



Herbicide Resistance Management Guide

An educational guide to help manage or delay the onset of herbicide resistance.



Bayer CropScience

GROWING A HEALTHIER WORLD

Some might call it a mission statement. We just call it a good idea.

Bayer CropScience is focused on addressing the world's agricultural challenges, big and small. It's a tall order, but our passion is rooted from the ground up — continuously working to improve agriculture, our communities and our well-being.

The Continuous Search

Cultivating ideas and answers with not only our people, but also with our customers, communities and partners, is our way to ensure we can help feed a hungry planet. Together, we are searching for new breakthroughs to sustain and enrich our growing environment. Bayer CropScience Canada is committed to:

- Investment in research and development to continue to develop ground-breaking crop and crop protection products like Liberty®, Infinity®, Prosaro®, Alion™, Titan® Emesto™, Velocity m3, Trilex® EverGol™ Raxil® and Varro™.
- Working within biology and chemistry to develop the LibertyLink® system, an integrated seed and crop protection solution for canola, soybeans and corn.
- Accelerating success through the dedication of 350 passionate people willing to roll up their sleeves.

Every Harvest Counts

There's a challenge to produce more food, fuel and fibre for a growing world population. That's why establishing a healthy harvest is vital to farming families and our communities. We know what's at stake.

For generations we've worked with farmers, distributors, food manufacturers and others to help create new approaches and solutions that can better service everyone along the value chain — from seed to harvest to the shelf.

We strive to help every inch of the field thrive so our communities thrive. And in doing so, we will not only grow a healthier world, but also provide peace of mind for our communities.

Learn more at BayerCropScience.ca to help cultivate ideas and answers — propelling farming's future together.

EVOLUTION OF WEED RESISTANCE

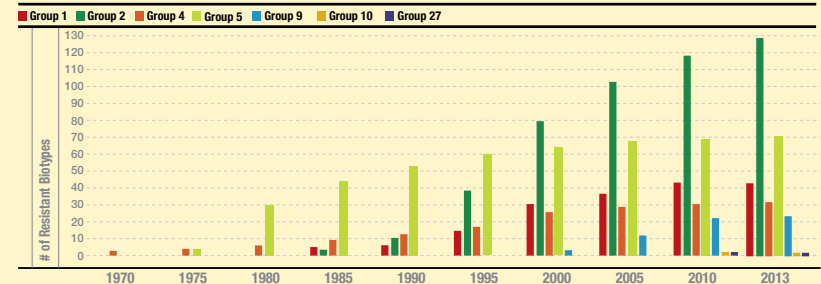
The use of herbicides in modern agricultural production systems has allowed growers to more effectively and efficiently control weeds, improve crop yields and increase profitability. Additionally, the adoption of herbicide-tolerant traits has allowed growers to apply non-selective herbicides over the top of crops, often with less tillage, fuel and labour. However, the evolution of herbicide-resistant weeds is an unfortunate side effect from the overuse of a single herbicide or mode of action.

The occurrence of herbicide-resistant weeds worldwide is tracked on the website: WeedScience.org. This site is run in conjunction with several global groups including the Herbicide Resistance Action Committee (HRAC) and the Canadian Weed Science Society (CWSS).

Cases of herbicide resistance are becoming increasingly common. There are over 380 resistant weed biotypes reported globally and 58 reported in Canada according to WeedScience.org. From a provincial standpoint, there are 20 biotypes in Alberta, 20 in Manitoba, 17 in Saskatchewan, 32 in Ontario and three in Quebec.

Globally, in the mid-1990's, there was a rapid increase in the number of reported weed biotypes resistant to ALS inhibitors, ACCase inhibitors and synthetic auxins. The advent of glyphosate-tolerant technology, combined with a decreased price and increased pre-emergent applications in the same period, set the timer on resistance evolution for glyphosate. The graph below illustrates the increase in herbicide-resistant weeds reported globally.

The Chronological Increase in the Global Number of Herbicide-Resistant Weeds For Several Herbicide Modes of Action



Source: Heap, I., WeedScience.org, 2013.

In Canada, some of the most widespread and increasingly important herbicide resistance problems in cereals, canola, corn, soybeans and pulses are associated with the following herbicide groups:

- Group 1 – ACCase inhibitors
- Group 2 – ALS inhibitors
- Group 5 – Photosystem II inhibitors (triazines)
- Group 9 – EPSP synthase inhibitors (glyphosate)

Several herbicide modes of action have recently gained broad acceptance in the marketplace to help manage common herbicide resistance issues including:

- Group 27 – HPPD inhibitors
- Group 10 – Glutamine synthetase inhibitors (glufosinate)
- Group 14 – PPO inhibitors (limited acres in Canada)

If not managed correctly, these more recent herbicide mode of action introductions could also lose their effectiveness in the future. To effectively manage the development of weed resistance, it is key to first understand how herbicide resistance develops.

THE SCIENCE OF WEED RESISTANCE

How do herbicides kill weeds?

Herbicides enter the plant at lethal dosages and interfere with crucial life processes necessary for the plant to live. The active ingredient often binds to a particular target site within the plant, usually an enzyme or protein essential to plant growth and development, creating a cascade of consequences that eventually lead to plant death. A small number of herbicides can act at multiple target sites.

What is resistance and how does it originate?

Resistance is a naturally occurring, inherited ability of some weed biotypes to survive a herbicide treatment that should, under normal use conditions, effectively control a weed population. Natural selection is the most common theory for the initial evolution of weed resistance within a weed population.

How do resistant weed biotypes increase in number?

When a herbicide is applied to a sensitive population, most of the weeds in the population die. Sometimes rare resistant weed biotypes survive, mature and produce seed. With repeated use of the same herbicide or family of related herbicides, or lack of diversity in the herbicide management program, the resistant weeds may eventually be 'selected' from the population and dominate. Generally, the more effective the herbicide, the greater the selection pressure and the greater the probability that only resistant weeds will survive.

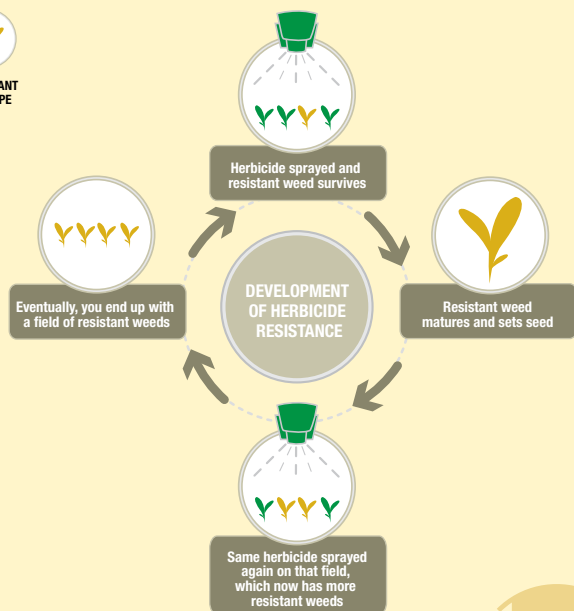
Selection of resistant weed biotypes with repeated applications of the same herbicide or same mode of action herbicides



SUSCEPTIBLE/
WILD BIOTYPE



RESISTANT
BIOTYPE



What occurs within a resistant weed biotype that allows it to survive a herbicide application?

Some weeds have naturally developed one or more mechanisms that allow them to survive a herbicide treatment. This generally begins at a very low frequency in a population. The resistance mechanism is often controlled by a single gene. The two most common resistance mechanisms present within a weed population are:

Target site resistance

The herbicide reaches the target site at a normally lethal dose, but modification or amplification of the target site gene(s)/enzyme(s) limits herbicide binding, and thus its impact.

Herbicides acting at a single target site are more prone to weeds developing resistance than those that act at multiple sites. This is because the odds of a single mutation conferring resistance to a single mode of action (MOA) are much more likely compared to multiple mutations at multiple target sites. Herbicides with multiple modes of action are an effective resistance deterrent if more than one herbicide component has activity on the weed(s) of concern.

Non-target site resistance

This occurs when the amount of active herbicide that reaches the target site is reduced (e.g. reduced uptake, reduced translocation, enhanced metabolism, sequestration, etc.).

Can weeds be resistant to more than one herbicide or herbicide family?

Weeds can develop resistance to more than a single herbicide or a single mode of action. Two terms commonly used to describe these types of resistance scenarios include:

Cross-resistance

Weeds are resistant to two or more herbicides with the same mode of action by way of a single resistance mechanism (e.g. weed is resistant to multiple or all active ingredients in Group 1, but is still susceptible to other herbicide modes of action).

Multiple resistance

Weeds are resistant to two or more herbicides with differing modes of action because they possess either a non-target site resistance mechanism that works on multiple modes of action or possess two (or more) unique target site mutations (e.g. weed is resistant to Group 1 and Group 2 herbicides).

The difficulty of controlling weeds with various forms of resistance can be ranked as follows (least difficult to most difficult):

1. Single resistance (one herbicide)
2. Cross-resistance (multiple herbicides, same mode of action)
3. Multiple resistance (multiple herbicides, various modes of action)

SINGLE



Example: weed is resistant to active ingredient X which is a Group 1, but is still susceptible to active ingredient Y, which is also a Group 1.

CROSS



Example: weed is resistant to multiple or all active ingredients in Group 1, but is still susceptible to other herbicide modes of action.

MULTIPLE



Example: weed is resistant to Group 1 and Group 2 herbicides.

THE SCIENCE OF WEED RESISTANCE

What actions increase the selection for herbicide resistance?

Weed management practices that can lead to increased selection pressure on weeds include:

- Using reduced rates of herbicides.
- Applying herbicides at inappropriate or delayed timing.
- Applying herbicides with the same mode of action multiple times during a growing season.
- Repeated use of herbicides with long residual activity.
- Using herbicides with the same mode of action for several consecutive growing seasons on the same field.
- Using herbicides as the only weed control option.

Rotation of crops, herbicide-tolerant traits and herbicide modes of action, as well as the inclusion of mechanical and cultural control methods where possible, can play important roles in delaying the evolution of resistance or managing existing resistant weed populations.

Identification of Weed Resistance

What to look for when identifying resistant weeds

Indicators of potential weed resistance are:

- A weed patch occurs in the same area year after year and is spreading.
- Dead weeds appear next to surviving weeds after the same herbicide application.
- Many weed species are managed, but one particular susceptible weed species is no longer controlled.

What should you do if you suspect you have herbicide resistant weeds?

The above indicators are not definitive proof of resistance and further testing is needed to confirm resistance. Contact your local agronomist or Bayer CropScience representative to have weed seeds collected and evaluated for potential resistance.

What management practices delay the onset or manage the spread of resistant weeds?

The best way to manage weed resistance is to prevent it from developing in your fields by implementing a diverse weed management program. This helps limit the selection pressure on weeds present in your fields. Use of Integrated Weed Management (IWM) strategies will help delay the development of resistance in weed populations.

MIX IT UP

Mix It Up is an initiative to elevate the importance and grower adoption of herbicide diversity. Herbicide mode of action (MOA) rotation is essential to improve weed resistance management.

- **Rotate herbicide modes of action.** Reduce the selection pressure of a single MOA by using multiple MOAs with activity on weeds of interest, both during the growing season and from year to year.
- **Rotate crops.** Crop rotation provides diversified weed management tools.

The following Integrated Weed Management techniques are effective in reducing problems with herbicide-resistant weed biotypes. It is best to use multiple practices to manage or delay resistance, as no single strategy is likely to be totally effective.

- 1. Know your weeds, know your fields.** Closely monitor problematic areas of difficult-to-control weeds or dense weed populations.
- 2. Start with clean fields.** Effective tillage or the use of a burndown herbicide program can control emerged weeds prior to planting.
- 3. Apply herbicides correctly.** Ensure proper application, including correct timing, full use rates and appropriate water volumes.
- 4. Control weed escapes.** Consider spot herbicide applications, cultivation, hand removal of weeds or other techniques to stop weed seed production.
- 5. Zero tolerance.** Reduce the herbicide-resistant weed seed bank. Do not allow surviving weeds to set seed. This will help decrease weed populations from year to year and prevent major weed shifts.
- 6. Clean equipment.** Prevent the spread of herbicide-resistant weeds and seeds.



Visit MixItUp.ca for more simple strategies and solutions.

What is herbicide classification by mode of action?

One simple way to delay or manage weed resistance is to use herbicides or herbicide tank mixes with differing modes of action from year to year. The Canadian Weed Science Society (CWSS), Weed Science Society of America (WSSA) and Herbicide Resistance Action Committee (HRAC) employ easy-to-use herbicide classification systems by mode of action, using numbers and letters, respectively.

The CWSS and WSSA group products with similar modes of action together by an assigned group number from 1 to 29. The Pest Management Regulatory Agency (PMRA) requests registrants voluntarily add a group number to the label showing the mode(s) of action of the herbicide or herbicide premixes. A condensed version of the classification document is located at the back of this brochure.

Alternatively, HRAC references herbicide classes by letter and number, as does the International Survey of Herbicide-Resistant Weeds (WeedScience.org), the reporting body for confirmed resistant weeds. On the following pages, we include both classifications for your reference.

Group 1

ACCCase Inhibitors HRAC Group A

What is a Group 1 herbicide?

- Inhibitor of acetyl-coenzyme A carboxylase (ACCCase) enzyme.
- Inhibition prevents the production of fatty acids and lipid synthesis leading to rapid cessation of plant growth at the growing point.
- Susceptible grasses generally die in 10 days to two weeks.
- Consists of products from three chemical families: aryloxyphenoxy-propionate (FOPs), cyclohexanedione (DIMs) and phenylpyrazoline (DENs).

Confirmed Group 1-Resistant Weed Species in Canada

- Green foxtail (West)
- Large crabgrass (East)
- Persian darnel (West)
- Wild oats (West)

Note: West refers to provinces from British Columbia to Manitoba, East refers to provinces from Ontario to the Atlantic.

How do weeds evolve resistance to Group 1 herbicides?

- Involves both target site and non-target site resistance mechanisms.
- Resistance is due to an altered ACCCase binding site or enhanced metabolism of the herbicide.

How many weeds have developed resistance to Group 1 herbicides?

Globally: 42 weed species confirmed

Canada: 4 weed species confirmed

COMMON GROUP 1 ACCCase INHIBITOR HERBICIDES

In-crop use of Group 1 herbicides is most common in cereals, canola, pulses and non-GM soybean production.

| WEST | PULSES |
|--|--|
| CANOLA | Assure II Centurion Equinox Odyssey DLX* Shadow RTM |
| Assure II Centurion® Equinox Odyssey DLX* Shadow RTM | EAST |
| CEREALS | CANOLA |
| Achieve Liquid Gold* Axial Axial iPak* Axial Xtreme* Broadband* Foothills NG Harmony brands* Horizon NG Liquid Achieve SC NextStep NG Puma® Advance Signal Traxos Tundra®* Wildcat | Assure II Poast Ultra Select® Venture L CEREALS Achieve Liquid Achieve Liquid Gold* Puma Advance SOYBEANS Excel® Super Glacier* Poast Ultra Select |

* Contains at least one non-Group 1 chemistry
† IMI tolerant canola only

BAYER CROPSCIENCE HERBICIDES FOR MANAGEMENT OF GROUP 1-RESISTANT GRASSY WEEDS

WEST

CANOLA

Liberty^{LL} (Group 10)

CEREALS

Varro (Group 2)

Velocity m3 (Group 2, 6, 27)

EAST

CANOLA

Liberty^{LL} (Group 10)

CORN

Converge® XT (Group 5, 27)

Liberty^{LL} (Group 10)

Option® (Group 2)

Vios™ G3 (Group 2, 27)

SOYBEAN

Liberty^{LL} (Group 10)

^{LL} = LibertyLink® canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

WILD OATS

Wild oats are the most prominent Group 1 herbicide-resistant grass weed on the Prairies. Recent surveys from Agriculture and Agri-Food Canada (AAFC) indicate Group 1-resistant species have been found in 55% of MB, 32% of SK and 39% of AB fields surveyed.

W



Group 2

ALS Inhibitors HRAC Group B

What is a Group 2 herbicide?

- Inhibitor of acetolactate synthase (ALS) or acetyohydroxy synthase (AHAS) enzyme.
- Inhibition leads to depletion of key branched-chain amino acids necessary for protein synthesis and plant growth.
- Susceptible weeds may take several weeks to die.
- Consists of products from primarily four chemical families: imidazolinone, sulfonyleurea, sulfonylaminocarbonyl-triazolinone and triazolopyrimidine.
- Group 2 active ingredients can have activity on broadleaf or grassy weeds and sometimes both.

Confirmed Group 2-Resistant Weed Species in Canada

- Ball mustard (West)
- Chickweed (West)
- Cleavers (West)
- Canada fleabane (East)
- Common ragweed (East)
- Common waterhemp (East)
- Cow cockle (West)
- Eastern black nightshade (East)
- Giant foxtail (East)
- Green foxtail (West & East)
- Hemp-nettle (West)
- Horseweed (East)
- Kochia (West)
- Lamb's-quarters (West & East)
- Narrow-leaved hawk's beard (West)
- Pale smartweed (West)
- Powell amaranth (West & East)
- Redroot pigweed (West & East)
- Russian thistle (West)
- Shepherd's purse (West)
- Spiny sow thistle (West)
- Stinkweed (West)
- Wild buckwheat (West)
- Wild mustard (West)
- Wild oat (West)



W



How do weeds evolve resistance to Group 2 herbicides?

- Involves both target and non-target site resistance mechanisms.
- The binding site on the ALS enzyme is altered, and the herbicide cannot attach itself to the protein. Additionally, enhanced herbicide metabolism has been shown as a resistance mechanism.

How many weeds have developed resistance to Group 2 herbicides?

Globally: 129 weed species confirmed
Canada: 25 weed species confirmed

KOCHIA

Kochia is now considered predominately resistant to Group 2 chemistry, as past AAFC surveys have confirmed resistance levels upwards of 90%.

COMMON GROUP 2 ALS INHIBITOR HERBICIDES

In-crop use of Group 2 herbicides is most common in cereals, Clearfield crops (canola, cereals and pulses), pulses, corn and to a lesser extent soybeans.

| WEST | EAST |
|----------------------------|-----------------|
| CANOLA | CANOLA |
| Absolute** [†] | Muster |
| Odyssey DLX** | CORN |
| Pursuit [†] | Accent brands* |
| Solo [†] | Battalion* |
| Tensile** [†] | Elim EP |
| CEREALS | Galaxy 2* |
| Adrenalin** [†] | Option Liquid |
| Ally | PeakPlus* |
| Altitude FX** [†] | Prism |
| Assert | Ultim 75DF |
| Avert | Ultim Total* |
| Barricade* | Vios G3* |
| Benchmark* | CEREALS |
| Broadband* | PeakPlus* |
| Broadside* | Refine |
| Everest | SOYBEANS |
| Everest GBX* | Broadstrike |
| Frontline* | Classic* |
| Harmony brands* | Cleansweep* |
| Retain* | Conquest LQ* |
| Refine | Firstrate |
| Sierra | Guardian* |
| Simplicity | Guardian Plus* |
| Spectrum* | Pinnacle SG |
| Stellar* | Pursuit |
| Tandem* | |
| Triton* | |
| Varro | |
| Velocity m3* | |
| PULSES | |
| Multistar | |
| Odyssey | |
| Odyssey DLX* | |
| Pursuit | |
| Solo | |
| Viper* | |

* Contains at least one non-Group 2 chemistry
[†] IMI tolerant canola only [‡] Clearfield wheat only

BAYER CROPSCIENCE HERBICIDES FOR MANAGEMENT OF GROUP 2-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST |
|-------------------------------------|
| CANOLA |
| Centurion (Group 1) |
| Liberty ^{LL} (Group 10) |
| CEREALS |
| Buctril [®] M (Group 4, 6) |
| Infinity (Group 6, 27) |
| Pardner [®] (Group 6) |
| Puma Advance (Group 1) |
| Thumper [®] (Group 4, 6) |
| Tundra (Group 1, 6, 27) |
| Velocity m3 (Group 2, 6, 27)* |
| PULSES |
| Centurion (Group 1) |
| Sencor [®] (Group 5) |
| EAST |
| CANOLA |
| Liberty ^{LL} (Group 10) |
| Select (Group 1) |
| CEREALS |
| Buctril M (Group 4, 6) |
| Infinity (Group 6, 27) |
| Puma Advance (Group 1) |
| CORN |
| Converge XT (Group 5, 27) |
| Liberty ^{LL} (Group 10) |
| SOYBEANS |
| Excel Super (Group 1) |
| Liberty ^{LL} (Group 10) |
| Select (Group 1) |
| Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only
* For control of Group 2-resistant broadleaf weeds

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.



Group 3

Cell Division Inhibitors HRAC Group K1

What is a Group 3 herbicide?

- Consist of products from two chemical families: dinitroaniline (DNAs) and phthalates.
- DNAs are pre-emergent soil-applied herbicides which inhibit cell division and elongation in plants by binding to the protein tubulin which is a key building block of microtubules. The effects of DNA herbicides generally occur in regions of the plant that are rapidly growing such as root meristems.
- DNAs stop root tip growth and result in swollen club-shaped roots. Shoot elongation is inhibited in broadleaf weeds resulting in a thickening of the stem. Generally DNAs will inhibit weed emergence; those that do emerge will display root pruning and stubby root tips.

How do weeds evolve resistance to Group 3 herbicides?

- Involves target site resistance mechanisms.
- Resistance to Group 3 herbicides results from amino acid base changes in the tubulin protein. These base changes prevent the herbicide from binding to the tubulin protein. As the herbicide cannot bind to the tubulin and inhibit microtubule formation, normal cell division and plant growth occurs.

How many weeds have developed resistance to Group 3 herbicides?

Globally: 11 weed species confirmed
Canada: 1 weed species confirmed

Confirmed Group 3-Resistant Weed Species in Canada

- Green foxtail (West)

GREEN FOXTAIL

Green foxtail is a monocot weed which first evolved resistance to Group 3, trifluralin herbicides in 1989.

W



COMMON GROUP 3 DINITROANILINE HERBICIDES

Group 3 herbicides are pre-seed soil-applied herbicides. By the late 1990's, the use of Group 3 herbicides declined significantly due to the need for soil incorporation and the growing popularity of reduced tillage. In addition, by the mid to late 1990's there were a growing number of alternative products available for in-crop weed control reducing the reliance on soil-incorporated Group 3 herbicides, most notably the herbicide-tolerant canola systems.

| WEST | EAST |
|----------------|-----------------|
| CANOLA | CANOLA |
| Edge | Treflan EC |
| Fortress* | CEREALS |
| Treflan | Treflan EC |
| CEREALS | CORN |
| Fortress* | Prowl 400 |
| Treflan | Prowl H2O |
| PULSES | SOYBEANS |
| Edge | Dacthal W-75 |
| Treflan | Prowl 400 |
| | Prowl H2O |
| | Treflan EC |

BAYER CROPS SCIENCE HERBICIDES FOR MANAGEMENT AND PREVENTION OF POTENTIAL GROUP 3-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST |
|----------------------------------|
| CANOLA |
| Centurion (Group 1) |
| Liberty ^{LL} (Group 10) |
| CEREALS |
| Buctril M (Group 4, 6) |
| Infinity (Group 6, 27) |
| Pardner (Group 6) |
| Puma Advance (Group 1) |
| Thumper (Group 4, 6) |
| Tundra (Group 1, 6, 27) |
| Varro (Group 2) |
| Velocity m3 (Group 2, 6, 27) |
| PULSES |
| Centurion (Group 1) |
| Sencor (Group 5) |
| EAST |
| CANOLA |
| Liberty ^{LL} (Group 10) |
| Select (Group 1) |
| CEREALS |
| Buctril M (Group 4, 6) |
| Infinity (Group 6, 27) |
| Pardner (Group 6) |
| Puma Advance (Group 1) |
| CORN |
| Converge XT (Group 5, 27) |
| Option Liquid (Group 2) |
| Liberty ^{LL} (Group 10) |
| Vios G3 (Group 2, 27) |
| SOYBEANS |
| Excel Super (Group 1) |
| Liberty ^{LL} (Group 10) |
| Select (Group 1) |
| Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

Group 4

Synthetic Auxins HRAC Group 0

What is a Group 4 herbicide?

- Acts similar to indole acetic acid (IAA), a naturally occurring plant hormone.
- Primary action is to affect cell wall plasticity and nucleic acid metabolism leading to uncontrolled cell division and growth, which causes vascular tissue destruction.
- Often produces epinastic-like symptoms (stem twisting, leaf malformations, etc.).
- Symptoms can often be seen within days of treatment.
- Consists of products from primarily four chemical families: phenoxy carboxylic acid, benzoic acid, pyridine carboxylic acid and quinoline carboxylic acid.

Confirmed Group 4-Resistant Weed Species in Canada

- Cleavers (West)
- Hemp-nettle (West)
- Wild carrot (East)
- Wild mustard (West)

How do weeds evolve resistance to Group 4 herbicides?

- The specific cellular or molecular binding site has not yet been identified.

How many weeds have developed resistance to Group 4 herbicides?

Globally: 30 weed species confirmed

Canada: 4 weed species confirmed

KOCHIA

Kochia plants have now developed multiple resistance to Group 2 + 9 + 4 in the United States.



CLEAVERS

Cleavers first developed resistance to Group 4 herbicides in 1996. Cleavers have evolved multiple resistance to both Group 2 and Group 4 herbicides.



WILD MUSTARD

Group 4-resistant wild mustard was first discovered in 1990.



COMMON GROUP 4 SYNTHETIC AUXIN HERBICIDES

Use of in-crop Group 4 herbicides are most common in cereals, corn and to a lesser extent, canola.

| WEST | | |
|----------------------|----------------|-----------------|
| CANOLA | MCPA | Dichlorprop |
| Absolute*† | Momentum | Estaprop brands |
| Lontrel | OcTTain | Lontrel |
| Tensile*† | Perimeter | MCPA |
| CEREALS | Prestige XC | Mecoprop |
| 2,4-D | Pulsar | Refine M* |
| Achieve Liquid Gold* | Retain* | Target |
| Adrenalin*‡ | Spectrum* | Trophy |
| Altitude FX*† | Stellar* | Tropotox Plus |
| Attain XC | Tandem* | CORN |
| Axial Xtreme* | Target | 2,4-D |
| Banvel | Thumper* | Accent 1-Pass* |
| Barricade* | Triton* | Accent Total* |
| Broadside* | Trophy | Banvel II |
| Buctril M* | EAST | Battalion* |
| Curtail M | CANOLA | Distinct* |
| Dyvel | Lontrel | Marksman* |
| Everest GBX* | CEREALS | PeakPlus* |
| Frontline* | 2,4-D | Tropotox Plus |
| Harmony* | Banvel II | Ultim Total* |
| Lontrel | Buctril M* | |
| | Dyvel | |

* Contains at least one non-Group 4 chemistry † IMI tolerant canola only ‡ Clearfield wheat only

BAYER CROPSCIENCE HERBICIDES FOR MANAGEMENT OF GROUP 4-RESISTANT BROADLEAF WEEDS

WEST

CANOLA

Liberty^{LL} (Group 10)

CEREALS

Infinity (Group 6, 27)

Pardner (Group 6)

Tundra (Group 1, 6, 27)

Varro (Group 2)

Velocity m3 (Group 2, 6, 27)

PULSES

Sencor (Group 5)

EAST

CANOLA

Liberty^{LL} (Group 10)

CEREALS

Infinity (Group 6, 27)

Pardner (Group 6)

CORN

Converge XT (Group 5, 27)

Liberty^{LL} (Group 10)

Option Liquid (Group 2)

Vios G3 (Group 2, 27)

SOYBEANS

Liberty^{LL} (Group 10)

Sencor (Group 5)

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

Group 5

PS II Site A Inhibitors HRAC Group C1

What is a Group 5 herbicide?

- Group 5 herbicides used in Canada consist of products from three chemical families: phenyl carbamates, triazines and triazinones.
- Group 5 herbicides bind to site A on the Q_B protein preventing the flow of high energy electrons out of photosystem II. This results in a buildup of high energy electrons and the formation of toxic radicals which degrade carotenoids and chlorophyll resulting in rapid chlorosis and necrosis in affected plants.

How do weeds evolve resistance to Group 5 herbicides?

- Target site resistance results from a mutation that alters the binding site A on the Q_B protein.
- Non-target site resistance mechanisms enhance metabolism.

How many weeds have developed resistance to Group 5 herbicides?

Globally: 69 weed species confirmed
Canada: 12 weed species confirmed

Confirmed Group 5-Resistant Weed Species in Canada

- Barnyard grass (East)
- Birdsrape mustard (East)
- Common groundsel (East)
- Common ragweed (East)
- Common waterhemp (East)
- Lamb's-quarters (East)
- Late flowering goosefoot (East)
- Powell amaranth (East)
- Redroot pigweed (East)
- Wild mustard (East & West)
- Witchgrass (East)
- Yellow foxtail (East)

Group 6

PS II Site B Inhibitors HRAC Group C3

What is a Group 6 herbicide?

- Group 6 herbicides used in Canada consist of products from two chemical families: benzthiadiazoles and nitriles.
- Similar to Group 5 herbicides, Group 6 herbicides inhibit photosystem II but at site B on the Q_B protein. The Q_B protein is a component of the electron transport sequence in photosystem II. Group 6 herbicides bind to site B on the Q_B protein preventing the flow of high energy electrons out of photosystem II. This results in a buildup of high energy electrons and the formation of toxic radicals which degrade carotenoids and chlorophyll resulting in rapid chlorosis and necrosis in affected plants.

How do weeds evolve resistance to Group 6 herbicides?

- Target site resistance results from a mutation that alters the binding site B on the Q_B protein which prevents the herbicide from binding and allows normal electron transfer to continue.
- Non-target site resistance mechanisms enhance metabolism.

How many weeds have developed resistance to Group 6 herbicides?

Globally: 4 weed species confirmed
Canada: 2 weed species confirmed

Confirmed Group 6-Resistant Weed Species in Canada

- Redroot pigweed (East)
- Smooth pigweed (East)

COMMON GROUP 5 PS II SITE A INHIBITOR HERBICIDES

Group 5 herbicides were first developed in the 1960's and can have both broadleaf and grassy weed activity. All herbicides in this group have soil activity. Most crop applications of Group 5 products provide short-term residual weed control. Atrazine is a commonly used product in corn and metribuzin is widely used in many crops. Metribuzin (Sencor) is the most widely used product in this group in Western Canada and has primarily broadleaf activity.

| WEST | |
|--|-----------------------------------|
| PULSES | Marksman* Primextra II Magnum* |
| Sencor | Princep Nine-T Sencor |
| EAST | SOYBEANS |
| CORN | Boundary* Conquest LQ* |
| Aatrex Liquid Converge XT* Laddok* | Sencor |

* Contains at least one non-Group 5 chemistry

COMMON GROUP 6 PS II SITE B INHIBITOR HERBICIDES

Bromoxynil was the first Group 6 herbicide registered in 1966. Group 6 herbicides are primarily used to control annual broadleaf weeds in a variety of crops including cereals, flax, corn and a number of forage crops. It is often formulated in combination with MCPA or 2,4-D to enhance the weed spectrum controlled. Unlike Group 5 herbicides, Group 6 herbicides generally exhibit little soil residual activity and are applied in foliar applications.

| WEST | EAST |
|--|--|
| CEREALS | CEREALS |
| Achieve Liquid Gold* Axial iPak* Buctril M* Infinity* Pardner Thumper* Tundra* Velocity m3* | Buctril M* Infinity* Pardner CORN Basagran Basagran Forté Buctril M* Pardner |
| PULSES | SOYBEANS |
| Basagran Basagran Forte Viper* | Basagran Basagran Forté Cleansweep* |

* Contains at least one non-Group 6 chemistry

BAYER CROPSOURCE HERBICIDES FOR MANAGEMENT OF GROUP 5-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST | CEREALS |
|--|--|
| CANOLA | Buctril M (Group 4, 6) Infinity (Group 6, 27) |
| Liberty ^{LL} (Group 10) | Puma Advance (Group 1) |
| CEREALS | CORN |
| Buctril M (Group 4, 6) Infinity (Group 6, 27) Pardner (Group 6) Thumper (Group 4, 6) Tundra (Group 1, 6, 27) Velocity m3 (Group 2, 6, 27) | Converge XT (Group 5, 27)* Excel Super (Group 1) Liberty ^{LL} (Group 10) Option Liquid (Group 2) Vios G3 (Group 2, 27) |
| EAST | SOYBEANS |
| CANOLA | Excel Super (Group 1) Liberty ^{LL} (Group 10) Select (Group 1) |
| Liberty ^{LL} (Group 10) Select (Group 1) | Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information. |

^{LL} = LibertyLink canola, corn or soybeans only
* Controls triazine-resistant weeds

BAYER CROPSOURCE HERBICIDES FOR MANAGEMENT AND PREVENTION OF POTENTIAL GROUP 6-RESISTANT BROADLEAF WEEDS

| WEST | EAST |
|---|---|
| CANOLA | CANOLA |
| Liberty ^{LL} (Group 10) | Liberty ^{LL} (Group 10) |
| CEREALS | CORN |
| Varro (Group 2) Velocity m3 (Group 2, 6, 27) | Converge XT (Group 5, 27) Liberty ^{LL} (Group 10) |
| PULSES | Option Liquid (Group 2) |
| Sencor (Group 5) | Vios G3 (Group 2, 27) |
| | SOYBEANS |
| | Liberty ^{LL} (Group 10) Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

What is a Group 8 herbicide?

- Group 8 herbicides used in Canada consist of products from two chemical families: thiocarbamates and pyrazoliums.
- Affected weeds frequently fail to emerge and exhibit a stunted and swollen coleoptile with abnormal growth of the first leaf. Those weeds that do emerge appear stunted and bright green.
- Thiocarbamate herbicides inhibit an enzyme essential for elongating fatty acid chains which form waxes and suberin. Waxes and suberin are important components of the waxy layer on the outside of the seedling which prevent water loss.

How do weeds evolve resistance to Group 8 herbicides?

- Group 8 herbicide resistance is not well understood.
- One possible mechanism of resistance to thiocarbamates is a result of elevated gibberellin levels which promotes rapid meristematic growth. Rapid meristematic growth allows the plant to minimize exposure to the herbicide-treated layer of soil and carry on with normal growth and development.

How many weeds have developed resistance to Group 8 herbicides?

Globally: 8 weed species confirmed
Canada: 1 weed species confirmed

Confirmed Group 8-Resistant Weed Species in Canada

- Wild oats (West)

WILD OATS

Wild oats first demonstrated resistance to Group 8 herbicides in 1998. The latest AAFC surveys indicate up to 15% of the fields surveyed contain Group 8-resistant wild oats.

W



COMMON GROUP 8 FATTY ACID AND LIPID BIOSYNTHESIS INHIBITOR HERBICIDES

Thiocarbamates are soil-applied herbicides that gained popularity in the 1960's as the first wild oat herbicides for cereals, oilseeds and pulses. By the late 1970's, their popularity declined with the introduction of Group 1 post-emergent wild oat herbicides. Currently, there is renewed interest due to growing Group 1-resistant wild oats.

| WEST |
|-------------------------------|
| CANOLA |
| Avadex Fortress* |
| CEREALS |
| Avadex Avenge Fortress* |
| EAST |
| N/A |

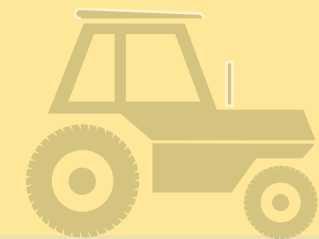
* Contains at least one non-Group 8 chemistry

BAYER CROPSCIENCE HERBICIDES FOR MANAGEMENT AND PREVENTION OF POTENTIAL GROUP 8-RESISTANT GRASSY WEEDS

| WEST | EAST |
|--|--|
| CANOLA | CANOLA |
| Centurion (Group 1) Liberty ^{LL} (Group 10) | Liberty ^{LL} (Group 10) Select (Group 1) |
| CEREALS | CEREALS |
| Puma Advance (Group 1) Tundra (Group 1, 6, 27) Varro (Group 2) Velocity m3 (Group 2, 6, 27) | Puma Advance (Group 1) CORN Converge XT (Group 5, 27) Liberty ^{LL} (Group 10) Option Liquid (Group 2) Vios G3 (Group 2, 27) |
| PULSES | SOYBEANS |
| Centurion (Group 1) | Excel Super (Group 1) Liberty ^{LL} (Group 10) Select (Group 1) |

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.



Group 9

EPSPS Inhibitors HRAC Group G

What is a Group 9 herbicide?

- Inhibitor of the chloroplast enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS).
- Inhibition leads to depletion of key amino acids that are necessary for protein synthesis and plant growth.
- Symptoms may take weeks to fully develop.
- Consists of one product from one major chemical family: glycine.

How do weeds evolve resistance to Group 9 herbicides?

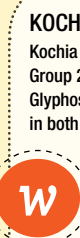
- There are three known mechanisms of resistance involving both target and non-target site resistance: target site resistance caused by EPSPS gene modification, and/or caused by gene amplification, and non-target site resistance caused by a reduced glyphosate translocation mechanism. A potential fourth mechanism, glyphosate metabolism, has also been identified.

How many weeds have developed resistance to Group 9 herbicides?

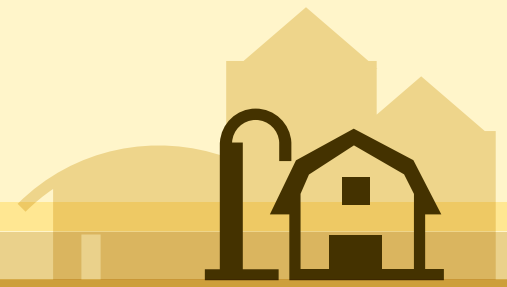
Globally: 24 weed species confirmed
Canada: 5 weed species confirmed

Confirmed Group 9-Resistant Weed Species in Canada

- Canada fleabane (East)
- Common ragweed (East)
- Giant ragweed (East)
- Horseweed (East)
- Kochia (West)



KOCHIA
Kochia was first confirmed resistant to both Group 2 and Group 9 herbicides in 2012. Glyphosate-resistant kochia is now confirmed in both AB and SK.



COMMON GROUP 9 EPSPS INHIBITOR HERBICIDES

Use of Group 9 herbicides is most common in canola[†], corn[†] and soybeans[†]. In cereals and pulses, Group 9 herbicides are used for burndown prior to planting, just prior to harvest, or just after harvest.

| WEST | EAST |
|---|--|
| CANOLA | CANOLA |
| CleanStart* Glyphosate products | Glyphosate products |
| CEREALS¹ | CEREALS¹ |
| CleanStart* Express* Express Pro* Glyphosate products Heat* Inferno duo* Pre-Pare* PrePass* Roundup StartUp* Takkle* Touchdown | CleanStart* CORN Glyphosate products Galaxy 2 Halx GT Vios G3* SOYBEANS Eragon ¹ Glyphosate products Guardian* Guardian Plus* |
| PULSES¹ | |
| CleanStart* Express SG* Glyphosate products Heat* | |

[†] Over-the-top use on glyphosate-tolerant crops only.
^{*} When applied with glyphosate contains more than one non-Group 9 chemistry.
¹ Glyphosate used as a pre-burn application or as a pre-harvest application.

BAYER CROPSOURCE HERBICIDES FOR MANAGEMENT OF GROUP 9-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST | EAST |
|---|--|
| CANOLA | CANOLA |
| Centurion (Group 1) Liberty ^{LL} (Group 10) | Liberty ^{LL} (Group 10) Select (Group 1) |
| CEREALS | CEREALS |
| Buctril M (Group 4, 6) Infinity (Group 6, 27) Pardner (Group 6) Puma Advance (Group 1) Thumper (Group 4, 6) Tundra (Group 1, 6, 27) Varro (Group 2) Velocity m3 (Group 2, 6, 27) | Buctril M (Group 4, 6) Infinity (Group 6, 27) Puma Advance (Group 1) CORN Converge XT (Group 5, 27) Liberty ^{LL} (Group 10) Option Liquid (Group 2) Vios G3 (Group 2, 27) |
| PULSES | SOYBEANS |
| Centurion (Group 1) Sencor (Group 5) | Excel Super (Group 1) Liberty ^{LL} (Group 10) Select (Group 1) Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only
Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.



COMMON RAGWEED
First developed resistance to glyphosate in Ontario in 2012.



Group 10

Glutamine Synthetase Inhibitors HRAC Group H

What is a Group 10 herbicide?

- Inhibitor of glutamine synthetase, a key enzyme in incorporating ammonium into amino acids.
- Blockage of this enzyme allows a buildup of phytotoxic ammonia.
- Consists of products from one chemical family: phosphinic acid (glufosinate).

How do weeds evolve resistance to Group 10 herbicides?

- Researchers are investigating how glutamine synthetase inhibitor resistance develops.

How many weeds have developed resistance to Group 10 herbicides?

Globally: 2 weed species confirmed
Canada: 0 weed species confirmed

How can Group 10 herbicides fit in my resistance management strategy?

- By introducing a new mode of action like a glutamine synthetase inhibitor, products such as Liberty may become key ingredients and management options for control of weeds resistant to ALS inhibitors, glyphosate, triazine and other herbicide modes of action.
- Liberty is used in-crop in LibertyLink herbicide-tolerant crops: corn, canola and soybeans.
- For a complete resistance management approach, rotate crops, herbicide-tolerant traits and herbicide modes of action.

COMMON GROUP 10 GLUTAMINE SYNTHETASE INHIBITOR HERBICIDES

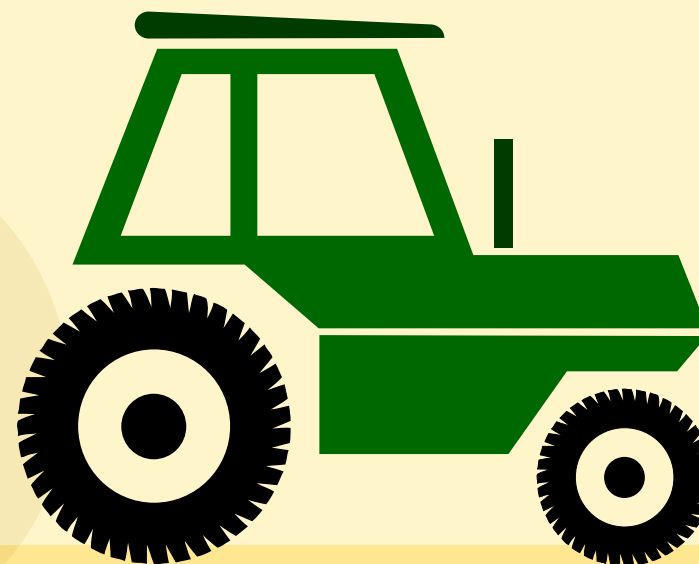
Use of Group 10 herbicides is most common in LibertyLink tolerant canola, corn and soybeans.

| WEST | EAST |
|----------------|-----------------|
| CANOLA | CANOLA |
| Liberty 150 SN | Liberty 200 SN |
| | CORN |
| | Liberty 200 SN |
| | SOYBEANS |
| | Liberty 200 SN |

BAYER CROPSCIENCE HERBICIDES FOR PREVENTION OF POTENTIAL GROUP 10-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST | EAST |
|------------------------------|---------------------------|
| CANOLA | CANOLA |
| Centurion (Group 1) | Select (Group 1) |
| CEREALS | CEREALS |
| Buctril M (Group 4, 6) | Buctril M (Group 4, 6) |
| Infinity (Group 6, 27) | Infinity (Group 6, 27) |
| Pardner (Group 6) | Puma Advance (Group 1) |
| Puma Advance (Group 1) | CORN |
| Thumper (Group 4, 6) | Converge XT (Group 5, 27) |
| Tundra (Group 1, 6, 27) | Excel Super (Group 1) |
| Varro (Group 2) | Option Liquid (Group 2) |
| Velocity m3 (Group 2, 6, 27) | Vios G3 (Group 2, 27) |
| PULSES | SOYBEANS |
| Centurion (Group 1) | Select (Group 1) |
| Sencor (Group 5) | Sencor (Group 5) |

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.



Group 14

PPO Inhibitors HRAC Group E

What is a Group 14 herbicide?

- Inhibitor of protoporphyrinogen oxidase (PPO) enzyme.
- Inhibition leads to a chain reaction resulting in the leaking of cell membranes.
- PPO inhibitors are typically most effective on annual broadleaf weeds.
- Consists of products from four major chemical families: diphenyl ether, N-phenylphthalimide, pyrimidinediones and triazolinone.

How do weeds evolve resistance to Group 14 herbicides?

- Target site resistance is conferred by an amino acid deletion in the PPO gene.

How many weeds have developed resistance to Group 14 herbicides?

Globally: 6 weed species confirmed
Canada: 0 weed species confirmed

| COMMON GROUP 14 PPO INHIBITOR HERBICIDES | |
|--|---------------------|
| Use of Group 14 herbicides are most commonly used as a pre-burn in combination with glyphosate prior to cereals, pulses, canola, corn and soybean. | |
| WEST | CORN ¹ |
| | Aim EC |
| CEREALS¹ | CleanStart Plus* |
| CleanStart* Heat* | Integrity* |
| | SOYBEANS |
| PULSES¹ | Aim EC ¹ |
| Authority* | Blazer |
| CleanStart* | BroadStar |
| Heat* | CleanStart Plus* |
| | Eragon ¹ |
| EAST | Guardian Plus* |
| CEREALS | Reflex |
| Aim EC ¹ | Valtera |

* When applied with glyphosate contains more than one non-Group 14 chemistry.
¹ Used only in pre-burn applications.

| BAYER CROPSCIENCE HERBICIDES FOR PREVENTION OF POTENTIAL GROUP 14-RESISTANT BROADLEAF WEEDS | |
|---|----------------------------------|
| WEST | EAST |
| CANOLA | CANOLA |
| Liberty ^{LL} (Group 1) | Liberty ^{LL} (Group 10) |
| CEREALS | CEREALS |
| Buctril M (Group 4, 6) | Buctril M (Group 4, 6) |
| Infinity (Group 6, 27) | Infinity (Group 6, 27) |
| Pardner (Group 6) | CORN |
| Thumper (Group 4, 6) | Converge XT (Group 5, 27) |
| Tundra (Group 1, 6, 27) | Liberty ^{LL} (Group 10) |
| Velocity m3 (Group 2, 6, 27) | Option Liquid (Group 2) |
| PULSES | Vios G3 (Group 2, 27) |
| Sencor (Group 5) | SOYBEANS |
| | Liberty ^{LL} (Group 10) |
| | Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only
Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

Group 15

Mitosis Inhibitors HRAC Group K3

What is a Group 15 herbicide?

- Inhibits cell growth and division by interfering with development of very long-chain fatty acids (VLCFA).
- Typically affects susceptible weeds prior to emergence but does not inhibit seed germination.
- Often applied as a soil treatment for control of annual grasses and small-seeded broadleaf weeds.
- Consists of products from primarily two chemical families: acetamide and chloracetamide.

How do weeds evolve resistance to Group 15 herbicides?

- This target site resistance appears to be due to an altered VLCFA synthase binding site.

How many weeds have developed resistance to Group 15 herbicides?

Globally: 4 weed species confirmed
Canada: 0 weed species confirmed

| COMMON GROUP 15 MITOSIS INHIBITOR HERBICIDES | |
|--|---------------------------|
| Use of Group 15 herbicides are most common in corn and soybean production. | |
| WEST | Halex GT* |
| | Integrity* |
| N/A | Primextra II Magnum* |
| | SOYBEANS |
| EAST | Boundary* |
| CORN | Dual II Magnum |
| Battalion* | Frontier Max [†] |
| Dual II Magnum | |
| Frontier Max | |

* Contains at least one non-Group 15 chemistry.
[†] Pre-emerge only

| BAYER CROPSCIENCE HERBICIDES FOR PREVENTION OF POTENTIAL GROUP 15-RESISTANT GRASSY OR BROADLEAF WEEDS | |
|---|----------------------------------|
| WEST | CORN |
| N/A | Converge XT (Group 5, 27) |
| | Liberty ^{LL} (Group 10) |
| EAST | Option Liquid (Group 2) |
| CANOLA | Vios G3 (Group 2, 27) |
| Liberty ^{LL} (Group 10) | SOYBEANS |
| Select (Group 1) | Excel Super (Group 1) |
| | Liberty ^{LL} (Group 10) |
| CEREALS | Select (Group 1) |
| Buctril M (Group 4, 6) | Sencor (Group 5) |
| Infinity (Group 6, 27) | |
| Puma Advance (Group 1) | |

^{LL} = LibertyLink canola, corn or soybeans only
Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

Group 22

PS I Inhibitors HRAC Group D

What is a Group 22 herbicide?

- Consist of products from one chemical family: bipyridiliums.
- Fast-acting, non-selective, contact herbicides.
- Divert electron transport in photosystem I.
- They divert electron flow in photosystem I forming toxic ultra-reactive hydroxyl radicals which disrupt proteins and lipids within the plant cell membranes resulting in rapid tissue desiccation and plant death.

How do weeds evolve resistance to Group 22 herbicides?

- Involves non-target site resistance through enhanced metabolism or sequestration.
- Biotypes displaying resistance due to enhanced metabolism are able to enzymatically degrade ultra-reactive hydroxyl radicals before they can disrupt cell proteins and lipids.
- Biotypes displaying resistance due to sequestration are able to accumulate the herbicide molecule in cell vacuoles or bind the herbicide to cell wall components preventing it from reaching the target site in photosystem I.

How many weeds have developed resistance to Group 22 herbicides?

Globally: 28 weed species confirmed
Canada: 3 weed species confirmed

Confirmed Group 22-Resistant Weed Species in Canada

- Eastern black nightshade (East)
- Horseweed (East)
- Virginia pepperweed (East)

EASTERN BLACK NIGHTSHADE

First confirmed resistance to Group 22 in Ontario in 2009.

W



COMMON GROUP 22 PS I INHIBITOR HERBICIDES

Group 22 herbicides were developed in the early 1960's. They are fast-acting, non-selective, non-translocated herbicides used primarily as desiccants in pulse crops, canola, mustard, sunflowers, potatoes and forage legumes.

| WEST | EAST |
|----------------------|----------------------|
| CANOLA | CANOLA |
| Gramoxone Reglone | Reglone |
| CEREALS | CORN |
| Gramoxone Reglone | Gramoxone |
| PULSES | SOYBEANS |
| Gramoxone Reglone | Gramoxone Reglone |

BAYER CROPSCIENCE HERBICIDES FOR MANAGEMENT AND PREVENTION OF POTENTIAL GROUP 22-RESISTANT GRASSY OR BROADLEAF WEEDS

| WEST | EAST |
|---|---|
| CANOLA | CANOLA |
| Centurion (Group 1) Liberty ^{LL} (Group 10) | Liberty ^{LL} (Group 10) Select (Group 1) |
| CEREALS | CEREALS |
| Buctril M (Group 4, 6) Infinity (Group 6, 27) Pardner (Group 6) Puma Advance (Group 1) Thumper (Group 4, 6) Tundra (Group 1, 6, 27) Varro (Group 2) Velocity m3 (Group 2, 6, 27) | Buctril M (Group 4, 6) Infinity (Group 6, 27) Puma Advance (Group 1) |
| PULSES | CORN |
| Centurion (Group 1) Sencor (Group 5) | Converge XT (Group 5, 27) Liberty ^{LL} (Group 10) Option Liquid (Group 2) Vios G3 (Group 2, 27) |
| | SOYBEANS |
| | Excel Super (Group 1) Liberty ^{LL} (Group 10) Select (Group 1) Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.

Group 27

HPPD Inhibitors HRAC Group F₂

What is a Group 27 herbicide?

- Inhibitor of 4-hydroxyphenylpyruvate-dioxygenase (HPPD) enzyme, which disrupts the formation of carotenoids.
- The lack of carotenoids results in the destruction of chlorophyll molecules by excessive light energy. This leads to characteristic bleaching of leaf tissue and rapid plant death (normally six to 14 days) after application.
- Consists of products from three main chemical families: triketone, isoxazole and pyrazole.

How do weeds evolve resistance to Group 27 herbicides?

- Due to the recent discovery of HPPD resistance, researchers are investigating how this resistance develops.

How many weeds have developed resistance to Group 27 herbicides?

Globally: 2 weed species confirmed
Canada: 0 weed species confirmed

How can Group 27 herbicides fit in my resistance management strategy?

By alternating and/or tank mixing HPPD inhibitors with other modes of action, these products can be key management options for control of weeds resistant to other herbicide groups.



| COMMON GROUP 27 HPPD INHIBITOR HERBICIDES | |
|--|----------------|
| Use of Group 27 herbicides is most common in cereal and corn production. | |
| WEST | EAST |
| CEREALS | CEREALS |
| Axial iPak* | Infinity* |
| Infinity* | CORN |
| Tundra* | Armezon |
| Velocity m3* | Callisto |
| | Converge XT* |
| | Halex GT* |
| | Vios G3* |

* Contains at least one non-Group 27 chemistry.

| BAYER CROPSCIENCE HERBICIDES FOR PREVENTION OF POTENTIAL GROUP 27-RESISTANT GRASSY OR BROADLEAF WEEDS | |
|---|---|
| WEST | EAST |
| CANOLA | CANOLA |
| Centurion (Group 1) Liberty ^{LL} (Group 10) | Liberty ^{LL} (Group 10) Select (Group 1) |
| CEREALS | CEREALS |
| Buctril M (Group 4, 6) Pardner (Group 6) Puma Advance (Group 1) | Buctril M (Group 4, 6) Puma Advance (Group 1) |
| Thumper (Group 4, 6) Varro (Group 2) | CORN |
| | Liberty ^{LL} (Group 10) Option Liquid (Group 2) |
| PULSES | SOYBEANS |
| Sencor (Group 5) | Excel Super (Group 1) Liberty ^{LL} (Group 10) Select (Group 1) Sencor (Group 5) |

^{LL} = LibertyLink canola, corn or soybeans only

Please refer to product labels for additional information on weeds controlled, application timings, precautions, restrictions and other important use information.



BAYER CROPSCIENCE HERBICIDE FEATURES

Buctril M / GROUP 4, 6

Buctril M is the most trusted broadleaf herbicide available to cereal, flax and corn growers. It provides fast-acting control of 28 broadleaf weeds across Canada. Buctril M tank mixes with many products, is easy to use and can be counted on for effective resistance management, containing Group 4 and Group 6 modes of action.

Centurion / GROUP 1

Centurion herbicide protects your canola, flax and pulses from 12 of Western Canada's toughest grassy weeds plus suppression of quackgrass in one post-emergent pass. Tank mixing with a multitude of products, including Liberty, creates effective, full-spectrum weed control for your InVigor® hybrid or LibertyLink canola.

Converge XT / GROUP 5, 27

Converge XT features strong residual activity that controls more weeds than the competition. It is the most consistent solution for crop-safe grassy and broadleaf weed control for corn growers. Make your first thought of the season the last time you think about weeds.

Excel Super / GROUP 1

Excel Super is a specially formulated post-emergent herbicide for superior control of tough annual grassy weeds plus volunteer corn in canola and soybeans. Its wide window of application works on actively growing weeds from the 1 to 6 leaf stage to control seven tough annual grassy weeds plus volunteer corn.

Infinity / GROUP 6, 27

With two powerful actives, Infinity provides exceptional broadleaf control for wheat and barley and other forage grasses. Infinity contains the only Group 27 active ingredient in cereals, is fast-acting and makes an excellent resistance management tool.

Liberty 150 / GROUP 10

As a Group 10 herbicide for canola, Liberty effectively controls Group 1-resistant wild oats and Group 2- and 9-resistant kochia as well as your regular problem weeds. Liberty's unique mode of action makes it an excellent resistance management tool by helping reduce the risk of glyphosate resistance and the development of resistant weeds, year after year.

Liberty 200 SN / GROUP 10

Liberty herbicide delivers fast, broad-spectrum grassy and broadleaf weed control in Herculex, Agrisure and SmartStax corn hybrids containing the LibertyLink trait, as well as new LibertyLink soybeans and InVigor canola hybrids.

Option Liquid / GROUP 2

Option Liquid provides broad-spectrum control of grassy and key broadleaf weeds in corn with a wide window of application from the one-to-eight leaf stage of corn.

Pardner / GROUP 6

Pardner herbicide provides powerful control of major broadleaf weeds in cereals, alfalfa, corn and a wide range of other crops and forage grasses. It controls 19 tough broadleaf weeds, many of which have Group 2-resistant biotypes, has no re-cropping restrictions and provides excellent crop safety.

Puma Advance / GROUP 1

Puma Advance provides affordable control of your toughest grassy weeds including wild oats, foxtail and barnyard grass. In addition to its outstanding crop safety, Puma Advance can also be applied on both wheat and barley and is available in up to 1000 acre bulk containers.

Select / GROUP 1

Select herbicide protects many broadleaf crops against the toughest grassy weeds, including quackgrass. Tank mix Select with Liberty for unsurpassed control of grassy weeds on InVigor canola and LibertyLink soybeans.

Sencor / GROUP 5

Sencor is a proven broad-spectrum herbicide registered for broadleaf weed control in a wide range of crops, most notably chickpeas, field peas, lentils and potatoes. Because of its Group 5 mode of action, Sencor helps manage and prevent Group 2-resistant broadleaf weeds including hemp-nettle, chickweed and wild mustard.

Thumper / GROUP 4, 6

Thumper provides reliable and outstanding control of 26 different broadleaf weeds for wheat and barley growers, including Group 2- and Group 9-resistant kochia. It contains Group 4 (2,4-D) and Group 6 (bromoxynil) active ingredients, making it an effective resistance management tool.

Tundra / GROUP 1, 6, 27

Wheat and barley growers love Tundra for its convenience and crop safety. This pre-mixed formulation offers powerful grassy and broadleaf control, a broadleaf herbicide resistance management tool and the convenience of bulk. Just add water and go.

Varro / GROUP 2


The tank mix-friendly grassy herbicide with activity on select broadleaves, Varro provides exceptional control of wild oats, even Group 1-resistant, and enables wheat growers to rotate back to sensitive crops like lentils and dry beans.

Velocity m3 / GROUP 2, 6, 27


Velocity m3 herbicide is the perfect all-in-one solution for your most difficult grassy and broadleaf weeds. With three different modes of action, Velocity m3 provides wheat growers with a strong resistance management tool and exceptional crop safety.

Vios G3 / GROUP 2, 27

Vios G3 herbicide is a one-pass, full season solution for Roundup Ready and LibertyLink corn hybrids. Containing two powerful active ingredients in an easy-to-use concentrated liquid formulation, Vios G3 provides effective resistance management and comprehensive broad-spectrum weed control. Just one 1.78 L jug treats 40 acres of corn, keeping weeds out of your field and off your mind.

 CANOLA

 WHEAT

 PULSES

 CORN

 SOYBEANS

HERBICIDE CLASSIFICATION BY MODE OF ACTION

| Group | WSSA | HRAC | Mode of Action | Chemical Family | Active Ingredient (AI) | | Premixtures & Co-Packs Containing AI | Region | Group | WSSA | HRAC | Mode of Action | Chemical Family | Active Ingredient (AI) | | Premixtures & Co-Packs Containing AI | Region | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------|-------------------------|-------------------------|--|----------------------------------|-------------------------------------|---------------------------------------|--|--|---|-------------|---------------------------------|--------------------|---|---|---|--|---------------|---|--------------------------|-----------------------|----------------|---------------|--------|--------|--|---|------|--------------------|------------|-------------------------|----------------|--|--|------|-----------------|----------------|--------------|---------|-----------|
| | | | | | Common Name | Trade Name | | | | | | | | Common Name | Trade Name | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | A | | ACCASE Inhibitors | Aryloxyphenoxy-propionate (FOPs) | Clofoprop-propargyl | Foothills NG, Horizon NG, NextStep NG | Traxos, Harmony brands, Signal, Cypress | West | 4 | 0 | | Synthetic Auxins | Benzoic acid | Dicamba | Barvel | DyVel, DyVel DSP, Harmony K, Pulsar, Rustler, Target, Takkle, Triton K, DB-858, DB-854, DB-10550 | West | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Fenoxaprop-p-ethyl | Puma Advance, Wildcat | Tundra | West | | | | | | DyVel, Marksman, Target, Distict, Accent Total, Accent 1-Pass, Ultim Total, PeakPlus, Battalion | East | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Fluazifop-p-butyl | Venture L | Muster Gold II | West & East | | | | | | Absolute, Curtail M, Eclipse, FlaxMax DLX, Prestige, Momentum, Spectrum, Tensile | West | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Quizalofop-p-ethyl | Assure II | Glacier | West | | | | | | | East | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Cyclohexanedione (DIMS) | Clethodim | Centurion, Shadow RTM, Select | | | | | | | West | Altitude, Attain, Axial Xtreme, Barricade, Everest GBX, Harmony Max, OctTain, Momentum, Prestige, Pulsar, Retain, Stellar, Tandem, Trophy | West | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Tepraloxymid | Equinox | FlaxMax DLX, Odyssey DLX | | | | | | West | | East | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Tralkoxydim | Liquid Achieve, Marengo | Achieve Liquid Gold | | | | | | West | | East | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Sethoxydim | Poast Ultra | | | | | | | East | | East | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Pinoxaden | Axial | Axial Xtreme, Axial iPak, Broadband, Traxos | | | | | | West | | West & East | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Phenylpyrazolin (DENS) | Imidazolinone | Imazamethabenz | Assert, Avert | Assert FL | | | | | West | Phenoxy | MCPA | MCPA | | Achieve Liquid Gold, Altitude FX, Asset FL, Broadside, Buctril M, Curtail M, Cypress, DyVel, FlaxMax DLX, Frontline, Prestige, Refine M, Spectrum, Stellar, Target, Trophy, Tropotox Plus | West | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Imazamox | Solo | Adrenalin SC, Altitude FX, Ares, Odyssey, Odyssey DLX, Tensile, Viper | | | | | West | | | Refine M, Trophy, Buctril M, Tropotox Plus, Dyvel, Target | East | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | Imazapyr | Ares | Absolute, Guardsman Gladiator, Multistar, Odyssey, Odyssey DLX | | | | | West | | | DyVel, Target | West | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Sulfonyl-aminocarbonyl-triazolinone | Flucarbazone | Everest, Pre-Pare, Sierra | Everest GBX, Inferno Duo | | | | | West | | Quinoline carboxylic acid | Quinclorac | | Triton C | | | West | | | | | | | | | | | | | | | | | | |
| | | | | | | Thiencarbazone | Varro | Velocity m3 | | | | | West | | Phenyl-carbamates | Desmedipham | | Betamix® B | | | West | | | | | | | | | | | | | | | | | | |
| | | | | | | Sulfonylurea | Clorimuron-ethyl | Classic | | | | | Guardian, Guardian Plus | | | East | Phenmedipham | | Betamix B | | | East | | | | | | | | | | | | | | | | | |
| | | | | | | | Ethametsulfuron methyl | Muster | | | | | Muster Gold II | | West | s-triazine | Atrazine | | Aatrex Liquid | | | East | | | | | | | | | | | | | | | | | |
| | | | | | | | Foramsulfuron | Option Liquid | | | | | | | East | Simazine | | Princep Nine-T | | | | East | | | | | | | | | | | | | | | | | |
| | | | | | | | Metsulfuron-methyl | Ally | | | | | Express Pro, PP23235 | | West | Triazinone | Metribuzin | Sencor | | Conquest LQ, Boundary | | West | | | | | | | | | | | | | | | | | |
| | | | | | | | Nicosulfuron | Accent | | | | | Accent Total, Accent 1-Pass, Ultim, Ultim Total, Galaxy 2 | | East | Benzthiadiazole | Bentazon | | Basagran, Basagran Forte | | | West | | | | | | | | | | | | | | | | | |
| Prosulfuron | Peak 75 WG | PeakPlus, Accent 1-Pass | East | Nitrile | Bromoxynil | Partner | | Achieve Liquid Gold, Axial iPak, Buctril M, Infinity, Thumper, Tundra, Velocity m3 | | West | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rimsulfuron | Prism | Prism, Elim EP | East | Glycine | Glyphosate | Glyphosate | Maverick III, Roundup Transorb HC, Roundup Ultra, Roundup WeatherMax, StartUp, Touchdown Total, Vantage Plus Max | Roundup brands, Touchdown | CleanStart Plus, Glacier, Galaxy 2, Halex GT, Guardian Plus | East | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Thifensulfuron-methyl | Pinnacle SG | Refine SG, Refine M | East | | | | | | | | Glutamine Synthetase Inhibitors | Phosphinic acid | Glufosinate Ammonium | Liberty 150 SN | Liberty 200 SN | | West | | | | | | | | | | | | | | | | | | | | | | |
| Triazolopyrimidine | Cloransulam-methyl | Firstate | | East | PPO Inhibitors | Pyrimidinedione | Salfutenacil | Heat | Eragon | Integrity | | | | | | | | West | | | | | | | | | | | | | | | | | | | | | |
| | Florasulam | | Assert FL, Benchmark, Broadband, Frontline, PrePass, Spectrum, Stellar | West | | | | | | | Triazololinone | Carfentrazone | Sulfentrazone | Authority | CleanStart, Authority Charge | CleanStart Plus | West | | | | | | | | | | | | | | | | | | | | | | |
| | Flumetsulam | Broadstrike | | East | N-phenylphthalimide | Flumioxazin | BroadStar, Valtera | Guardian Plus | | | | | | | | | | East | | | | | | | | | | | | | | | | | | | | | |
| | Pyroxulam | Simplicity | Tandem | West | | | | | | | Diphenyl ether | Acifluorfen | Blazer | Reflex | | | East | | | | | | | | | | | | | | | | | | | | | | |
| Ethalfuralin | Edge | | West | Mitosis Inhibitors | Acetamide | s-metolachlor/benoxacor | Dual II Magnum | Primextra II Magnum, Boundary, Battalion, Halex GT | | East | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pendimethalin | Prowl 400, Prowl H20 | | East | | | | | | | | Chloroacetamide | Dimethenamid-P | Frontier Max | Reglone | Integrity | | West & East | | | | | | | | | | | | | | | | | | | | | | |
| Trifluralin | Bonanza, Rival, Treflan | Fortress | West | Bipyridylum | Paraquat | Gramoxone | | | | West & East | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Treflan | | | East | | | | | | | | Isoxazole | Isoxaflutole | | | | Converge XT | East | | | | | | | | | | | | | | | | | | | | | | |
| Chlorthal-dimethyl | Dacthal W-75 | | East | Pyrazole | Pyrasulfotole | | | | Axial iPak, Infinity, Tundra, Velocity m3 | West | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | Triketone | Mesotrione | Callisto | Halex GT | Vios G3 | | East | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | K1 | | Cell Division Inhibitors | Dinitroaniline | Ethalfuralin | Edge | | West | 15 | K3 | | Mitosis Inhibitors | Triazololinone | Sulfentrazone | Authority | CleanStart Plus | West | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Pendimethalin | Prowl 400, Prowl H20 | | East | | | | | | N-phenylphthalimide | Flumioxazin | BroadStar, Valtera | Guardian Plus | | | East | | | | | | | | | | | | | | | | | | | |
| | | | | | Trifluralin | Bonanza, Rival, Treflan | Fortress | West | | | | | | | | | | | | | Diphenyl ether | Acifluorfen | Blazer | Reflex | | | East | | | | | | | | | | | | |
| | | | | | Treflan | | | East | | | | | | | | | | | | | | | | | | | | Mitosis Inhibitors | Acetamide | s-metolachlor/benoxacor | Dual II Magnum | Primextra II Magnum, Boundary, Battalion, Halex GT | | East | | | | | |
| | | | | | Chlorthal-dimethyl | Dacthal W-75 | | East | | | | | | | | | | | | | | | | | | | | | | | | | | | Chloroacetamide | Dimethenamid-P | Frontier Max | Reglone | Integrity |
| | | | | | | | | Bipyridylum | | | | | Paraquat | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | Isoxazole | Isoxaflutole | | | | Converge XT | East | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | Pyrazole | Pyrasulfotole | | | | Axial iPak, Infinity, Tundra, Velocity m3 | West | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | Triketone | Mesotrione | Callisto | Halex GT | Vios G3 | | East | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

This table is a partial listing of WSSA, HRAC-approved group numbers or letters and a partial listing of active ingredients and products which may be contained within a chemical family. Bayer CropScience commercial products are highlighted in blue.

For a complete listing of herbicide mechanisms of action, refer to the Summary of Herbicide Mechanism of Action According to the Weed Science Society of America (WSSA) available at WSSA.net/wp-content/uploads/WSSA-Mechanism-of-Action.pdf.

All information referenced in this guide, including confirmed herbicide-resistant weeds, modes of action and herbicide brands, are current as of July 2013.



For more information, visit BayerCropScience.ca



BayerCropScience.ca or 1 888-283-6847 or contact your Bayer CropScience representative.

Always read and follow label directions. Alion™, Betamix®, Buctril®, Emesto™, EverGol™, Excel®, Converge®, Infinity®, InVigor®, Liberty®, LibertyLink®, Option®, Pardner®, Prostaro®, Puma®, Raxil®, Sencor®, Titan®, Thumper®, Trilex®, Tundra®, Varro™ and Vios™ are trademarks of the Bayer Group. Centurion® and Select® are registered trademarks of Arysta LifeScience. All other products mentioned are trademarks of their respective companies. Bayer CropScience is a member of CropLife Canada.