BEST MANAGEMENT PRACTICES TO MINIMIZE THE RESISTANCE RISK
MANAGING TO PREVENT THE DEVELOPMENT OF HERBICIDE RESISTANT WEED POPULATIONS

Tools and Practices
Preventing the development of herbicide resistant weed populations isn’t a one-person, one-company or one-way solution. It requires joint efforts by manufacturers, distributors, retailers, agronomists and growers. Our goal is to provide you — the people that growers turn to for advice — with the necessary tools to feel comfortable in preventing herbicide resistance by recommending effective solutions.

This guidebook goes beyond our three best management practices to explain herbicide resistance, resistant weeds and the importance of protecting our technologies.

We will fully outline our individual best management practices later in this guidebook.

The Dow AgroSciences Way
Each entity in the crop protection industry has a different approach to discussing herbicide resistance. What’s our way? The principles of resistance management — known in the industry as best management practices — are basic: protect the efficacy of current herbicides by diversifying herbicide selections, integrating weed management as part of production practices and diligence to ever-shifting pest populations.

Dow AgroSciences is stepping up and asking growers to evaluate their current weed management practices as well as identify and alter those practices having the greatest risk for the development of herbicide resistant weed populations. And, we’re doing so by bringing attention to herbicide resistance management and identifying our three categories of best management practices.

DOW AGROSCIENCES BEST MANAGEMENT PRACTICES
1. Understand the chemistry
2. Switch it up
3. Pay attention

We know that to be true stewards, preventing herbicide resistance development means recommending the best agronomic practices, regardless of the product brand. To be true partners in stewardship we need to be right alongside you and growers preventing herbicide resistance. At times, the topic of herbicide resistance may seem overly technical; we designed this tool to help break it down into valuable and useful content, ultimately helping to minimize the risks of resistance development and maximize weed management results, for everyone.
What is Herbicide Resistance?

The definition of resistance is the ability to prevent something from having an effect. Herbicide resistance occurs when a weed population changes in response to herbicide use and other crop management decisions.

**MYTH 1: HERBICIDE-RESISTANT WEEDS BEGAN WITH THE INTRODUCTION OF HERBICIDE-RESISTANT CROPS**

Resistant weeds have been evolving worldwide due to selection pressure from effective herbicides. Resistant weed “biotypes” are a consequence of basic evolutionary selection processes. Since herbicide resistance was first reported in 1957, more than 400 weed biotypes have been identified as having resistance to one or more herbicide groups. Nearly every mode of action group has one or more weed biotypes with resistance.

Current information on the status of herbicide-resistant weeds can be found at www.weedscience.org.

**Examples of known plant resistance to common modes of action include:**

- Group 1 (ACCase Inhibitor) resistant wild oats and Italian ryegrass along with Group 2 (ALS Inhibitor) herbicide resistant kochia and Russian thistle, and Group 9 (EPSP Synthase) herbicide resistant kochia.

**MYTH 2: HERBICIDES ALTERED THE WEEDS’ GENETIC MAKE-UP, MAKING THEM RESISTANT**

Herbicides themselves have not caused a change in plant genetics. Rather, effective herbicides have selected for biotypes of weeds having genetic resistance that already existed in the population. (Initial frequency is estimated to be one in a million or less.) These mutant plants were able to survive a dose of herbicide lethal to the wild type and produce the only seed of that species in the field. After years (or seasons) of repeated treatment or selection using the same herbicide, resistant biotypes become the most common biotype in that field.

Preventing herbicide resistance and conserving current weed management technology is important. Growers must take every opportunity to prevent surviving weeds from producing seed.

Repeated use of the same practices without monitoring fields allows herbicide resistant populations of weeds to quickly become common in that field, with resistance then persisting in the soil seed bank for several years.

The old adage “one year’s seeding equals seven year’s weeding” is as true for herbicide resistant biotypes as it is for overall weed populations.
It Pays to Stay One Step Ahead

When resistant weed populations do develop, growers face additional control costs, including additional herbicide applications or higher-cost herbicides, greater labor or tillage expense to remove resistant weeds, and potential yield loss.

Just as with any other types of resistance, herbicide resistant populations develop with repeated selection pressure over time and plant generations, mainly by the repeated use of a single herbicide mode of action group.

How Resistance Works

Herbicides are categorized into groups based on the mode of action. The term *mode of action* refers to the sequence of events from absorption into plants to plant death. Within a mode of action, herbicides are also categorized as families based on their molecular structure.

Meaning, herbicides in the same mode of action group may be of different molecular structure and have different physical attributes, but still kill plants in the same manner.

Weed biotypes that are resistant across different herbicide families within a mode of action are said to be cross-resistant. Examples of cross resistance include biotypes of wild oats found to be resistant to the “fop” and “dim” families of Group 1 herbicides. Kochia biotypes have been found to be resistant to sulfonylurea and imidazolinone family of Group 2 herbicides. Italian ryegrass has been found to be resistant to multiple Group 1 herbicides.

Herbicide resistance should not be confused with the natural tolerance some species exhibit. It is important to always read product labels to determine which herbicides claim suppression of a particular weed species, which may be an indication of a degree of tolerance for that species. Additionally, talk with your agronomist or sales representative to determine expected levels of control of a particular weed with a particular product to best determine whether you are seeing true resistance or simply greater tolerance due to environmental or other conditions.

Ultimately, the activity of a particular herbicide and the development of herbicide resistant populations are an interaction of the herbicide, the weed and the environment or production practices. Thus, it is necessary to determine which herbicides may be more prone to, which weeds are more prone to, and which production or environmental factors favor, the development of resistant weeds.
What Does Resistance Look Like?
Indications that populations of herbicide resistant biotypes are developing vary. The following list is intended to act as an outline for possible resistant weed biotypes. Dow AgroSciences recommends watching for:

- Dead weeds next to surviving weeds of the same species following a herbicide application
- Patches of weeds coming back in the same area year after year, particularly along field margins or points of entry
- Recurring weed patches that are spreading, particularly in the direction of tillage or harvest operations

So, How do you Minimize Herbicide Resistance?
Best management practices to minimize development of herbicide resistant populations involve avoiding repeated applications of the same herbicide mode of action, using the same tillage practices every year or planting the same crop every year. In other words, using a multifaceted approach to weed control and crop production within each crop and throughout the crop rotation is the best approach to battle herbicide resistance.

WHAT IS A “BEST MANAGEMENT PRACTICE”?
A BMP is a practice determined to be the most efficient, practical and cost-effective measure to combat herbicide resistance. These are tactics or practices implemented prior to, during and after the cropping season, or at any time throughout the rotation.

Wild mustard
Sinapis arvensis

Blue mustard
Chorispora tenella
DOW AGROSCIENCES RECOMMENDS
THE FOLLOWING THREE BEST MANAGEMENT PRACTICES TO MINIMIZE THE RISK OF HERBICIDE RESISTANCE:

**BMP # 1: Understand the Chemistry**

Resistance is an evolutionary process, so there is a science behind it. Resistance always begins and ends at the molecular or genetic level. It’s important to know your herbicide classes and rotate herbicides with different and multiple modes of action annually as well as throughout the growing season. **This includes rotating herbicide groups, not just brand names.** Research continuously shows that using multiple modes of action in a single herbicide application is an effective strategy in managing herbicide resistance.

*Herbicide resistance* is the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to a wild type.

*Herbicide tolerance* is the natural, inherent ability of a species to survive and reproduce after herbicide treatment.

The herbicide’s **mode of action** refers to the overall manner in which a herbicide is absorbed, translocated or moved within the plant, accumulates and affects the specific enzyme or other growth regulatory systems of the plant.

An **active ingredient** is the component responsible for the herbicide’s phytotoxicity. It is the chemical that “controls” the target weed at the site of action.

**The mixture of active and inert (inactive) ingredients in the herbicide product is called the product formulation.**

Weeds contain a tremendous amount of genetic variation. Herbicide products that include multiple, effective modes of action rely on a cohesive approach that uses multiple modes selecting for different mutations within the targeted weed population within a single application.
It's important to ensure each different active ingredient provides some amount of control of the target weed.

**Dow AgroSciences recommendations to growers:**

- Reduce the selection pressure on a single mode of action by using products containing multiple active ingredients of multiple modes of action or tank mix products with different modes of action
- Rotate herbicides to delay or eliminate the onset of resistance to a single mode of action
- When using herbicide-tolerant crop systems such as Roundup Ready®, LibertyLink®, or Clearfield®, rotate crop varieties with different herbicide-tolerant traits or use varieties with herbicide-tolerant trait stacks for more efficient herbicide rotation
- Use herbicide combinations that provide multiple modes of action and overlapping weed activity
- Control all weed escapes prior to seed production

When planning management practices it’s important to think about how specific practices will affect each individual field. For example, when growing a rotation of corn, wheat and soybeans, there are more herbicide modes of action labeled for corn and soybeans than wheat. It is important to utilize the widest range of products throughout the rotation, not just within an individual crop. This is particularly important when growing crops that have very few mode of action and herbicide product options, such as dry beans or canola.

Also, it is important to take advantage of pre-plant, harvest aid, post-harvest, and fallow periods to apply unique control methods to further diversify management programs while reducing the overall weed population.

**Knowing Modes of Action**

In 1997, herbicides were classified into mode of action groups based on the sequence of events from absorption into plants to plant death. The idea is that clearer guidelines could be used to recommend proper rotations by selecting the properly designated herbicide products to eliminate or reduce the potential for herbicide resistance development.

**How Does This Classification Work?**

Each herbicide active ingredient is assigned to a mode of action designated by a group number. Other countries may use a similar system, but designate herbicide mode of action groups by letter. Within each numbered group there may be several herbicide families with different molecular structures but having the same mode of action (the same kill mechanism). Families are groups of molecules with similar structure, physical properties and activity.
GROUP 1  
**MODE OF ACTION:** Acetyl-coenzyme A carboxylase (ACCase) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aryloxyphenypropionate ('OPPv')</td>
<td>quizalofop</td>
<td>Assert® 4L</td>
</tr>
<tr>
<td></td>
<td>clodinafop</td>
<td>Discover® MG</td>
</tr>
<tr>
<td></td>
<td>floraoxyn</td>
<td>Fusilade®</td>
</tr>
<tr>
<td></td>
<td>diclofop</td>
<td>Hoan®</td>
</tr>
<tr>
<td>Cyclhexanedione ('dms')</td>
<td>fenoxyprop</td>
<td>Puma® Wolverine®</td>
</tr>
<tr>
<td></td>
<td>tralkoxydim</td>
<td>Achieve®</td>
</tr>
<tr>
<td></td>
<td>sethoxydim</td>
<td>Poast®</td>
</tr>
<tr>
<td></td>
<td>clodinafop</td>
<td>SelectMax®</td>
</tr>
<tr>
<td>Phenylpyrazoline</td>
<td>pinoxadon</td>
<td>Axis® TRC Axial® XL</td>
</tr>
</tbody>
</table>

GROUP 2  
**MODE OF ACTION:** Acetylactate synthase (ALS or AHAS) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfonylurea</td>
<td>chlorimuron</td>
<td>Classic®</td>
</tr>
<tr>
<td></td>
<td>chlorosulfuron</td>
<td>Finesse®</td>
</tr>
<tr>
<td></td>
<td>haloxyuron</td>
<td>Perim®</td>
</tr>
<tr>
<td></td>
<td>mesosulfuron</td>
<td>Rinfine® Max Osprey®</td>
</tr>
<tr>
<td></td>
<td>metsulfuron</td>
<td>Ally®</td>
</tr>
<tr>
<td></td>
<td>prosulfuron</td>
<td>Peak®</td>
</tr>
<tr>
<td></td>
<td>rimsulfuron</td>
<td>Bas®</td>
</tr>
<tr>
<td></td>
<td>sulfosulfuron</td>
<td>Maverick®</td>
</tr>
<tr>
<td></td>
<td>thifensulfuron</td>
<td>Affinity® BroadSpec</td>
</tr>
<tr>
<td></td>
<td>triasulfuron</td>
<td>Amber®</td>
</tr>
<tr>
<td></td>
<td>tribenuron</td>
<td>Affinity® BroadSpec</td>
</tr>
<tr>
<td>Imidazolinone</td>
<td>imazamethabenz</td>
<td>Assent®</td>
</tr>
<tr>
<td></td>
<td>imazamox</td>
<td>Beyo® Rapt®</td>
</tr>
<tr>
<td></td>
<td>imazethapyr</td>
<td>Pursuit®</td>
</tr>
<tr>
<td>Triazolopyrimidine</td>
<td>fluazifop</td>
<td>GoldSky® Stare® 5L</td>
</tr>
<tr>
<td></td>
<td>pyraflufen</td>
<td>GoldSky® PowerFlex® HL Simplicity® CA</td>
</tr>
<tr>
<td>Sulfonyliminocarbonyl-triazoline</td>
<td>flucarbazone</td>
<td>Everest®</td>
</tr>
<tr>
<td></td>
<td>propoxycarbazone</td>
<td>Olympus®</td>
</tr>
<tr>
<td>Triazoline</td>
<td>thiencarbazone</td>
<td>Huskie® Complete Verio®</td>
</tr>
</tbody>
</table>

GROUP 3  
**MODE OF ACTION:** Microtubule assembly (mitosis) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dinitroaniline</td>
<td>trifluralin</td>
<td>Treffan® TR-10®</td>
</tr>
<tr>
<td></td>
<td>pendimethalin</td>
<td>Power® H2O</td>
</tr>
<tr>
<td></td>
<td>ethylfluralin</td>
<td>Sonalan® HFP</td>
</tr>
</tbody>
</table>

GROUP 4  
**MODE OF ACTION:** Synthetic auxins

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyridine carboxylic acid</td>
<td>clopyralid</td>
<td>WildWay® Stinger®</td>
</tr>
<tr>
<td></td>
<td>fluroxypyr</td>
<td>GoldSky® WideWay® Starane® Ultra</td>
</tr>
<tr>
<td>Phenoxy carboxylic acid</td>
<td>picloram</td>
<td>Tordon®</td>
</tr>
<tr>
<td></td>
<td>dicamba</td>
<td>Clarity® Pulstar®</td>
</tr>
<tr>
<td>Quinoline carboxylic acid</td>
<td>2,4-D</td>
<td>2,4-D Curtail® M</td>
</tr>
</tbody>
</table>

GROUP 5  
**MODE OF ACTION:** Photosystem II inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrite</td>
<td>bromoxynil</td>
<td>Buctril® Huskie® Bronate® Advanced® Wolverine® Starane® NXT</td>
</tr>
</tbody>
</table>

GROUP 6  
**MODE OF ACTION:** Photosystem II inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrite</td>
<td>bromoxynil</td>
<td>Durango® DMA®</td>
</tr>
</tbody>
</table>

GROUP 7  
**MODE OF ACTION:** EPSP synthesis inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate</td>
<td>glyphosate</td>
<td>Roundup®</td>
</tr>
</tbody>
</table>

GROUP 8  
**MODE OF ACTION:** Glutamine synthase inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphonic acid</td>
<td>glufosinate</td>
<td>Ignite® Liberty®</td>
</tr>
</tbody>
</table>

GROUP 9  
**MODE OF ACTION:** Protoporphyrinogen oxidase (PPO) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenoxypyrale</td>
<td>saflufenacil</td>
<td>Sharp®</td>
</tr>
<tr>
<td>N-phenyl-pthalimides</td>
<td>fumigaizin</td>
<td>Valor® Fierce®</td>
</tr>
<tr>
<td>Triazolinone</td>
<td>carfentrazone</td>
<td>Al® Shasta®</td>
</tr>
<tr>
<td></td>
<td>sulforfural</td>
<td>Spartan®</td>
</tr>
</tbody>
</table>

GROUP 10  
**MODE OF ACTION:** Lipid inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxycetamide</td>
<td>fluazifop</td>
<td>Aton® Wolverine®</td>
</tr>
<tr>
<td>Isoxazolinone</td>
<td>pyroxasulfone</td>
<td>Zidua® Fierce®</td>
</tr>
</tbody>
</table>

GROUP 11  
**MODE OF ACTION:** Photosystem I (PSI) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bipyridyllium</td>
<td>paraquat</td>
<td>Bronate® M</td>
</tr>
</tbody>
</table>

GROUP 12  
**MODE OF ACTION:** 4-hydroxyphenyl-pyruvate-dioxygenase (HPPD) inhibitor

<table>
<thead>
<tr>
<th>CHEMICAL FAMILY</th>
<th>ACTIVE INGREDIENT</th>
<th>CEREALS PRODUCT TRADE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrazole</td>
<td>pyraflufen</td>
<td>Huskie® Wolverine®</td>
</tr>
</tbody>
</table>
The table inside outlines a list of commonly used herbicide groups. The table also shows chemical families, active ingredients and popular cereal herbicides for each family.

HERBICIDE MODES OF ACTION CLASSIFICATIONS

Tracking Each Rotation
Understanding the chemistry and product options is crucial to minimizing resistance. Managing the herbicide and crop rotation is a key defense.

While consistency is something most companies strive for in products and services, it can be detrimental when it comes to preventing and managing herbicide resistance.

Diversity in product selection is critical to the prevention of herbicide resistant weed populations. It’s imperative to keep a log and track herbicide and crop rotation information for each field and for each crop within that field. Similarly, it is important to continually monitor weed populations in each field from year to year. Again, the development of herbicide resistant populations is a result of the interaction of the herbicides, the weed species, and the environment or production practices. Keeping track of the production practices in a particular field and monitoring the results provides you with information to avoid creating intensive selection for resistant biotypes.

We’ve outlined one of the simplest and best ways to take control of a herbicide resistance management program: set up a rotation tracker. This allows the growers and/or the retailer to keep track of crops and herbicides used annually and seasonally in each field.

After recording these practices for a few years for each field, this tracker will create a go-to guide to help avoid creating intensive selection for resistant weed biotypes.

Here’s an example of a spreadsheet created to track both crop and herbicide rotation information.

<table>
<thead>
<tr>
<th>HERBICIDE &amp; CROP ROTATION TRACKER</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIELD ID:</td>
</tr>
<tr>
<td>YEAR/SEASON:</td>
</tr>
<tr>
<td>CROP:</td>
</tr>
<tr>
<td>PRE-PLANT APPLICATION</td>
</tr>
<tr>
<td>PRODUCT NAME:</td>
</tr>
<tr>
<td>MODE OF ACTION GROUP #(S)</td>
</tr>
<tr>
<td>PRE-/EARLY-POST EMERGENCE APPLICATION</td>
</tr>
<tr>
<td>PRODUCT NAME:</td>
</tr>
<tr>
<td>MODE OF ACTION GROUP #(S)</td>
</tr>
<tr>
<td>POST-HARVEST APPLICATION</td>
</tr>
<tr>
<td>PRODUCT NAME:</td>
</tr>
<tr>
<td>MODE OF ACTION GROUP #(S)</td>
</tr>
</tbody>
</table>

What You Need to Know About Tank-Mix Partners
Tank mixing herbicides is another way to add additional modes of action into a single herbicide application. This allows growers to broaden weed spectrum control, increase the level of control and reduce the risk of weeds building resistance or tolerance.
Cultural weed management refers to agronomic practices, including crop rotation, soil fertility, etc. The key to any successful weed management practice is starting with a clean slate at planting. The use of a pre-plant burndown herbicide program or effective pre-plant tillage can ensure seeding into a clean, weed-free field, which provides an environment more favorable to the development of an aggressively competitive crop. Additionally, using a residual herbicide when possible will delay early emerging weeds which, again, adds to the competitiveness of the crop and allows for easier control of smaller, later-emerging weeds with post-emergence herbicide applications.

Pre-emergence herbicides: Herbicides that are applied before the target weed germinates and emerges. These herbicides may or may not control emerged weeds.

Post-emergence herbicides: These herbicides are applied to the foliage of the target weed after it has emerged from the soil. These herbicides may or may not provide residual control.

Herbicides must be used properly to be most effective. It’s critical to follow all label instructions, including correct timing, full use rates and appropriate spray volumes. It is also critical to integrate production practices that enhance the competitiveness of the crop and reduce the addition of herbicide resistance to the soil seed bank.

Dow AgroSciences recommendations to growers:

- Rotate crops to diversify your weed management tools (broadleaf vs. grass crops; fallow options)
- Choose rotations with crops of diverse seeding and maturity dates (winter- vs. spring-seeded crops; early- vs. late-seeded spring crops)
- Consider including forages or other perennial crops as part of the rotation, with multiple harvests per year and multiple years of stand
- Use seeding rates and row spacings that provide the greatest competition to weeds
- Use clean, weed-free seed. Saved seed may contain weed seed that has survived your weed management program. Using saved seed means you are now moving those resistant weed biotype’s seeds to every field on the farm
- Use the most competitive crop varieties, if possible
- Use fertilizer at appropriate rates, timings, and placement to increase competitiveness of the crop in relation to the weed
- Ensure equipment is properly cleaned between fields, particularly leased or contracted harvest equipment
- Apply herbicides to actively growing weeds in the proper growth stages for most effective control
- Always tarp trucks when transporting grain to prevent weed seed from traveling off loads onto neighboring fields and encourage your neighbors to do the same
Operating at Your Optimal Level

There are multiple operational factors that impact the effectiveness of herbicide applications. Some of these include: carrier volume, application speed, adjuvants, tank-mix partners and any other factor that affects spray coverage or interferes with herbicide activity.

An adjuvant is any material that is added to a herbicide carrier solution or water to enhance or modify the performance of the herbicide. These may include surfactants, water conditioners, compatibility agents and others.

Surfactants are compounds that lower the surface tension between two liquids or between a liquid and solid, helping herbicides to do their jobs. Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents and dispersants.

Ensuring proper herbicide application maximizes control and minimizes potential for weed escapes. Always apply herbicides to small, actively growing weeds, as they are more likely to absorb more of the active ingredient. Moreover, at the time when weeds are small, early in the season, it’s more likely that available soil moisture, sunlight and optimal soil nutrient levels will greatly enhance crop growth and competition to suppress later-emerging weeds.

Plan to apply post-emergence herbicides when weeds are less than 4 inches tall. Early season weed competition can cause the most detrimental losses of the season, so the use of available pre-emergence residual herbicides to control early-season weeds typically result in greater crop yields when effectively managed.

Keep in mind that herbicides may work quickly or more slowly, depending on their mode of action and environmental conditions. You may notice responses to herbicides within a few days or over a couple of weeks. The expected time of response for each individual herbicide can often be found on the product label.

Application Guidelines for Proper Herbicide Resistance Management

Getting the most from your herbicides and avoiding resistance starts with selecting the right product. If certain chemicals are applied at the wrong growth stage, they may be ineffective or even damage the crop. There are three essential cultural elements to take into consideration for maximizing herbicide performance:

1. Crop and weed staging: efficacy and safety of the herbicide really depends on an accurate assessment of your cereal crop’s growth stage, along with weed growth, to determine appropriate application timing.
2. Proper spray volume, pressure, adjuvants, nozzle selection and other factors to ensure a safe and effective application.
3. Follow any and all tank-mix procedures accordingly.

Barnyardgrass
Echinochloa crus-galli (L.)
Recognizing Growth Stages for Sprayer Applications

There are several different scales that outline growth and development states of cereal crops. Purdue University Extension states that the most commonly used scales include the Feekes scale, the Haun scale, the BBCH scale and the Zadoks scale. Each scale includes a varying amount of detail to describe the different stages. The Feekes scale is most commonly used throughout the United States.

Below is an outline of the most important growth stages for proper herbicide application featuring Dow AgroSciences herbicide products:
Timing is Important
Below we’ve outlined a proper weed management action timeline for managing herbicide resistance in wheat:

WINTER WHEAT

AUGUST-OCTOBER: Pre-plant period of upcoming crop
Use tillage or burndown applications to control weeds present prior to crop planting. Effectiveness of pre-plant weed control will depend largely on moisture conditions leading up to winter wheat planting.

OCTOBER-DECEMBER: Pre-emergence and early development of crop
If conditions allow, apply pre-emergence or early post-emergence residual herbicides such as PowerFlex® HL as part of a two phase approach to winter annual grass weed control. PowerFlex HL or other products can provide a unique mode of action at a unique timing for control of grass weeds such as downy brome.
Alternatively, if fall moisture is adequate and the crop has developed past the 3-leaf stage, November may provide an opportunity for post-emergence applications for downy brome or other winter annual weed species.

FEBRUARY-MAY: Early spring development
Scout fields following winter dormancy to determine the extent of populations of winter and early spring annual weeds. If grass and broadleaf weed development are substantially different, consider splitting grass and broadleaf herbicide applications to provide greatest control of all targeted weeds.

MAY-JUNE: Pre-harvest period
Once crop has headed, scout fields for escaped weeds. Identify the weeds and determine the best strategy for preventing seed production. In extreme situations, this may include harvesting the crop for hay or simply using mowing, tillage or herbicide applications to destroy the weed escapes and the crop. Generally, once the crop has reached the soft dough stage of development, pre-harvest or harvest aid applications of labeled herbicides can be done safely. Read and follow all label directions for harvest aid applications.

JUNE-SEPTEMBER: Harvest strategies
Minimize movement of herbicide resistant weeds between and within fields. Evaluate weed populations and weed escapes just prior to crop harvest. If possible, harvest fields with suspected populations of herbicide resistant weeds last. Similarly, isolate areas of individual fields with suspected resistance and harvest those portions of the field last. Know where custom harvest equipment has been and ensure equipment is clean before it enters the field and as it leaves your fields. Tarp all loads of grain as they leave your field and encourage your neighbors to do the same.

APPLY ALL HERBICIDES AT THE PROPER TIMING FOR CROP AND WEED DEVELOPMENT AND UNDER CONDITIONS THAT PROVIDE OPTIMAL CONTROL WITH LESS CHANCE FOR CROP INJURY.
SPRING AND WINTER WHEAT

AUGUST-OCTOBER: Post-harvest period of previous crop
Use tillage and/or nonselective herbicide applications to control escaped weeds post-harvest. Control of weeds following harvest will prevent seed production of any weeds present in that field. This amounts to a genetic dead end for potentially resistant biotypes.

OCTOBER-DECEMBER: Fall setup for the following year’s spring seeding or fallow
Typically, late fall provides an opportunity for the most effective control of perennial weeds, such as quackgrass or Canada thistle. Applications at this timing allow for greater herbicide movement to the weed’s roots or rhizomes and provide total above- and below-ground control of perennial weeds.

Additionally, burndown of volunteer grain and winter annual weeds just ahead of winter freeze can allow for earlier planting of crops the following spring.

For fields being rotated to fallow, adding a residual herbicide to the burndown application can provide better weed control throughout the fallow period, with less potential for injury to the crop seeded after fallow.

DECEMBER-FEBRUARY: Review your strategy and plan weed management for the upcoming year
Familiarize yourself with the herbicide mode of action groups so that knowledgeable changes can be made both in long- and short-term planning of weed management options.

FEBRUARY-MAY: Pre-plant period
Scout fields to determine extent and development of weeds coming out of winter. Determine optimal timing of burndown and pre-emergence herbicide applications to provide greatest weed control with the least concern over the “green bridge” effect on root and foliar diseases for the spring-planted cereal crop. The advantage of a fall burndown program could be important as effective fall control could mean much earlier planting for greater yield potential.

MAY-JUNE: Early crop development
As stated earlier for winter wheat, it is critical to repeatedly scout fields to determine the most effective timing of herbicides for the targeted weeds. Again, it is important to make sure the crop development stage allows for the most effective and safe applications.

JUNE-SEPTEMBER: Pre-harvest and harvest strategies
Consider pre-harvest and at-harvest options previously described for winter wheat.

DON’T BE AFRAID TO TRY NEW STRATEGIES — KEEPING IN MIND THAT NO SINGLE APPROACH WILL BE COMPLETELY EFFECTIVE ON ITS OWN.

Weed resistance management practices will not be identical for every grower or in every field. It is important to use multiple practices to manage or delay resistance.
BMP #3: Pay Attention

You have to know your fields and know your weeds to detect a problem. Scouting regularly and responding quickly to changes in weed populations are the most effective ways to stay in front of herbicide resistance. Learn which weeds have been identified as being particularly prone to the development of resistance, and scout to determine if you have those particular species of weeds. If you do, take an even harder look at your herbicide, tillage and cultural methods of weed control to determine the most and least effective methods of control.

It is equally important to understand the weed pressure and history within each field. Closely monitor problematic areas that have difficult-to-control weeds or dense weed populations. Scout for weed escapes and look for any indicators identifying possibly resistant weeds.

Irregularly shaped patches of a single weed species in a field are a good indicator that herbicide resistance may be an issue.

Proper identification of weed species will help pinpoint which herbicide program will work best on each acre.

**Why is Scouting Important?**

The ultimate goal in herbicide resistance management is to reduce weed populations from year to year, allowing for more efficient use of herbicides and other cultural practices to control weeds. Repeatedly monitoring fields helps detect problems before weeds become too large to control effectively. Pre-plant and post-harvest can be critical times for resistance management due to the additional herbicide and tillage options available.

**Dow AgroSciences recommendations to growers:**

- Do not allow weed escapes to produce seed; use effective post-harvest tillage or herbicide applications
- If escape plants do manage to mature, remove these seed-bearing plants from the field and destroy
- Always clean equipment when moving between fields
- If substantial seed rain has occurred, consider partial field burning if allowed by local laws
- Contact a local retailer, crop protection company or extension service to determine options to test your specific issue

**PROPER IDENTIFICATION OF WEEP SPECIES WILL HELP PINPOINT WHICH HERBICIDE PROGRAM WILL WORK BEST ON EACH ACRE.**
WEEDS FOUND IN CEREALS CROPS

Common chickweed
Steallaria media (L.) Vill.

Common cocklebur
Xanthium strumarium L.

Common mallow
Malva neglecta Wall.

Common ragweed
Ambrosia artemisiifolia L.

Biennial wormwood
Artemisia biennis Willd.

Blue mustard
Chorispora tenella

Canada thistle
Cirsium arvense (L.) Scop.

Catchweed bedstraw
Galium aparine L.

Field bindweed
Convolvulus arvensis L.

Flixweed
Descurainia sophia (L.) Webb ex Prantl

Horseweed
Conyza canadensis (L.) Cronq.

Kochia
Kochia scoparia (L.) Schrad.

Lambsquarters
Chenopodium album L.

Marshelder
Iva xanthifolia Nutt.

Mayweed, Chamomile
(Chamomile) Anthemis cotula L.

Nightshade
Solanum ptycanthum Dun. ex DC.

Penny-cress, field
Thlaspi arvense L.

Pigweed
Amaranthus spp.

Pinnate tansymustard
Descurainia pinnata

Prickly lettuce
Lactuca serriola L.

Russian thistle
Salsola iberca Senn. & Pau

Smartweed (annual)
Polygonum hydropiper

Sowthistle, perennial
Sonchus arvensis

Sunflower
Helianthus annuus L.

Volunteer canola
Brassica napus

Volunteer flax
Linum usitatissimum

Wild buckwheat
Polygonum convolvulus L.

Wild mustard
Snaps arvensis

Grasses

Annual bluegrass
Poa annua

Barnyardgrass
Echinochloa crus-galli (L.)

Cheat
Bromus secalinus

Downy brome (cheatgrass)
Bromus tectorum L.

Italian ryegrass
Lolium perenne L.

Wild oats
Avena fatua L.

Yellow foxtail
Setaria glauca (L.) Beauv.
What to do With Weed Escapes?

When you find weed escapes, it’s time to start from the beginning of your herbicide resistance management program and review your best management practices, as well as our recommended lists.

There are several options for removal of weed escapes that survive herbicide applications. These include spot application, manual removal and/or cultivation.

**Spot application** permits application of the chemical just to target weeds. Foliar applications should be made with a low-pressure (20-50 psi) backpack sprayer or small tank sprayer equipped with a wand applicator. A sprayer nozzle that creates a flat or cone-shape pattern is preferable in these situations. Do not spray in windy conditions or if there is a chance of precipitation; the herbicide needs to dry for at least two hours to ensure proper absorption. The addition of a surfactant to the mixture helps provide complete leaf coverage and increases the rate of absorption. The herbicide should cover the foliage thoroughly but not to the point of run-off.

**Manual removal** of weeds is one effective method of managing weed escapes, but can also be tedious and time-consuming. This can be done using hoes or sickles. All weeds should be bagged and removed from the field and roadside completely.

**Cultivate** in areas of suspected herbicide resistant weeds. It is best to cut around those areas and harvest last or even burn the standing crop in limited areas. Also, due to weeds encroaching from the field edge, some farmers will harvest from the center of the field outward. It’s a good idea to make sure trucks are tarped to ensure you don’t spread the resistance problem to your neighbors; encourage them to do the same.

At Dow AgroSciences, we are committed to increasing crop productivity through higher yields, better varieties, and more targeted management control. Our products and services are designed to solve pressing crop production problems for our customers, boosting agriculture productivity to maximum sustainable levels to meet the growing needs of our world’s rapidly expanding population.

Our herbicide resistance best management practices align directly with our mission. Leadership in this industry is important, and it’s important to us. When it comes to products and industry trust—even for something as specific as herbicide resistance management—we know that we have an opportunity and a commitment to our customers to be a leader.

What is good for the industry and for growers is good for us, so we aren’t looking to change the basic industry recommendations for minimizing and preventing resistance. However, we know that you, along with growers and consultants, are the ones in the fields every day fighting this battle. So, we will continue to provide you with simple, useful tools and resources and work with you towards managing resistance.

IF YOU ARE INTERESTED IN ANY ADDITIONAL INFORMATION, please contact your Dow AgroSciences sales representative or email the Dow AgroSciences Cereal Herbicides Product Manager at FUSCRLS@dow.com.

You can find a complete list of Dow AgroSciences sales representatives in your area and additional herbicide resistance management materials on our website, www.dowagro.com/gameon.
Solutions for the Growing World


^Dow Diamond, Curtail, Durango, DMA, GoldSky, PowerFlex, Simplicity, Sonalan, Starane, Stinger, Tordon, Treflan, TR-10, and WideMatch are registered trademarks of The Dow Chemical Company (“Dow”) or an affiliated company of Dow.

Tordon 22K, Tordon 101M and Tordon K are federally Restricted Use Pesticides. Durango DMA, GoldSky, PowerFlex HL, Simplicity CA, Starane Flex, Starane NKT, Starane Ultra and WideMatch are not registered for sale or use in all states. Stinger is not available for sale, distribution or use in Nassau and Suffolk counties in the state of New York. Contact your state pesticide regulatory agency to determine if a product is registered for sale or use in your state. Always read and follow label directions.

M01-137-19B  MC (7-14)  010-43154
DOW30864-7

Beyond, Clarity, Clearfield, Facet, Poast, Paramount, Pursuit, Prowl, Raptor, Sharpen and Zidua are registered trademarks of BASF Corporation.

Axiom, Bronate, Buctril, Hoeon, Huskie, Ignite, Liberty, LibertyLink, Osprey, Puma, Rimfire, Varro and Wolverine are registered trademarks of Bayer CropScience USA, Inc.

Aim, Shark and Spartan are registered trademarks of FMC Corporation.

Affinity, Ally, Assure, Basis, Classic, Express, Finesse, Glean and Harmony are registered trademarks of E.I. DuPont de Nemours and Co., Inc.

Permit is a registered trademark of Nissan Chemical Industries Ltd.

Fierce, SelectMax and Valor are registered trademarks of Valent U.S.A. Corporation.

AAtrex, Achieve, Amber, Axial, Beacon, Discover, Fusiarcide, Gramoxone, Peak, Pulsar, Rave and Sierra are trademarks of Syngenta Group Company.

Maverick, Outrider, Roundup, and Roundup Ready are registered trademarks of Monsanto Technology LLC.

Everest is a registered trademark of Arysta LifeScience North America, LLC.

Assert is a registered trademark of Nufarm Agriculture, Inc.