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Iowa corn and soybean growers have had a long history of working with the herbicide dicamba, the active ingredient that was originally sold as Banvel. In fact, dicamba was registered 42 years ago. During this time, corn growers have frequently used dicamba products to effectively manage many broadleaf weeds in corn with either preemergence or early postemergence applications. However, growers have also learned that soybeans are highly sensitive to dicamba. With the adoption of glyphosate-resistant corn hybrids and the availability of new corn herbicides, growers and applicators may be inclined to think that worries about dicamba are history. Nevertheless, situations arise each year where dicamba has caused damage to soybeans. Many growers are also aware of new herbicide-resistant traits that are under development, including dicamba-resistant soybeans. If dicamba is used in dicamba-resistant soybeans, growers and applicators should be prepared to use this technology in a manner to lessen the risk of off-target injury.

Dicamba and symptomology background information

Dicamba is the common name for the active ingredient used in Banvel, Clarity, and many other formulations (e.g. Rifle, Sterling, Sterling Blue, and Vanquish). Dicamba is also a component in several premixtures such as Distinct, Status, Marksman, Northstar, and Weedmaster. Dicamba is classified as a growth regulator herbicide because it mimics the natural plant hormones called auxins, which regulate numerous growth processes. When dicamba is applied to a plant, it deregulates gene expression and leads to abnormal cell division, cell elongation, epinasty, and other deleterious effects. Because dicamba can translocate in the phloem along with sugars, it can accumulate in meristems or growing points where it can disrupt cell division. It can also stimulate cell division in mature stem tissues and result in the formation of callus tissue. The swollen, split stems of velvetleaf or pigweed that have tumor-type growths after an application of dicamba are an example of this callus growth.

Soybeans are particularly sensitive to dicamba. When a soybean plant is exposed to low dicamba doses, leaves that already expanded will generally not show visual symptoms. Leaves that are still expanding or developing in the growing point will show symptoms that are often described as leaf puckering. Leaf strapping with parallel veins can also occur, often with higher doses of exposure. One key in differentiating dicamba-induced injury from other causes of leaf distortions on soybeans is the pattern in which the symptoms are expressed on the soybean plant. Puckered leaves often will not be noticed until about 10 days after soybeans have been exposed to dicamba because this is the length of time for the second new trifoliate leaf to develop which often has noticeable injury. Because dicamba is acting at the meristem where leaves are developing, it is common for about five new trifoliate leaves to exhibit symptoms after exposure before the plant "grows out" of the injury. The puckered soybean leaflets are also rather diagnostic since the tip of the leaf is often blunted and yellowish as this portion of the leaf was not able to expand and develop normally. If the damage at the growing point is severe and its growth is inhibited, the axillary buds will be released at the leaf nodes and the soybean plant may grow one or more branches. The first trifoliate leaves on these branches will also exhibit leaf puckering. This pattern of symptomology is different than the damage of other herbicides like the PPO-inhibitors that may crinkle new soybean leaves. The PPO-inhibitors are contact herbicides and their damage will usually only affect one trifoliate, not a series of new leaves like dicamba. A photo gallery of dicamba injury symptoms and mimics is available in the bulletin Dicamba injury to soybeans (Proost and Boerboom 2004) and can be downloaded for review.

Soybean exposure to dicamba

The three primary routes that dicamba can move to soybeans are by 1) spray particle drift, 2) volatility, and 3) spray tank contamination. In my experience in receiving questions and complaints about dicamba injury to soybeans, I would rank spray tank contamination and spray particle drift as the two primary causes of injury with volatility as a less frequent source. Although dicamba use on corn has greatly diminished this decade (only 4% of Iowa corn acres were treated with dicamba in 2005 as compared to 34% in 1995 [NASS]), drift can still be an issue. Dicamba was either the third or fourth most common pesticide cited in drift complaints during 2002 to 2004 by the Iowa Department of Agriculture (AAPCO 2005).

Spray particle drift

Droplet size plays a major role in particle drift. Small droplets take longer to reach the ground, increasing their susceptibility to drift. For example, a droplet from a fine spray (100 microns) takes 10 seconds to fall 10 feet whereas a droplet from a coarse spray (400 microns) takes only 2 seconds. Add a 3 mph wind, and the fine droplet will drift 44 feet while the coarse droplet will drift only 9 feet.

The Spray Drift Task Force reported that drift from 8004 flat fan nozzles at a 20 inch height with 40 psi and an 8 mph wind was about 0.5% at 25 ft, 0.2% at 100 ft, and 0.125% at 200 ft. This level of drift may not be noticeable with many herbicides, but dicamba drift at any of these levels can cause soybean injury. In these studies, drift was greatly increased with higher boom heights or smaller droplet sizes. It is impossible to eliminate tiny drift-prone droplets, but they can be minimized with proper application techniques for correct boom height, spray pressure and nozzle selection.

Dicamba vapors

A second source of dicamba movement from corn fields is when dicamba volatilizes to a vapor. All dicamba formulations volatilize, but some volatilize more than others. For example, in a study where field corn was sprayed to test dicamba volatility, the dimethylamine salt of dicamba (formulation used in Banvel) injured adjacent soybeans about twice as much as when the sodium salt of dicamba (formulation used in NorthStar). Weather conditions play an important role in increasing or decreasing volatilization. For example, volatilization and the potential for vapor movement increases at high temperatures and low relative humidity. However, as little as 0.04 inch of rainfall can dramatically decrease volatilization by washing dicamba off corn and weed leaves and onto the soil where it is less likely to volatilize. Overall, the potential for dicamba vapor movement is greatest under hot, dry conditions during and after the application.

Contaminated Spray

The third source of dicamba movement to soybeans is contaminated spray. This may occur from a contaminated spray tank, make-up water or nurse tank, transfer hoses, measuring containers, screens with residues, or re-used jugs. It has been reported that as little as 0.01% contamination with dicamba can cause minor leaf puckering on soybean. To illustrate how small this amount is, consider a 500 gallon spray tank that applied Clarity at 1 pt/a. If 6.4 oz (3/4 cup) of this spray solution remained in the tank, sump, or lines, this amount would be sufficient to contaminate the next 500 gallon load at the 0.01% level.

It's important to note that even spray tanks cleaned using common procedures (rather than more thorough label directions) can leave measurable concentrations of dicamba. Weed researchers at UW tested a sprayer for residues after spraying dicamba. The tank was drained, washed with an ammonia-water solution which was also flushed through the booms, and re-filled with water. The water from the spray tank and water sprayed out of the boom was sampled and analyzed for dicamba (Table 1). The dicamba concentration in the spray tank's water was extremely low, but the concentration may have been sufficient to cause minor injury symptoms. The water from the spray boom contained a higher concentration of dicamba which might cause moderate soybean injury. This concentration suggests the boom was not adequately cleaned.

Table 1. Dicamba residues detected in water after a sprayer was drained, washed and flushed with an ammonia-water solution, and re-filled with water.

Water source	Dicamba (ppb)	Percent of use rate*
Spray tank	945	0.02%
Spray boom	24,800	0.63%

*based on 1 pt/a Banvel or Clarity applied in 15 GPA water.

Similarly, small amounts of dicamba from the improper use of an old jug to shuttle glyphosate or adjuvants can contaminate spray solutions. The reuse of old herbicide containers in this manner is illegal. Only 0.05 oz of Banvel or Clarity would contaminate a 500-gallon load (calibrated to spray 15 GPA) at the 0.01% level. A non-rinsed jug could certainly retain this small amount of dicamba.

Dicamba injury and soybean yield loss

Without a doubt, extremely low dicamba concentrations can cause soybean injury symptoms. Minor symptoms, while often causing concern, do not result in yield loss. As dicamba concentrations increase, injury symptoms and the potential for soybean yield loss also increase (Table 2). The level of yield loss depends on the amount of dicamba that reached the soybean and the plant's growth stage. It's impossible to state the exact dicamba concentration that causes yield loss due to soybean's ability to recover from injury, differences among varieties, and variation in growing conditions among years. Certain soybean herbicides may also act synergistically with dicamba to increase the potential for yield loss (Brown et al. 2009, Kelley et al. 2005). Yield is most often lost when severe injury symptoms persist through the growing season. In general, experiments have shown that soybeans recover from minor to moderate dicamba injury in the vegetative stage without suffering significant yield loss. However, yield loss is more likely to occur when soybeans are exposed to dicamba after they begin to bloom. Fortunately, soybeans are more frequently exposed to dicamba in the vegetative stage than in the reproductive stage.

Table 2. Summary of three simulated dicamba drift studies on soybean yield. The dicamba rates are expressed on the basis of a 4 lb ae/gal formulation like Banvel or Clarity and yields are expressed as a percentage of nontreated soybeans.

Boerboom (2004)		Wax et al. (1969)			Auch and Arnold (1979)			
Dicamba rate	Stage V2-3 Yield	Dicamba rate	Prebloom Yield	Bloom	Dicamba rate	1-2 trifol. Yield	3-4 trifol.	Early bloom
(oz/a)	(%)	(oz/a)	(% of control)		(oz/a)	(% of control)		
0.01	98	0.03	91	82	0.03	100	110	114
0.02	99	0.12	85	86	0.30	108	102	91
0.04	91	0.25	93	80	1.6	100	80	46
0.16	81	0.50	86	49				
		1.00	81	26				

Evolving issues with dicamba

The use of dicamba as the sole or primary herbicide for broadleaf weed control in corn has diminished as previously noted. However, dicamba use has regained some momentum when Status is used as a tank mix partner with glyphosate when spraying glyphosate-resistant corn hybrids. Status is a mixture of dicamba plus diflufenzopyr plus safener. While the actual rate of dicamba in Status is less than the historical use rate in Banvel and the use rates of Status with glyphosate may be reduced compared to labeled rates, Status still contains dicamba and it can elicit symptoms on soybeans and reduce yield at higher rates (Table 3). Growers and applicators still need to be mindful of the potential for spray particle drift, volatility, and spray tank contamination with this new use pattern of dicamba.

Table 3. Soybean injury and yield following simulated drift of dicamba plus diflufenzopyr when applied to soybeans with 2 to 3 trifoliate leaves. The referenced rate is based on the Distinct formulation (Brown et al. 2009).

Dicamba/diflufenzopyr rate	Injury after 28 days	Soybean yield
(oz/a)	(%)	(% of control)
0.04	18	94
0.2	31	94
0.4	43	87
0.8	60	69

A controversial combo

The title of this proceedings and presentation references the controversial combination of dicamba and soybeans. Frequently the current controversy is whether or not dicamba caused the observed leaf puckering symptoms on the soybeans. There is often a degree of denial that drift or volatility could have occurred over the required distance to cause the injury or that a spray tank could have been contaminated after cleaning. However, if the pattern and symptoms on the soybeans match those of dicamba, there is often a dicamba source that will explain the problem. It is important to recognize the incredibly low dose of dicamba that can trigger injury symptoms on soybeans and accept this potential.

A second controversial combination of dicamba and soybeans could develop in the future with the introduction of dicamba-resistant soybeans. If this technology is adopted on a modest or major scale, the number of acres treated with dicamba will increase again. Since dicamba was used on a significant percentage of corn acres in the past, this would not seem to pose any unique concerns. However, the use pattern of dicamba in soybeans may be different than when dicamba is used in corn. One key consideration may be the environmental conditions at the times of application. If dicamba is used in preplant burndown applications in soybeans, risks of off-target movement would seem to be similar to current uses in corn, but postemergence use in soybean may differ substantially from use in corn. Early postemergence applications in corn may be almost one month earlier than current glyphosate applications in soybeans. If dicamba is applied with glyphosate, dicamba may be applied when weather conditions are warmer than when corn is sprayed. For Des Moines, IA, the average maximum temperature in May is 73 F and the average maximum in June is 82 F. Higher temperatures during applications to soybeans may increase the risk of dicamba volatility and off-site movement.

A second consideration for dicamba use in soybeans is the greater potential for application errors. If dicamba is applied with sprayers that are treating both dicamba-resistant soybeans and soybeans that lack this trait during the same time period, tank contamination problems may increase in frequency. Previously, dicamba was generally applied to corn before soybeans were sprayed. This separation in application periods greatly reduced the potential for tank contamination problems. However, dicamba plus glyphosate applications would likely be made during the same time period as traditional glyphosate applications. Dedicated sprayers or thorough dicamba tank cleanout will be needed to avoided serious soybean injury.

The impending challenges with dicamba-resistant soybeans are not unique to this trait or technology. Soybeans with 2,4-D resistance are under a similar time line for development as dicamba-resistance. While soybeans may not be as sensitive to 2,4-D as dicamba, tank contamination will still be a concern and 2,4-D volatility will also be a concern for other sensitive crops like grapes and tomatoes. Other herbicide-resistant traits under development include Optimum GAT soybeans, which combines an ALS resistance trait with glyphosate and the potential for HPPD-resistant soybeans. In both cases, tank contamination can cause noticeable injury to soybeans that lack that specific resistance trait. In all of these cases, growers and applicators need to be well educated to understand the limits to these new technologies so that they can be used to their full potential without causing unfortunate and costly accidents.

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