Handling Herbicide Injury in Specialty Crops

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Introduction

Inadvertent herbicide injury can be devastating to many vegetables, fruits, and ornamentals, representing a very real threat to commercial specialty crop producers. Depending on the severity of exposure, plants can suffer stunting, irregular growth, deformed fruit, decline, and/or death. Some plants, such as tomatoes, peppers, grapes, beans, and strawberries, are many times more sensitive to some categories of herbicides and can show severe damage even from trace amounts. Preventing herbicide injury can be challenging, as some herbicides drift more easily than others during application; volatilize from plant leaves or soil days after they have been correctly applied; or even be unintentionally applied to sensitive crops through sprayer contamination. No matter the source, herbicide damage results in substantial losses for commercial specialty crop farmers. Here, we offer advice on how to recognize and avoid herbicide drift damage, as well as steps to take if your crop is a victim of herbicide drift.



Figure 1 shows a severely herbicide damaged pepper. Photo credit C. Molnar

Common types of herbicides

Most of the damage to specialty crops comes from Group 4 herbicides (synthetic auxins) due to their relatively high vapor pressure, a measure of how well a substance evaporates, and to the fact that many broadleaf plants are highly sensitive to them. Table 1 shows the vapor pressure ratings of several Group 4 herbicides.

Table 1. Vapor pressure ratings of several Group 4 (synthetic auxins) herbicides (source: National Pesticide Information Center).

Active Ingredient	Common Trade Names	Vapor Pressure µPa @ 77˚F
dicamba acid[a]	-	4,500
2,4-D ester	LV4, LV6	480
triclopyr ester	Remedy Ultra, Garlon 4	480
clopyralid	Stinger, Transline	167
2,4-D choline	Freelexx	19
2.4-D amine	Amine 4	13
picloram	Tordon 22K, Triumph 22K	11
triclopyr amine	Garlon 3A	1
aminopyralid	Milestone, Whetstone	<1

[a]any dicamba product can become an acid

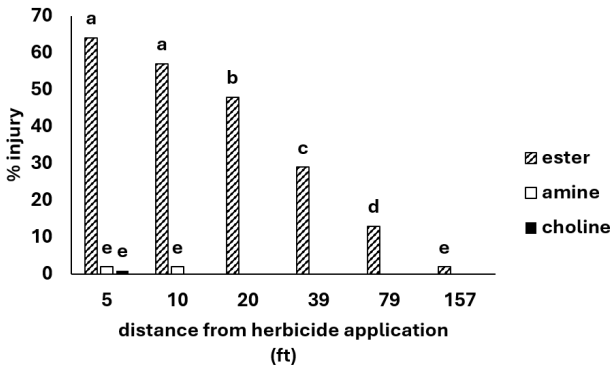
Dicamba

Dicamba causes more damage from offsite movement than any other herbicide. Among the herbicides listed in Table 1, it is the only one whose volatility is dependent on the acidity of its surroundings, whether that be in

a spray mixture or after it has dried on plant leaves. When hydrogen ions (H^+) are added to a spray mixture, the mixture becomes more acidic (the pH decreases). These positively charged H^+ ions combine with the negatively charged dicamba molecule to make highly volatile dicamba acid. Crops and weeds will only take up a portion of the herbicide that is applied to them. The portion of the herbicide that is not utilized by the plant will dry and remain on the leaf surface and can be dissolved with dew or other precipitation events. The continual exposure to moisture will allow H^+ ions to be bound to the water and then volatilize for several days following application. The rule of thumb is to always keep the surrounding liquid, whether that be the spray mixture or plant surface moisture above pH five. While this sounds daunting, here are some steps to help achieve this, but they are not guaranteed to eliminate volatilization:

1. **Avoid DMA dicamba formulations**
   Dimethylamine (DMA) salt is the original version of dicamba, which was released in the 1960s as Banvel. Unfortunately, DMA adds H^+ ions to the spray mixture. If spraying dicamba, choose a formulation that's either a sodium (Na^+) salt, diglycolamine (DGA) salt, or BAMPA salt. The sodium salt formulations (Status, Distinct) are only labeled for use in corn. DGA salt formulations (Clarity, Diflexx, and several others) are labeled for many uses. BAPMA salt formulation (Engenia) is only labeled for use in dicamba-tolerant soybeans and cotton.
2. **Add a volatility reducing agent**
   Volatility reducing agents (VRAs) work by either scavenging H^+ ions from the spray mixture or by raising the pH to make the mixture less acidic. They also add potassium (K^+) ions, which can bind to the dicamba molecule as the spray mixture dries on the plant's surface. Dicamba bound to a K^+ ion is stable, unlike Dicamba bound to H^+ that forms dicamba acid. The VRA should always be added to the spray mixture prior to adding dicamba.
3. **Avoid adding glyphosate**
   Studies have shown that glyphosate is the largest addition of H^+ ions to a spray mixture, often pulling the spray mixture's pH down by 1 to 2 units. Some professionals advise against mixing glyphosate and dicamba to minimize the volatilization risk. If you must add glyphosate, use the K^+ salt form of glyphosate (Roundup PowerMax, Roundup WeatherMax) instead of an isopropylamine (IPA) salt (Roundup Original). The K^+ ions released when the glyphosate dissolves in the spray mixture adds additional protection against dicamba molecules from binding with H^+ ions while in the spray mixture and on the plant foliage. It is typically recommended to add the glyphosate after the VRA and the dicamba.
4. **Avoid adding ammonium sulfate**
   Ammonium sulfate (AMS) also adds H^+ ions to spray mixtures, but not usually to the degree in which glyphosate does. Several non-AMS products exist for those who need to improve the performance of glyphosate in hard water situations.

Table 2. Percent injury to cotton following the application of three different 2,4-D formulations applied at various distances from the cotton. Bars with a different letter are significantly different (p>0.01). Adapted from Mueller et al. (2022).



Other volatile Group 4 herbicides

Though Dicamba is the only herbicide mentioned in Table 1 whose volatility can be reduced with a VRA, the best way to minimize damage from 2,4-D and triclopyr is to use the correct formulation. Table 2 shows that 2,4-D ester can cause damage up to 157 ft away from the application, while the amine form only caused damage at 10 ft away and the choline form caused damage at only 5 ft. Esters are usually chosen because they can penetrate thick, waxy leaf cuticles better than amines or cholines. Unfortunately, esters are highly volatile during warmer weather, which is usually defined as temperatures warmer than 85 degrees F. Leaves tend

to have a thicker waxy cuticle in fall that develops in response to cooler temperatures and as a carryover from summer drought. Therefore, fall is usually a better time to apply ester herbicide formulations; in fall, there are also less plants to damage from offsite movement.

Recognizing herbicide injury

Herbicide injury can be difficult to conclusively identify as damage can mimic abiotic disorders and some diseases. Glyphosate injury tends to produce pale areas or necrotic spots on leaves and stems that can resemble fungal or bacterial diseases, as well as some mosaic viruses. On some woody ornamentals, such as roses, glyphosate can cause twisting, stunting, and distorted leaves that can resemble rose rosette virus (Figure 2A-D). Strawberries may develop symptoms of twisted stems and stunted growth from glyphosate damage (Figure 3). Group 4 herbicides, such as 2,4-D and Dicamba, produce distorted or cupped leaves, twisted growth, and stunting that mimic many viral diseases in many vegetable crops. In tomatoes, Cucumber Mosaic Virus (Figure 4), a common virus in South Dakota, can produce cupping, leaf distortion, and yellowing seen from both glyphosate and dicamba damage. In peppers, the symptoms of leaf distortion, stunting, and yellowing associated with herbicide damage most closely resemble Tomato Spotted Wilt Virus (Figure 5), which is another common virus in the state. Other viruses, such as the Potyvirus referenced in Figure 6 can also cause symptoms of leaf distortion and yellowing that resemble herbicide damage. Differentiating between viruses and herbicide damage can be challenging and may require testing to rule out viral pathogens.

Some plants are extremely sensitive to some groups of herbicides (Figures 7 and 8). Tomatoes, peppers, beans and grapes are some of the most sensitive plants to synthetic auxins (like 2,4-D and dicamba), with exposures of 1/100 to 1/1000 of normal applications causing noticeable damage. Cultivars can vary in how sensitive they are to developing physical damage, which can give the appearance of variable damage.

Herbicide injury is more often recognized by patterns in how damage develops and less in direct symptoms. Herbicide injury damage generally develops quickly after exposure, most often affects new growth only and appears in large patches of plantings, possibly on every plant. Damage is often worse from the direction in which the herbicide was applied. Plants may recover or 'grow out' of damage depending on the level of severity of exposure. In contrast, most diseases occur randomly throughout plantings, rarely affect every plant evenly, develop on older growth first, and worsen with time as plants do not recover on their own. Many diseases develop at certain times in the growing season or only under certain conditions, whereas herbicide injury can occur at any time.



Figure 2. shows the comparison of rose rosette virus (A and B) to glyphosate herbicide damage (C and D). Leaf distortion, stunted growth, and bunched growth are common with both disease and herbicide damage. One major difference is that roses will recover from herbicide damage and damaged branches will harden off and eventually defoliate. This does not occur with RRV infections.



Figure 3. Strawberries with Paraquot (left, photo credit: Don Ferrin, Louisiana State University Agricultural Center, Bugwood.org) and clomazone injury (right, Photo credit: Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org)



Figure 4. A Tomato with Cucumber Mosaic Virus. Elizabeth Bush, Virginia Polytechnic Institute and State University, Bugwood.org



Figure 5. A pepper plant with Tomato Spotted Wilt Virus. Tomato Spotted Wilt Virus is a very common viral disease in South Dakota. Photo credit Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org



Figure 6. A Butternut Squash vine with an unknown Potyvirus. Many viral diseases can imitate symptoms of herbicide damage. However, viral diseases tend to infect plants at random, which can be seen with other healthy vines next to the symptomatic vine in the center. This can help pin down the cause of symptoms. Photo credit C. Molnar



Figure 7. A tomato (left) and a pepper (right) showing classic signs of group 4 herbicide damage such as leaf narrowing (strapping), curling, and distortion. Photo credit C. Molnar



Figure 8. Solanaceous crops like tomatoes (left) and eggplants (right) are extremely sensitive to group 4 herbicides. Photo Credit C. Molnar

SDSU Plant Diagnostic Services

Plants that are suspected of herbicide damage or potential viral infections can be sent to the SDSU Plant Diagnostic Clinic for testing to determine if viruses are present. There are fees associated with diagnostic services ($25-$100). South Dakota Agricultural Laboratories in Brookings can test for herbicide residues. They offer a plant growth regulator (PGR) screen for approximately $250 that tests for 16 different active ingredients including dicamba and 2,4-D. The website for a sample submission form: https://sdaglabs.com/wp-content/uploads/2025/05/2025-pesticide-residue-submission-form-sdal.pdf

Preventing damage

The most important risk for herbicide damage is herbicide drift, or the lateral movement of herbicide from where it was intended. Drift is mostly likely the result of applicator error, but factors such as environmental conditions, like wind, and herbicide formulations play important roles.

When you are making the application mixture, follow all label instructions and implement practices identified by the label to reduce drift. Common practices to reduce drift include increasing droplet size (by reducing pressure or using nozzles that generate larger droplets), adding adjuvants (such as drift control agents), and spraying as close to the target as possible. Another factor to consider is avoiding applications during environmental conditions that promote drift, such as high wind speeds, inversions, high heat, and low relative humidity.

If someone else is making the application mixture, there are a few ways you can protect your interests from the effects of pesticide drift. The most important action is establishing a relationship with the applicator, because open and comfortable communication between you and the applicator is your greatest weapon against drift. Other possible methods to protect your interests from drift include physical barriers, such as tall-growing, dense plant stands, mesh screens, plastic tarp, or other physical barriers. These barriers act to “catch” drift particles before they can hit sensitive or more desirable plants. When planning or scouting crops, be sure to appropriately assess the risk of drift damage and implement protections accordingly.

Other potential sources of herbicide exposure include trace residues in sprayers, mulch, compost, and manure used for fertilizer. Designate sprayers by labeling in large, clear writing to only be used for pesticide applications and clean tanks after each use with tank cleaning solutions that dissolve pesticide residues (both oil and water formulations). Residues on plants treated with herbicide that are then used for mulch have been observed to cause injury in tomatoes grown in contaminated mulch. Animals that have recently fed on herbicide laden forage may excrete the herbicide active ingredient in dung in concentrations high enough to damage or kill plants and should not be used for fertilizer. Be very careful where you source your specialty crop farm additives, and do not hesitate to question the supplier about the source of the materials.

What to do if your plants are exposed to herbicide

STOP! If you believe your person (any body part) has come into contact with pesticide drift particles, remove contaminated clothing as soon as possible and wash exposed areas with soap and warm water. Contaminated clothing items (shoes, socks, pants, etc.) should be separated and placed into separate, resealable (preferably) bags, labeled as “Pesticide Contaminated,” and placed in a secure location until pesticide tests can be conducted or the investigation concludes. If pesticide testing is unnecessary, contaminated clothing should be kept separate from other clothing, washed alone (preferably in a separate washer), at the highest water level possible for your washer, at the highest temperature possible, and with an additional rinse. Contaminated clothes should be dried outdoors when weather allows. If you believe you, a family member, your pet, or livestock are experiencing physical symptoms of pesticide exposure, seek medical or veterinary care immediately. *Note: the onset of physical symptoms can be delayed.*

Instances of pesticide drift should be reported to the South Dakota Department of Agriculture and Natural Resources (DANR) within 30 days. The DANR investigates allegations of violations of pesticide law but is not responsible for any civil action. DANR will not make determinations of applicator liability and does not assess damages to assist in civil cases or insurance settlements. Investigations may include collecting soil, plant, and water samples; photographs of affected

areas; interviews of witnesses; collecting spray records; and other methods to gather necessary information to make a final determination on a case. You can find more information on the DANR's Pesticide Enforcement webpage, and you can submit a drift complaint using the DANR's Pesticide Incident Form.

If you believe you have been personally harmed (including losses to your crop revenue) by pesticide drift or misuse, it is recommended that you contact your insurance company and/or private legal counsel to advise you of your rights. If you feel the instance reflects a criminal offense, contact local law enforcement.

DISCARD ALL AFFECTED PRODUCE AND CUT FLOWERS. There are no recovery treatments for drift damage in plants. Produce and flowers affected by drift should be thrown away in household or commercial garbage collection bins and never consumed, sold, used for feed, mulch, or seed, or allowed into the grain supply. The chemical that caused the damage may be unknown and is likely not labeled for use on the plant in question or in the concentration applied. As such, the effects of that chemical and/or concentration may be unstudied or unknown, and safety for you and others cannot be guaranteed. As fruits and vegetables concentrate resources into their actively growing areas, particularly the fruit of plants, these can become enriched in any chemicals that they take up and may be at much higher levels of contamination than other parts of the plant, making consuming affected produce more dangerous.

For additional information on herbicide damages in South Dakota, see here: https://extension.sdstate.edu/herbicide-damage-fruits-and-vegetables

Off-target damage to specialty crops by herbicides can be difficult and challenging to prevent and manage. For questions regarding handling of pesticides, please contact Stephen Robertson; for questions regarding potential diseases or identification of symptoms, please contact Cody Molnar; for questions about herbicides and their usage, please contact Graig Reicks.

Sources

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