

c) Physical drift of spray particles during the actual application process. This cause of exposure may be the easiest to identify based on field observations. The labels of many postemergence herbicides have statements regarding wind speed and drift. Most specify that applications should not be made when wind speed is in excess of ***x*** miles per hour or moving toward a sensitive crop. Soybeans exposed to growth regulator corn herbicides through drift will usually have been exposed to a much greater amount of herbicide than if the exposure had occurred via the processes outlined previously in a or b. The symptoms from exposure to high doses are often different than those caused by exposure to very low doses.

Theory 2: The soybean plant is expressing a physiological response to somewhat adverse growing conditions.

This theory generally attempts to exclude exposure to a growth regulating herbicide as the causal agent. Rather, soybeans express cupping symptoms due to environmental factors that adversely impact growth. Very few components in the puckered soybean "equation" have held consistent over the past several years except the majority of cases are not noticed or reported until after the first few days when air temperatures exceed 90 degrees. Soybeans may be entering into a phase of very rapid growth and development and some speculate that this phase may disrupt the hormonal balance within the plant. This theory exists because there have been cases of puckered soybeans that had not been sprayed with any postemergence herbicide and no corn fields were nearby. However, currently there is no data that supports this theory.

Theory 3: The response is induced by a postemergence herbicide application.

The majority of calls and soybean samples that we receive that demonstrate leaf puckering were previously treated with a postemergence herbicide, usually a translocated herbicide such as Pursuit, Synchrony STS, Classic, FirstRate or a glyphosate-containing product, but in some instances a contact herbicide. Many of these applications include spray additives such as oil concentrates (petroleum or vegetable base) and an ammonium nitrogen fertilizer (28% UAN or ammonium sulfate). How can these applications induce puckering? Some theoretical explanations include:

a) Translocated herbicides move into the apical meristem, the location of hormonal control, and disrupt the hormone balance of the plant. Following the disruption of hormonal balance, the plant exhibits some response such a leaf cupping or puckering.

b) The spray additives are able to remove dicamba residues from the spray equipment (see 1a above).

c) If 28% UAN was used, the level of biuret may be high enough to induce the response.

So what exactly is the cause of puckered soybeans? In short, no data exist that definitively explain every case of puckered soybeans. It is unlikely that one "blanket" explanation exists - each case may be somewhat unique. Data exists that describes the response of soybeans to exposure to growth regulator herbicides, but other factors may also be at work. If puckered soybean plants were actually exposed to a plant growth regulator herbicide such as dicamba, will yield be adversely effected? The available literature tends to suggest that this type of injury does not always necessarily result in soybean yield loss, but several factors are involved in determining if yield loss will occur. In particular, soybean variety, time of exposure, and dosage are important factors that determine if yield loss will or will not occur. Much of the available research suggests that if minor exposure occurs during early vegetative development, yield loss is less likely to occur than if exposure occurs when soybean have entered the reproductive stage of development.

Current research at the University of Illinois is investigating soybean leaf cupping in the field and laboratory. In particular, molecular biology techniques are being utilized to determine if a diagnostic tool can be developed to conclusively identify if leaf cupping or puckering is due to exposure from growth regulator herbicides. This research has recently identified a gene which is expressed when the plant is exposed to growth regulator herbicides. If this tool is successfully developed it may narrow down some of the mystery that often follows the soybean leaf puckering phenomenon.