Understanding Dicamba Volatility

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Dicamba is a synthetic auxin herbicide (Group 4) that has been commonly used for broadleaf weed control in corn, sorghum, small grains, pasture, and turf. Dicamba is now also used in novel dicamba-resistant soybean (Roundup Ready 2 Xtend® and XtendFlex®) for control of broadleaf weeds (i.e. waterhemp, giant ragweed, horseweed) that have evolved resistance to glyphosate and other commonly used herbicides. Dicamba use in dicamba-resistant soybean has led to more cases of dicamba injury to non-target plants, especially non-dicamba-resistant soybean, which can occur from spray tank contamination, particle drift, applications during temperature inversions, and/or volatilization. Certain broadleaf species are highly sensitive to this herbicide. For example, it is estimated that only 0.044 ml/acre (0.0154 g active ingredient/acre) of the herbicide Xtendimax would be needed to cause 5% visual injury to non-dicamba-resistant soybean plants (Figure 1).

Volatilization is one potential method of off-target dicamba movement which can result in unintended injury in sensitive species. For dicamba to be approved for use in soybeans, crop protection industry companies developed less volatile dicamba formulations (released in 2017) and volatility reducing agents (released in 2021) which are required for use in dicamba-resistant soybean. Despite the use of less volatile dicamba products and tank-mix additions to reduce volatility, volatilization is still being reported as the culprit of some of the dicamba off-target movement reported in the US. This factsheet was developed to help applicators, farmers, and decision influencers better understand the complexity of dicamba volatilization and make responsible application decisions to minimize injury on neighboring crops/vegetation.

Various dicamba injury symptoms in soybean from volatilization (~21 days after exposure)

How volatile is dicamba?

The potential for volatilization of a chemical can be correlated to its vapor pressure. Herbicides with higher vapor pressure are more prone to volatilization. Dicamba is more volatile than the herbicide active ingredients glyphosate, glufosinate, 2,4-D, and trifluralin but less volatile than clomazone (Table 1). The high potential for volatility isn't the only factor driving large scale dicamba injury. There is a combination of factors that contribute to the high frequency of dicamba injury observed in soybean compared to these other herbicides including the extremely high sensitivity of soybean to dicamba, the presence of more susceptible vegetation during a post-emergence application timing (trifluralin and clomazone are applied at preemergence), and more field area treated with dicamba compared to some other volatile herbicides (i.e., trifluralin, clomazone).

Figure 1. Visual representation of 0.044 ml of red dye next to a quarter. [Photo credit: Dr. Andrew Kniss https://plantoutofplace.com/2018/12/how-much-dicamba-is-required-to-injure-soybeans/}

Table 1. Vapor pressure and volatilization potential of various herbicides (Higher vapor pressure indicates a higher volatility potential)

Active ingredient	Trade name (example)	~Vapor Pressure* (mm Hg at 25C)	2020 a.i. % Treated U.S. Soybean Acres**	Volatility Potential (Lowest to Highest)
glufosinate	Liberty	0.000000000009	17	
glyphosate	Roundup	0.000000098	94	
2,4-D	2,4-D Ester	0.00000706	30	
trifluralin	Treflan	0.0000458	1	
dicamba	XtendiMax	0.0000125	24	
clomazone	Command	0.00014	-	

Note that clomazone is more volatile than dicamba

*Source: PubChem. https://pubchem.ncbi.nlm.nih.gov/
**Application data includes all applications following harvest of the previous crop until harvest of the 2020 soybean crop, Source: USDA NASS. https://quickstats.nass.usda.gov/results/01439D0D-C74B-37E6-95CA-2F65EF91B816#02F3F29F-5252-34AF-BAA1-9CC4B35F5711

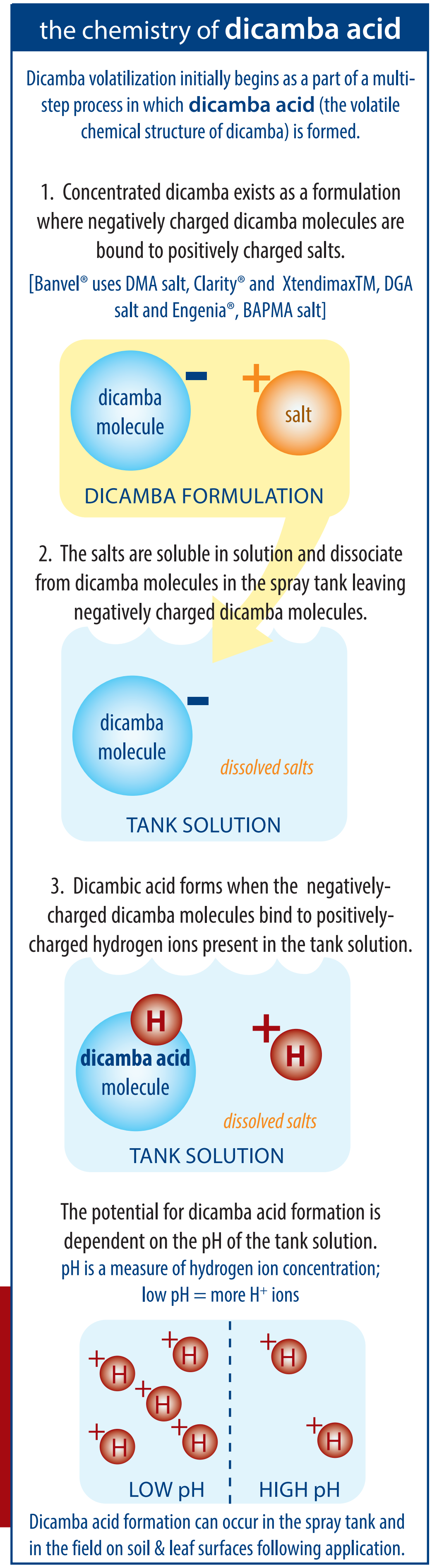
Dicamba acid formation from low spray solution pH

Dicamba volatilization is the process where the chemical is vaporized into a gas. Dicamba volatilization initially begins as part of a multi-step process in which the volatile chemical structure of dicamba, dicamba acid, is formed (Figure 2).

1. Concentrated dicamba exists as a formulation where the dicamba molecules are bound to salts (i.e. DMA salt – Banvel®, DGA salt – Clarity® & Xtendimax™, BAPMA salt-Engenia®).
2. The salts dissolve in solution and dissociate from dicamba molecules in the spray tank leaving an anionic, or negatively charged, dicamba molecule.
3. The anionic dicamba molecule can accept an H+ ion in solution and form dicamba acid. The potential for this to happen is dependent on the solution pH, where pH is a measure of the H+ ion concentration (H+ concentration increases as pH decreases).
4. Dicamba acid formation increases as solution pH drops below 7 and becomes concerning when solution pH is ≤ 5.
5. Formation of dicamba acid can occur in the spray tank and in the field on soil and leaf surfaces (which can dictate the pH of the dicamba environment) for some time following herbicide application.

*Abbreviations- Dimethylamine, DMA. Diglycolamine, DGA. N,N-Bis[3-aminopropyl]methylamine, BAPMA.

Figure 2. Dicamba acid formation.



Factors that increase dicamba injury from volatilization following application

Application decisions that reduce dicamba volatilization include using the right tank-mix products, using proper nozzle selection (i.e. coarse droplets), and monitoring application conditions. First, applicators can select dicamba formulations that have a lower potential for volatilization. Research has shown that the potential for volatilization differs between formulations depending on the salt (volatility risk: DMA > DGA > BAPMA) and whether they contain Vaporgrip (i.e. Xtendimax with Vaporgrip, Tavium), an acetic acid buffer (Mueller and Steckel, 2019a; Striegel et al., 2020). Research has shown that some commonly used dicamba tank-mix partners (i.e. glyphosate) can reduce spray solution pH (Mueller and Steckel, 2019a; Striegel et al., 2021) which can increase the amount of dicamba acid formed and potential for volatilization. This has led to the development of volatility reduction agents (also known as pH buffering adjuvants; i.e. VaporGrip® Xtra Agent, Sentris™) which buffer the spray solution from pH reduction and are now required in dicamba applications made to resistant soybean. The amount of dicamba volatilization occurring has been shown to be directly correlated to temperature. As the air temperature increases (≥ 86 °F) so will the volatilization of dicamba (Mueller and Steckel, 2019b). Vaporized dicamba can cause more injury when vapor is concentrated in an air mass, such as occurs during a temperature inversion (Bish et al., 2019). A temperature inversion occurs when a cool stable air mass settles below a warm air mass; temperature inversions commonly occur in the evening and early mornings. Wisconsin research has shown that the risk of dicamba injury from volatilization is greatest when low wind speeds (stable atmospheric conditions) and high temperatures occur simultaneously following application (Striegel et al., 2021). The combined effects of low spray solution pH (≤ 5), high temperature (≥ 86 °F), and low wind speeds (≤ 3 mph) increase the likelihood of injury from dicamba volatilization.

Dicamba acid formation increases for every unit (1.0) drop in pH below 7 and **becomes concerning when solution pH is below or equal to 5.**

Take-home points

- ✓ Spray solution pH > 5 is needed to reduce the formation of dicamba acid. This can be done using pH buffers (i.e. VaporGrip® Xtra Agent, Sentris™) and avoiding the use of glyphosate in tank-mixes with dicamba.
- ✓ Warm temperatures (≥ 86 °F) during and following application increase the risk of dicamba volatility and reduce dicamba weed control efficacy.
- ✓ Don't apply dicamba during temperature inversion conditions (wind speeds < 3 mph).
- ✓ Spray particle drift can be a major concern for off-target movement of dicamba. Applications during wind speeds of 3-10 mph, using an approved drift reduction adjuvant at recommended boom height, and selecting nozzles that allow for the use of larger spray droplets at lower pressure can help minimize spray particle drift.
- ✓ Tank contamination is a common means for dicamba injury to susceptible crops. Contamination can occur when spray systems (sprayer, tanks, hoses, nozzles, measuring devices, etc.) aren't thoroughly cleaned before use in a susceptible crop. Dicamba residue can become tied up on old herbicide residues in a spray tank and/or get trapped in abrasions and cracks on the inside of tanks or hoses. To separate tank contamination from volatility or drift it is important to assess the pattern of injury observed to see if it matches that from the spray equipment used.
- ✓ Similar risks for dicamba volatility, drift, and spray tank contamination from soybean applications also occur from dicamba applied in corn (i.e., Status, DiFlexx, Clarity) and other crops.
- ✓ Despite major efforts to reduce dicamba off-target movement (e.g., novel herbicide formulations, volatility reduction agents, strict application requirements), the continuous adoption of dicamba in large scale will likely continue to result in off-target movement and injury to sensitive species. The adoption of best management application practices can help reduce the injured area.

Dicamba stewardship considerations in crop production

Dicamba works best on very small weeds and may result in incomplete control of medium-large weeds (>4"), which can increase the likelihood of evolved herbicide resistance. Additionally, reliance on dicamba for POST weed control in corn, soybean, and small grains in the same fields over multiple seasons greatly increases the likelihood of evolved resistance to dicamba. Resistance to dicamba has already been documented in the U.S. and cases will likely become more frequent if resistance management is not practiced. Implementing integrated weed management practices (i.e. diverse crop rotations, cover crops, narrow-row spacing, rotating and mixing herbicide site of actions (SOAs)) and taking advantage of the additional options for POST weed control of broadleaf weeds in corn can help maintain effective use of dicamba to control troublesome broadleaf weeds (i.e., waterhemp, giant ragweed, horseweed) in soybean, where broadleaf weed control options are limited.

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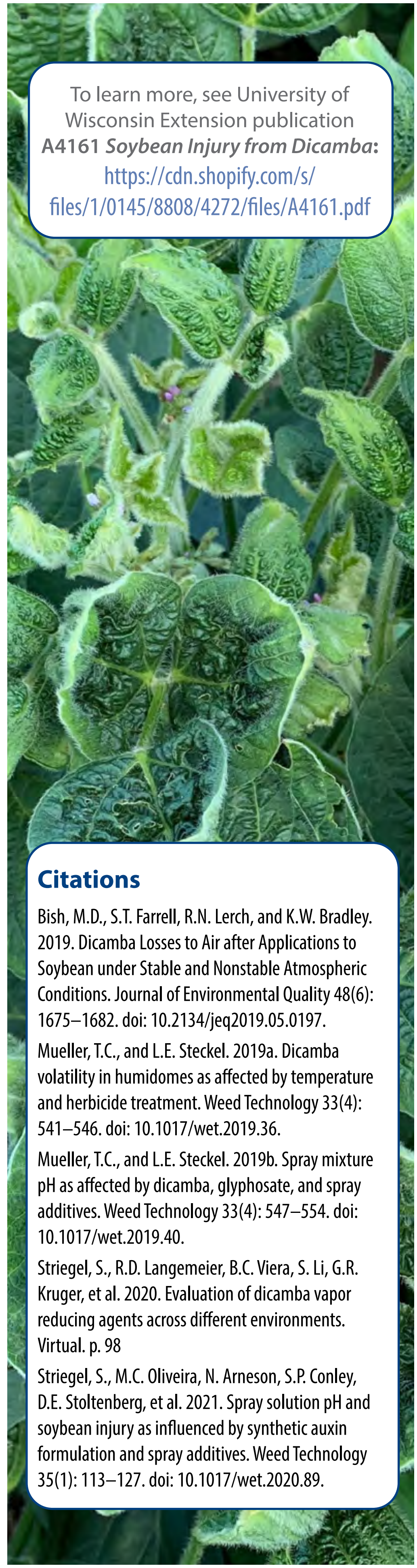

To learn more, see University of Wisconsin Extension publication **A4161 *Soybean Injury from Dicamba*:** https://cdn.shopify.com/s/files/1/0145/8808/4272/files/A4161.pdf

Citations

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