# 2,4-D- and Dicamba-tolerant Crops — Some Facts to Consider

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## Introduction

The impending approval and use of soybean varieties that are tolerant of the herbicides 2,4-D and dicamba has been generating some conversation and debate.

Many groups and individuals — including weed scientists, agronomic crop growers, and specialty crop growers — are concerned about 2,4-D- and dicamba-resistant crops. They say such crops are unnecessary, will make farmers more dependent on the intellectual property held by large corporations, will injure nontarget crops sensitive to 2,4-D and dicamba, and will accelerate the evolution of herbicide resistance in weeds.

Others argue that 2,4-D and dicamba have been used on millions of acres since the 1960s and has not resulted in widespread damage, so using them on tolerant crops should not concern growers of high-value horticulture crops.

It is important to note that there is *no* unified opinion on this topic among weed scientists or agronomic crop growers. This publication shares the perspective of some Purdue University scientists on the subject of managing weeds in crops, explains why 2,4-D- and dicamba-tolerant crops were developed, and discusses some of the concerns surrounding the short- and long-term effects of this technology.

## Background on Weed Management and Current Problems

Since they were introduced by Monsanto in 1996, genetically engineered Roundup Ready® (RR) crops revolutionized weed management and no-till practices in agronomic cropping systems. RR crops were resistant to the herbicide glyphosate, which meant that producers could apply this one herbicide postemergence during the crop season and achieve excellent, broad-spectrum weed control. RR soybean was introduced in the United States in 1996 followed shortly thereafter by RR cotton and RR corn. Additional crops (including canola and sugar beet) have also been released.

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Weed management in RR crops has been excellent and has given agricultural producers simpler, less expensive weed control with glyphosate-based herbicides. However, after countless glyphosate applications over many years and many millions of acres, there has been the widespread development of weed populations that are resistant to glyphosate.

The first problem weed known to develop glyphosate resistance since the introduction of RR technology was marestail (horseweed). Today, there are 22 weeds worldwide reported to be resistant to glyphosate. In Indiana, marestail, giant ragweed, and waterhemp are three problem weeds that have documented glyphosate resistance. Several other weeds are suspected to have developed resistance.

The Purdue Extension *Glyphosate, Weeds, and Crops* publication series (available from the Education Store, www.the-education-store.com) documents several glyphosate-resistant weeds and recommends management practices.

The existence of glyphosate-resistant weeds requires producers to use additional herbicide tools and cultural practices to effectively manage the weeds. These additional practices add cost to the production system. Often, there are no effective herbicides that are easily available for some crops, or it is not desirable or possible to use more intensive tillage on large acreages. The presence of glyphosate-resistant weeds imperils the long-term sustainability of the RR system unless producers practice more integrated weed management that relies less on the sole use of glyphosate.

## New Weed Management Approaches

In response to the evolution of glyphosate-resistant weeds, agricultural chemical companies have been investigating new methods of weed control. They have been developing new herbicides or (more commonly) using genetic engineering to obtain crop plants that are resistant to other herbicides. Developing new herbicides is difficult. To our knowledge, no university in the country is evaluating any new herbicide active ingredient. In fact, the crop protection industry has not commercialized an herbicide with a new mode of action in at least 10 years.

Companies are searching for new active ingredients, but the cost of developing them and the limited potential for economic return have made it difficult to bring new products to market. Part of this is due to the fact that glyphosate has dominated the herbicide market since the introduction of RR crops in 1996. Furthermore, with no new herbicide modes of action on the horizon and herbicide-resistant weed populations on the rise in every state that grows corn and soybeans, there are few tools left to protect crop yields from weed infestations on large monocultures.

The same technology that allowed glyphosate to be used on crops provides the ability to introduce herbicide tolerance traits into crops, thereby allowing existing herbicides to be used in that new crop. So, companies have taken advantage of this technology to provide a solution to weed control problems. This provides "unique" tools for managing our current list of herbicide-resistant weeds.

Companies decided to introduce 2,4-D and dicamba resistance into crops for fairly straightforward reasons. First, these herbicide chemistries have shown excellent resilience and few herbicide-resistant weeds have occurred after more than 50 years of use. Second, these herbicides provide excellent control of glyphosate-resistant broadleaf weeds such as marestail, giant ragweed, common waterhemp, and other broadleaf weeds.

## Developments in Herbicide-resistant Crops

Two major companies have developed cropping systems with 2,4-D and dicamba herbicide resistance: Dow AgroSciences and Monsanto Company. Dow AgroSciences and Monsanto have taken proactive steps to address concerns of off-target movement by developing new formulations that, according to product labels and technical use guidelines for seed products, will require new application methods. If used, these methods can minimize, if not eliminate, off-target movement. The following are brief summaries of each system.

### *Dow AgroSciences Technology*

Dow AgroSciences calls their 2,4-D-resistant technology the Enlist™ Weed Control System in corn, soybean, and cotton. This technology became possible when the company inserted genes into high-acreage agronomic crops that allow the plants to metabolize 2,4-D. Dow AgroSciences also developed a new Enlist Duo™ herbicide that contains glyphosate and a new formulation of 2,4-D: choline. The herbicide features what Dow AgroSciences calls Colex-D™ Technology. The new choline formulation provides ultra-low volatility, minimized potential for drift, lower odor, and better handling characteristics than commercially available 2,4-D amine or ester formulations.

The drift potential of any 2,4-D formulation depends on using nozzles that reduce driftable fines (droplets less than 200 microns). Proprietary components in the Colex-D™ formulation will reduce the amount of driftable fines.

All Enlist™ crops will have traits that make them tolerant to 2,4-D as well as glyphosate. Enlist™ corn will also have tolerance to the "-fop" grass herbicides that contain quizalofop (such as Targa® and Assure®). Enlist™ soybean, cotton, and corn will also be resistant to glufosinate.

Depending on regulatory approval, these crops are being targeted for commercial sale in 2013 for corn, 2014 for soybean, and 2015 for cotton.

### *Monsanto Technology*

Monsanto is developing crops after discovering a gene that allows plants to metabolize dicamba. Their Roundup Ready Plus Xtend System® will allow applicators to spray glyphosate and dicamba over tolerant crops.

Monsanto is collaborating with BASF to address dicamba's potential to injure off-target vegetation through drift or volatilization. The danger for drift is an ever-present concern for any herbicide application and a major concern for all crops. There have been many cases of dicamba drift over the past 20 years, and many people have worried that the widespread use of dicamba-resistant corn, soybean, and cotton could increase off-target movement of dicamba.

Monsanto and BASF are developing application programs, enhancing dicamba formulations, and creating product stewardship programs that aim to minimize the risk of off-target movement. Using nonapproved dicamba formulations with higher volatility characteristics will not be allowed or recommended by Monsanto.

Monsanto has communicated several required parts of the anticipated stewardship program to be included on the EPA label of new dicamba formulations. Proposed application requirements include:

- Using application technologies that produce very coarse to ultra coarse droplets (and eliminate fine spray particles).
- Applying herbicides only when wind speeds are less than 10 MPH.
- Warning against applications when conditions are favorable for temperature inversions.
- Requiring buffers between application sites and sensitive species.

Final application requirements and buffer zones are not finalized and will be determined with the aid of valid research results and input from the appropriate regulatory authorities.

The plants in this soybean field have been injured by a growth regulator herbicide.

Monsanto is performing extensive work to develop dicamba-resistant soybean, corn, and cotton. Cotton will be tolerant to glyphosate, dicamba, and glufosinate. The target dates for dicamba-resistant crops depends on regulatory approval, but the most current estimates say they will be available for 2015.

## Logic for this Technology

The logic for these technologies is that traits for crop resistance to 2,4-D or dicamba, when stacked with other herbicide resistance traits will reduce the risk of crop injury often associated with pre-plant 2,4-D or dicamba applications. They'll also improve control of difficult and resistant weeds in no-till and conventional systems any time from preplant into the growing season. The technologies will offer growers flexibility to control weeds, allow them to continue using reduced tillage practices, and will help reduce the risk of selecting for glyphosate-resistant weeds.

Both technologies will include the use of preemergence soil residual herbicides and postemergence herbicides. The goal is to effectively limit the potential for weeds to develop herbicide resistance, which would make the new herbicide-tolerant crop technologies more sustainable.

## Concerns About Off-site Movement

Concerns exist because the most common drift complaint in the spring consists of preplant burndown herbicides used for no-till corn and soybeans that have injured ornamental plants. The herbicides involved in these complaints almost always include one or more of the following: 2,4-D, glyphosate, atrazine, acetochlor, or paraquat. Growers of crops or plants that are sensitive to these herbicides, rural homeowners, and those concerned about maintaining wild habitats for pollinators are concerned that widespread use of 2,4-D and dicamba will have detrimental effects on sensitive plants. These concerns exist despite the fact that both herbicides have been used postemergence for more than 40 years (dicamba) and 60 years (2,4-D) in many different crops and are still widely used today.

The main concern about these technologies is that off-site movement via particle drift or volatility will damage sensitive crops (including agronomic crops that are not resistant to 2,4-D or dicamba), specialty crops (such as tomato, grape, and melons), and nursery plantings. There is also concern that these technologies will injure home gardens and landscapes.

Another major concern is that once these crops become commercialized, the acreage sprayed with 2,4-D and dicamba would increase to encompass the majority of agronomic acres in the United States. Since much of this acreage could be sprayed two or three times each growing season, some argue that it greatly increases the potential for off-site movement — even if most applications occur under the best of conditions — and for weeds to develop resistance to 2,4-D or dicamba.

The authors definitely appreciate these concerns, so the rest of this publication addresses issues that affect off-site movement.

## Factors Affecting Off-site Movement

Understanding off-site movement potential involves specific knowledge of the herbicide's chemical and physical properties that can influence off-site movement. It is important to know the differences between drift and volatility.

### *Drift*

Drift is the physical movement of spray particles by wind after the particles leave the sprayer and before they reach the intended target. Drift occurs when spray applications occur in unfavorable weather conditions, but most commonly happens when windy conditions are combined with poor application techniques. One of these poor application techniques is using spray nozzles that produce small droplets (less than 200 microns). These small droplets are light and easily carried by wind.

Drift is a major concern with all chemicals but in reality, application technology and restrictions about applying herbicides during adverse environmental conditions, when properly followed, greatly reduce this problem.

### *Volatility*

Volatility is much different than drift. Volatility is the movement of the gaseous form of the herbicide after it has been deposited on its intended target as a liquid. After deposition, the herbicide changes from a liquid to a gaseous form, and the gaseous form moves off the target with wind currents.

Volatilization involves a phase change in which a liquid or solid phase may be transformed into vapor by rising temperatures or drops in external pressure. The tendency of an organic substance to volatilize is expressed by its vapor pressure — more volatile compounds have higher vapor pressure values.

An herbicide's volatility is influenced by many factors, including its vapor pressure, concentration, and rate of transport to the surface of the leaf or soil. Other factors influence volatility including the temperature of the air, leaf, or soil; the water content of leaf or soil surface; and the velocity of air movement above the surface of the leaf or soil. Reducing the water content on the leaf or soil surface can reduce volatility by increasing sites for adsorption. Conversely, water can assist volatility through "wicking," which is an upward movement effect in which compounds are transported to the soil surface as water moves upward in the soil profile due to water evaporating at the soil surface.

The distribution of a chemical between water and air is an expression of Henry's Law. Without going into confusing detail, Henry's Law accounts for the concentration of the pesticide in water and air along with the influence of temperature, herbicide solubility, molecular weight, and (most importantly) its vapor pressure. If an herbicide has a vapor pressure that allows a greater proportion of it to be present in air, that chemical more readily goes from a liquid to a gas and can move away from its target to a nontarget plant. This is a situation to avoid, and the herbicide industry has developed newer chemistries that have vapor pressures that are not conducive to volatilization.

Herbicides like Treflan® (which are still popular) have a fairly high vapor pressure so they must be incorporated in the soil to trap the herbicide in the soil matrix. Command® was somewhat infamous for off-site movement in the late 1980s because of its high vapor pressure, but refinements in its formulation eliminated this concern. It is important to note that most herbicides introduced today have lower volatility formulations that have reduced off-site movement concerns.

The big concern with 2,4-D and dicamba is that volatility and drift problems still exist. The known volatility problems of certain 2,4-D and dicamba formulations are also well documented and are being addressed by both companies through the development of newer, lower volatility formulations. However, a concern is that low-cost, generic formulations of both 2,4-D and dicamba are still readily available and growers may turn to these options if economics favor a lower application cost.

## Methods of Minimizing Off-site Movement

As mentioned above, volatility and drift are different factors that affect the off-site movement of herbicides. Spray operators can control drift, and manufacturers have made substantial improvements to spray nozzle technology in recent years. A recent paper presented at the Weed Science Society of America (WSSA) meeting showed that driftable spray droplets can be reduced from 30 percent down to 2 percent by simply upgrading the nozzle technology in current spray setups. This type of information will be important for all spray operators to consider as they spray near sensitive vegetation.

However, the most important thing operators can do to minimize drift is to spray only when winds are *not* blowing toward sensitive vegetation.

On the other hand, operators cannot control volatility except by choosing nonvolatile or low-volatile formulations. Volatility occurs after spray is deposited on the target, when the herbicide turns into a vapor and moves away from the target. Operators can control volatility only if they do not spray formulations that have high vapor pressures.

Both Dow AgroSciences and Monsanto are developing application techniques that aim to minimize these concerns. They are taking measures that include developing herbicide formulations that are less volatile and have improved handling characteristics, creating better spray nozzle technology, and improving overall application requirements.

When the new cropping technologies become commercially available, it will be important for users to apply the new herbicide formulations responsibly and in ways that minimize volatility concerns and physical drift. Purdue weed scientists believe operators can minimize drift by using proper sprayer technology. Purdue weed scientists will need to educate applicators about the factors (both human and environmental) that increase the potential for off-site herbicide movement.

Another tool is the Purdue-based Driftwatch program (www.driftwatch.org), a voluntary sensitive crop reporting system that notifies farmers and pesticide applicators about locations where spray drift may be a concern. We feel that more programs like Driftwatch will become common as more information becomes available about how best to use these herbicide-resistant crops while avoiding potential damage from herbicide use.

The next few years will be interesting as herbicide-tolerant crop technology is developed, approved for release, labeled, and used. Everyone will be watching how herbicides are used and applied and how the issues related to off-site movement are addressed. There is much work that still needs to be done to ensure that when these herbicide-tolerant crop systems are commercially available they are effective and economical, manage weeds, and do not damage nontarget plants.

## Summary

- We recognize the need to manage glyphosate-resistant weeds for the sustainability of Roundup Ready® agronomic cropping systems, which provide economical means to protect crop yields.
- The introduction of 2,4-D- and dicamba-resistant crops represents a new technology that can help maintain near-term productivity in our efficient, simplified monoculture systems of commodity crops. However, we must not become overly reliant on this technology as the only solution to manage weeds and maintain high crop productivity. A diversified approach to weed management must not be lost. The most durable and productive weed management system must integrate many tools, including genetic, cultural, nonchemical, and chemical methods.
- We recognize the potential risks that the increased use of growth regulator herbicides (2,4-D and dicamba) can have near sensitive crops, organic farms, and rural home gardens and landscapes.
- We also note that it is not only 2,4-D- and dicamba-sensitive crops (such as vegetables, trees, and ornamentals) that are threatened, but that 2,4-D-resistant crops may be vulnerable to dicamba, and dicamba-resistant crops may be vulnerable to 2,4-D.

- We recognize the potential risk that growth regulator herbicides (2,4-D and dicamba) may have if they are applied later in the growing season than they are currently.
- Dow AgroSciences is developing a low-volatile choline formulation of 2,4-D, drift management solutions, and product stewardship programs as part of their Colex-D™ Technology. Monsanto and BASF are developing application programs, enhanced/improved dicamba formulations, and product stewardship programs intended to minimize the risk of off-target movement. However, concern remains that some older, more volatile formulations are slated to receive "label support," not just the newly developed formula
- We encourage all growers of sensitive crops and cropping areas to register their fields with Driftwatch (www.driftwatch.org) so that pesticide applicators will be aware of potential problems. However, we do not believe the onus should be solely on these growers. The manufacturers of herbicide-resistant crop technologies must carefully monitor the situation after they release these crops, and they should document any and all drift cases.
- We strongly recommend that the U.S. Environmental Protection Agency restrict, by label, the use of higher volatile formulations on any Roundup Ready® crops and that record-keeping requirements (similar to those in place for restricted use (RUP) products) makes sense to help in any investigation of off-target movement.
- It is critical that registering companies develop marketing plans that tie technology purchases to the use of the newly developed formulations to reduce the economic risk of generic formulation use that would lead to unacceptable risk of potential volatility exposures.
- We encourage more stringent label restrictions on allowable wind application conditions, (currently at 15 mph) and to restrict any application when winds are blowing toward sensitive crops or homes. Wind restrictions should be much lower (10 mph), and labels should specify that applications should also be avoided under temperature inversion conditions.




These tomato plants have been injured by a growth regulator herbicide.

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