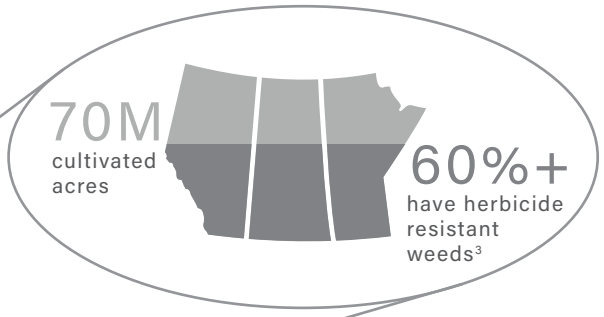
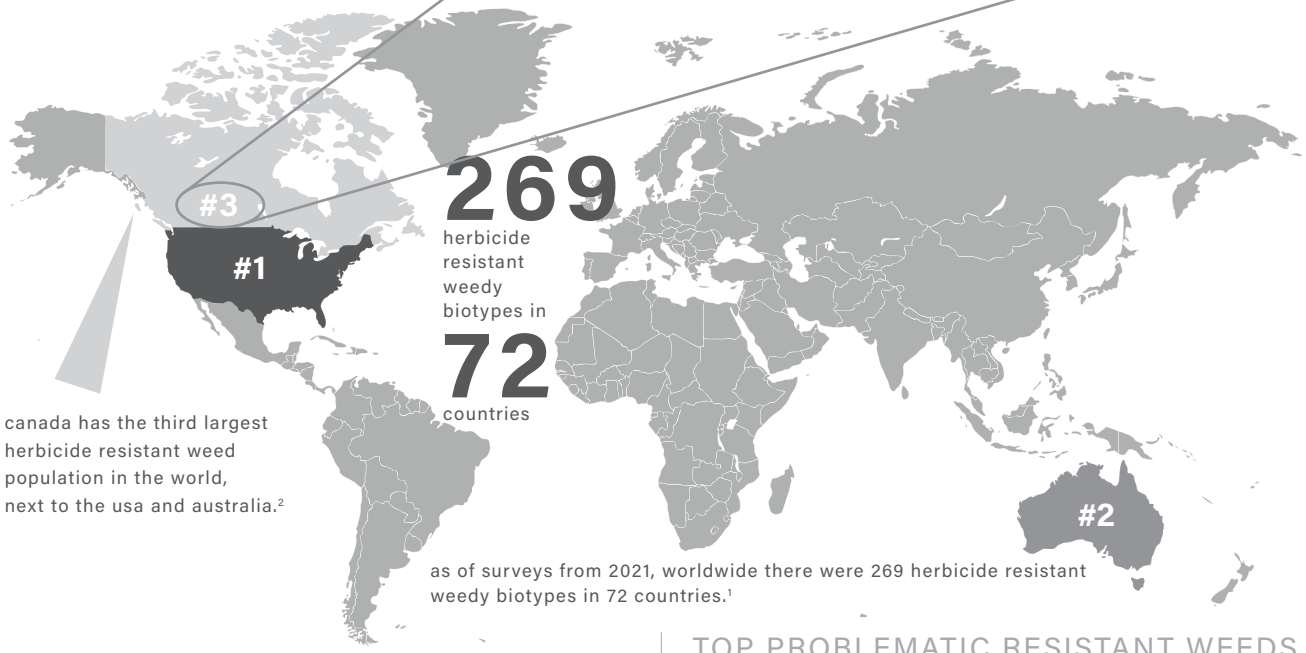
DEFY RESISTANCE

2023/2024

THE FACTS ABOUT HERBICIDE RESISTANCE





269 herbicide resistant weedy biotypes in **72** countries

canada has the third largest herbicide resistant weed population in the world, next to the usa and australia.[2]

as of surveys from 2021, worldwide there were 269 herbicide resistant weedy biotypes in 72 countries.[1]

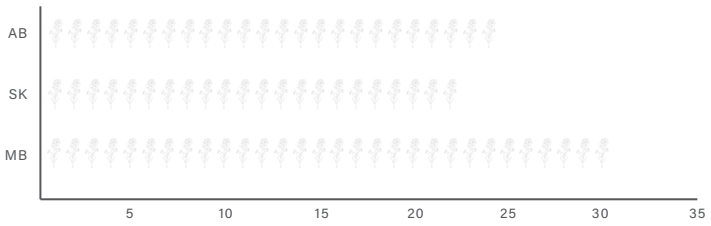
COST TO CANADIAN GROWERS

herbicide resistance costs canadian growers

UP TO $1.5B

annually due to increased herbicide use and decreased yield and quality.[4]

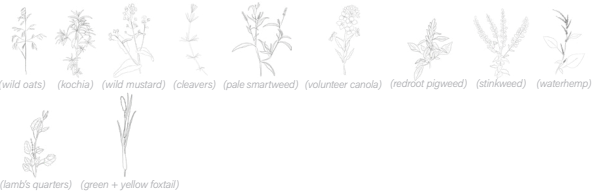
NUMBER OF HERBICIDE RESISTANT WEED SPECIES PER PRAIRIE PROVINCE[5]



TOP PROBLEMATIC RESISTANT WEEDS IN WESTERN CANADA

GROUP 1 RESISTANCE

GROUP 2 RESISTANCE



GROUP 4 RESISTANCE

GROUP 9 RESISTANCE

GROUP 10 RESISTANCE

GROUPS 14 OR 15 RESISTANCE

$20 per acre per year

10 yrs

a recent study reported that a proactive resistance management strategy for kochia in western canada can gain a farmer as much as $20/acre/year over 10 years.[6]

BEST PRACTICES FOR BATTLING HERBICIDE RESISTANCE

- determine your long-term strategy
- crop diversity and rotation
- **Multiple Effective Modes of Action (MEMOA)**
- enhanced competitiveness of the crop
- pre- and post-harvest herbicide application
- clean your equipment
- accurate recordkeeping

WHAT'S NEW? AS OF 2020...

2014/2015 — 2019/2020

11.8 M acres ► 15.3 M acres

of herbicide resistant weeds in farmland under annual crop production in Saskatchewan[7]

&

the first glyphosate-resistant downy brome was confirmed = the first glyphosate-resistant grass weed identified in Canada[5]

"NO HERBICIDE HAS BEEN LOST TO AGRICULTURE; THEY ARE TODAY, AND WILL REMAIN, AN INTEGRAL PART OF FOOD PRODUCTION THROUGH THEIR EFFECTIVE USE IN COMBINATION WITH WEED CONTROL PRACTICES."

- herbicide resistance action committee

[1] International Herbicide-Resistant Weed Database, Weed Science, https://www.weedscience.org/Home.aspx. [2] Cross, Brian, "The Future of Resistance is Unfolding Now," *Western Producer*, https://www.producer.com/crops/the-future-of-resistance-is-unfolding-now/. [3] Geddes, Charles M., Mattea M. Pittman, Shaun M. Sharpe, and Julia Y. Leeson, "Saskatchewan survey of herbicide-resistant weeds in 2019 and 2020." [5] Duckworth, Barbara, "Canada is the third in the world for herbicide-resistant weeds," *Western Producer*, January 3, 2019. [6]"Managing Herbicide-Resistant Kochia," Manage Resistance Now, https://manageresistancenow.ca/weeds/managing-herbicide-resistant-kochia/. [7&8] "Scenario-specific options will improve herbicide-resistant weed management," *Canola Research Hub,* November 10, 2022, https://www.canolacouncil.org/research-blog/scenario-specific-options-will-improve-herbicide-resistant-weed-management/

defyresistance.com

DEFY RESISTANCE™

DEFY RESISTANCE GUIDE

introduction

One result of modern agriculture and the reliance on herbicides is the emergence of weed populations which are resistant to products designed to control them. All natural weed populations, regardless of the application of any weed killer, likely contain individual plants (bio-types) which are resistant to herbicides. Repeated use of a herbicide will expose the weed population to a "selection pressure," which may lead to an increase in the number of surviving resistant individuals in the population. Consequently, the resistant weed population may increase to the point that adequate weed control cannot be achieved by that herbicide.

Despite this seemingly dramatic development, no herbicides have been lost to agriculture; they are today, and will remain, an integral part of food production through their effective use in combination with other weed control practices.

glossary of terms

ALS
the acetolactate synthase enzyme.

BIO-TYPE
a group of organisms having the same genotype, or any number of strains of a species of microorganisms having differentiable physiologic characteristics.

COOL WEATHER GERMINATING
a seed which germinates in cold soil and matures with cool weather and short periods of daylight.

CROSS POLLINATION
pollination of a flower or plant with pollen from another flower or plant causing the progeny (seed) to exhibit characteristics of both parents.

DEFY RESISTANCE
an information-based campaign designed to help farmers slow down or reduce the negative impact of herbicide-resistant weeds.

DEFY RESISTANCE HEADQUARTERS
any ag dealer who has been selected to be part of the Defy Resistance initiative. These dealers will have experts who are equipped with spreading the word about herbicide resistance in Western Canada and are a trusted resource for all farmers with herbicide resistance issues.

EPSPS
the enzyme 5-enolpyruvylshimate-3-phosphate synthase.

HERBICIDE GROUPS
a herbicide is described as being a member of a particular numbered group. These numbers refer to a specific mode of action.

HERBICIDE RESISTANCE
the inherited ability of an individual plant to survive a herbicide application that would kill a normal population of the same species.

HERBICIDE ROTATION
the practice of rotating herbicides with different modes of action so the same mode of action is not used year after year on the same field.

MODE OF ACTION
the way a herbicide kills a weed is called its mode of action (MOA). Most often it describes the disruption in a plant process, such as an enzyme inhibitor like ALS (Group 2) or a cell membrane disrupter, like PPO (Group 14).

MULTIPLE EFFECTIVE MODES OF ACTION (MEMOA)
two or more herbicidal actives from different modes of action that each control the same target weed. (ie. a Group 2 and a Group 4 that both control wild mustard, used together will control the weed with multiple effective modes of action control.)

MULTIPLE MODES OF ACTION
different modes of action, not necessarily on the specific target weed. (ie. a Group 1 for grassy weeds and a Group 2 for broadleaf weeds is still called multiple modes of action.)

PPO
the protoporphyrinogen oxidase enzyme.

RECORD-KEEPING (CROP PROTECTION PRODUCTS)
the practice of keeping track of all crop protection inputs applied to each field each year.

SITE OF ACTION
the site of action is the specific binding site or enzyme impacted by the herbicide active ingredient. It may also be referred to as the target site. One herbicide may have multiple sites of action. Or herbicides with different modes of action may act at different sites of action.

TARGET-SITE MUTATION
a change to the molecular target of the herbicide.

do i have it? how did i get it?

At this point, it should be assumed that at least a small number of plants in any weed population are naturally resistant to a given herbicide and repeated application of that herbicide will allow these plants to survive and set seed. However, there are several factors to consider when evaluating herbicide resistance risk. Some of these relate to the biology of the weed species in question, others relate to farming practices.

NUMBER OR DENSITY OF WEEDS – As resistant plants are assumed to be present in all natural weed populations, the higher the density of weeds, the higher the chance that some resistant individuals will be present.

BIOLOGY OF THE PLANT – Some weed species have a higher propensity toward resistance development; this relates to genetic diversity within the species and, in practical terms, refers to the frequency of resistant individuals within the natural population. Plant species with a longer soil dormancy will tend to exhibit a slower resistance development under a selection pressure as the germination of new, susceptible plants will tend to dilute the resistant population.

FREQUENT USE OF HERBICIDES WITH A SIMILAR SITE OF ACTION – The combination of "frequent use" and "similar site of action" is the single most important factor in the development of herbicide resistance.

CROPPING ROTATIONS WITH RELIANCE PRIMARILY ON HERBICIDES FOR WEED CONTROL – The crop rotation is important in that it will determine the frequency and type of herbicide able to be applied. It is also the major factor in the selection of non-chemical weed control options. Additionally, the cropping period for the various crops will have a strong impact on the weed flora present.

LACK OF NON-CHEMICAL WEED CONTROL PRACTICES – Cultural or non-chemical weed control techniques, incorporated into an integrated approach is essential to the development of a sustainable crop management system.

Failure to achieve expected weed control levels does not necessarily indicate herbicide resistance. A full analysis of the herbicide application, rate of use, weed type and stage of growth, climatic conditions, and agronomic practice should be reviewed. If, after the initial investigation, resistance is still suspected, then consideration of historical information may point to factors leading to resistance development.

1. Has the same herbicide, or herbicides with the same site of action, been used in the same field repeatedly or in the general area for several years?
2. Has the uncontrolled species been successfully controlled in the past by the herbicide in question or by the current treatment?
3. Has a decline in the control been noticed in recent years?
4. Are there weeds that survived in patches in the field, with no discernible pattern?
5. Are there known cases of resistant weeds in adjacent fields, farms, roadsides, etc.?
6. Is the level of weed control generally good on the other susceptible species except the ones not controlled?

If the answer to any of these questions is “yes” and all other factors have been ruled out, then resistance should be strongly suspected. Steps should then be taken to leave a small area to collect a sample of whole plant or seeds from the suspected resistant weed population for a resistance confirmation test.

IS HERBICIDE RESISTANCE REVERSIBLE?

NO. HERBICIDE-RESISTANT WEED SPECIES WILL MAINTAIN THEIR STRUCTURE OVER THOSE CHEMISTRIES AS LONG AS THEIR OFFSPRING CONTINUE TO ADD WEED SEEDS TO THE SOIL. STOPPING THE USE OF THOSE HERBICIDES WILL NOT REVERSE THOSE GENETICS.

DEFY RESISTANCE PRACTICES & GUIDELINES

determine your long-term strategy

When faced with herbicide resistance the most important management strategy to remember is to give it time. Herbicide resistance isn't a problem you will be able to solve in a season with one chemical application. Herbicide resistance management requires a strategy that your Defy Resistance Headquarters can help you develop and maintain.

crop diversity and rotation

Typically, weed resistance occurs in crop production systems that have not been diverse. Rotating crops with three to four different species allows for different herbicides to be used from year to year. The more years you give a field between the use of one specific herbicide mode of action, the more likely you can stay ahead of the weeds resistant to it.

One thing that is sometimes overlooked is that canola tolerance allows the farmer to extend herbicide rotation to different modes of action by utilizing all three tolerance platforms - LibertyLink®, glyphosate tolerant and Clearfield® Canola. Keep in mind though that a tight canola rotation can lead to disease issues that need to be carefully managed.

multiple effective modes of action

When a plant develops herbicide resistance, it has adapted in a way which makes herbicides ineffective to the plant. There are various mechanisms that allow plants to exhibit herbicide resistance. Using multiple effective modes of action helps prevent plants from adapting as quickly, due to the number of ways it would have to adapt at once.

enhanced competitiveness of the crop

Weeds are an issue because they compete for the same resources required by the crop, most importantly soil nutrients, moisture, and space. Crop competition plays a key role in controlling weed populations – a healthy crop stand enhances herbicide performance and out-competes the weeds. Management practices that establish an early, vigorous crop stand are essential to reducing resistant weeds. Proper fertility, including starter fertilizer with the seed for early growth ahead of weeds, seed treatments to prevent seedling disease, and elimination of weeds pre-seed all contribute to the crop getting off to a rapid, competitive start.

pre-seed, pre-harvest, and post-harvest herbicide application

Any time a population of resistant weeds can be controlled prior to the crop being seeded, or after the crop is harvested, the battle against resistance gets a boost. In spring, the early control ensures weed growth doesn't take important moisture and nutrients and lessens the weed pressure in the crop. Herbicide resistant weeds that are allowed to set seed will be a problem for years to come. Depending upon the weed, a pre-harvest herbicide application may allow for control of the weed prior to seed set. Post-harvest weed control can also reduce weed populations and seed set.

clean your equipment

Equipment can spread resistant bio-types from field to field. It is crucial to ensure all equipment is thoroughly cleaned before moving from one field to another to prevent the spread of herbicide-resistant weeds across your farm.

accurate record-keeping

Record-keeping may not be the job you signed up for when deciding to farm, but it is now an essential part of the business. It's important to keep track of what is seeded, sprayed, and the crop yield on every acre of your land to ensure your rotations are managed properly and herbicides (and their groups) aren't being over-used on a field-by-field basis.

GROUP 1-RESISTANT WILD OATS
(avena fatua)

Wild oats are the most economically detrimental weed species in the Canadian Prairies, according to Agriculture and Agri-Food Canada. It takes very few wild oat plants to cause a significant reduction in the yield of all major crops. Wild oats' delayed germination makes it extremely competitive and difficult to control.

Sixty percent of wild oats across the Canadian Prairies display some level of herbicide resistance. Leaving these plants uncontrolled increases the prevalence of resistant wild oats, and can negatively impact the crop's yield and profits each year.

Group 1-resistant wild oats have developed a target-site mutation. Group 1 herbicides work by attaching themselves to the acetyl-CoA carboxylase enzyme in the weed and inhibiting cell growth. Group 1-resistant wild oats have a mutated targeted enzyme, so ACCase inhibiting herbicides can no longer attach there, making them ineffective.

GROUP 2-RESISTANT WILD OATS
(avena fatua)

Wild oats were the first weeds noticed in Western Canada to have resistance to Group 1 herbicides, so the answer for many farmers to control wild oats was to switch to a Group 2 herbicide. This solution did work for many farmers for many years, until wild oats' resistance to Group 2 herbicides was noticed on these same farms years later.

Where the complete switch was made to Group 2 herbicides, selection pressure was increased resulting in the development of Group 2 herbicide resistance in only a few years. As of 2020, surveys indicated that 69% of in-field wild oats have herbicide resistance. This

reinforces the need to keep using all the tools in proper rotation and in combination with other practices, even if one mode of action becomes less effective.

Wild oats became resistant to Group 2 herbicides by developing a target-site mutation of the acetolactate synthase (ALS) enzyme, which is a key enzyme in the bio-synthesis of the branched-chain amino acids isoleucine, leucine, and valine. This mutation allows the plant to block the effect of the Group 2 herbicide, allowing normal plant growth through these amino acids.

GROUP 15-RESISTANT WILD OATS
(avena fatua)

Repeated use of highly effective Group 1 and 2 graminicides has resulted in the development of wild oat resistance. With an increased awareness of how repetitive selection exacerbates the development of resistance, growers moved to new chemistries. Unfortunately, the problem has reared its ugly head again as reliance on Group 15 herbicides has resulted in the confirmation of resistance to this mode of action in several geographies in Western Canada.

It should be noted that Group 8 herbicides have been reclassified as Group 15.

Group 15 herbicides work as shoot-growth inhibitors. A shoot-growth inhibitor prevents the formation of very-long-chain fatty acids in the cell membranes preventing growth of the the seedling shoot, which affects the weed prior to its emergence. It is believed that the resistance mechanism for Group 15 for wild oats is metabolic but may also be due in part to cross-resistance with Groups 1 and 2 herbicides.

Additional to herbicides, including alternative management practices for wild oats will help with control, such as: increasing seeding rate to boost crop competition, seeding early to reduce yield losses, the use of precision fertilizer techniques, and strategic crop rotation.

GROUP 2- AND 9-RESISTANT KOCHIA
(bassia scoparia)

Kochia's early germination, multiple flushes, and extensive root system that allows it to tolerate drought, has made it one of Western Canada's most difficult weeds to control, and it is now showing resistance to Group 2 and 9 herbicides.

A small number of Group 2-resistant populations were identified in the early 1990s, with the trait spreading rapidly. By the early 2000s, it was generally assumed that all kochia was Group 2 resistant. Research has shown when kochia has developed a resistance to Group 9 herbicides, it is already resistant to Group 2 herbicides. These plants show multiple resistance to Group 2 and Group 9 herbicides.

Group 2 resistance in kochia was caused by the target-site mutation of the acetolactate synthase (ALS) enzyme, rendering Group 2 herbicides ineffective.

Group 9-resistant kochia is a different mechanism than most other herbicide-resistant weeds. Herbicides often work by linking to a target enzyme site to disrupt the growth process of the weed. Weeds often become resistant by changing the shape of the targeted enzyme, not allowing the herbicide to link to the site. For glyphosate-resistant kochia, instead of changing the shape of the target enzyme, the plant produces more of the enzyme, tying the glyphosate up with the original site and continuing as normal with the new enzymes.

With kochia, it's important to prevent seed production which will cause spreading. Kochia seeds are short-lived and preventing seed production will dramatically decrease next year's infestation. An effective herbicide program (see page 32) combined with patch mowing are effective ways of preventing kochia from setting seed.

Research has also determined that increasing the rate of glyphosate applied, to overcome enzyme (EPSP synthase) overproduction is not a long-term strategy. Increasing the rate of glyphosate is more likely to simply increase the level of resistance due to increased selection pressure.

GROUP 4-RESISTANT KOCHIA
(bassia scoparia)

A 2021 study of kochia indicated 78% of kochia populations are showing resistance to Group 9 herbicides and 44% showing resistance to Group 4 herbicides. Compared to a survey from 2017 where only 18% of the kochia samples were resistant to Group 4 herbicides, the increase over 4 years is notable, and it is believed by researchers that it will show the same rapid spread as Groups 2 and 9.

Because of kochia's short seedbank longevity, delayed and reduced germination, and slower seedling development, additional strategies should be considered, such as, delayed pre-seed weed control, or early seeding to enhance crop competitiveness. Controlling kochia weed escapes to minimize gene flow is also crucial.

GROUP 14-RESISTANT KOCHIA
(bassia scoparia)

In 2021, Agriculture and Agri-Food Canada researchers in Saskatchewan confirmed a population of kochia with resistance to Group 14 herbicides, calling into questions the longevity of another valuable tool. At this time, testing has been done on saflufenacil, carfentrazone, and sulfentrazone, but there may be other actives in the group that kochia is not showing resistance to yet.

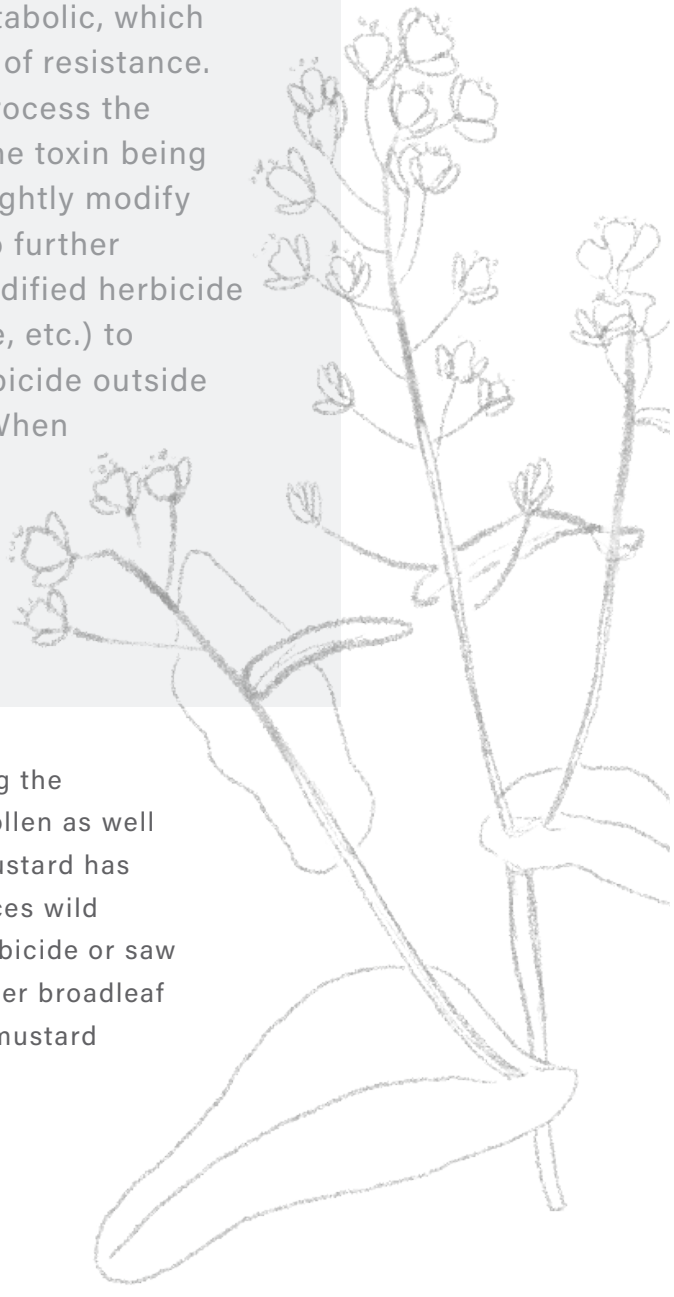
Group 14 herbicides are protoporphyrinogen oxidase (PPO) inhibitors, which are light dependent. It hasn't been specifically determined for kochia how the resistance mechanism works, but it is likely, as with other weeds, that there is a mutation to the target site.

Just because there has been a control escape, doesn't mean your whole field is resistant, so be aware of the possibility, but don't discount the herbicide right away. It will be important for farmers to continue to watch how kochia responds to herbicide treatments.

GROUP 2-RESISTANT WILD MUSTARD
(sinapis arvensis)

Wild mustard is an aggressive annual weed and can present a serious problem in canola and spring cereals. Its early germination under cool spring temperatures allow wild mustard to take over quickly. Some Group 2 herbicide resistance was found in wild mustard in Alberta in 1993 and Manitoba in the early 1990s, it wasn't again noted until 2000 in Manitoba. In a year where growing conditions allowed cool weather weeds to thrive, and persistent wild mustard infestations were seen surviving up to two applications of a Group 2 herbicide. Group 2-resistant wild mustard is also now prevalent in western Saskatchewan.

Wild mustard's herbicide resistance is metabolic, which is a more variable and unpredictable level of resistance. Herbicide metabolism is a three-phase process the plant undergoes to naturally dispose of the toxin being administered. To begin, the plant must slightly modify the herbicide molecule, predisposing it to further modification. Then it will combine the modified herbicide with another molecule (sugar, glutathione, etc.) to facilitate the final step of moving the herbicide outside the cell, isolating it from the target site. When metabolic resistance occurs, the rate of herbicide metabolism is altered and the herbicide is rendered ineffective at controlling the plant.



Wild mustard is a weed that outcrosses readily, creating the potential for rapid spread of herbicide resistance via pollen as well as through seed movement. At this time, not all wild mustard has Group 2 herbicide resistance, but any grower who notices wild mustard that was difficult to control with a Group 2 herbicide or saw variable control of wild mustard but good control of other broadleaf weeds, should consider the possibility that those wild mustard populations are herbicide resistant.

GROUP 2-RESISTANT CLEAVERS
(galium aparine)

Cleavers is an extremely competitive broadleaf weed which grows as a spring or winter annual and is particularly damaging in a canola crop, as their seeds are similar shape and size. Cleavers grow well in cool conditions, often experienced in the spring, in Western Canada. Even though little else may be growing in a typical cool spring, cleavers could be digging in their roots and the pre-seed burndown could be too late.

Group 2-resistant cleavers are now spreading rapidly and growers should take actions assuming they have Group 2-resistant cleavers or will have them soon. If growers know their cleavers are not Group 2 resistant, now is the time to move to a multi effective mode of action herbicide and/or a different mode of action in their herbicide rotation which is very effective at controlling cleavers.

Like most other Group 2-resistant weeds, cleavers has adapted to ALS inhibitors by mutating its ALS enzyme, stopping the ability of Group 2 herbicides from causing plant death.

As cleavers are a cool weather germinating plant, and often overwintering, the most important part of cleavers control is catching them early.

A fall burndown with a combination of glyphosate and a second herbicide (preferably a Group 4) effective at controlling cleavers is recommended. If a fall treatment is not possible, spring pre-seed burndown is critical, using a combination of actives. Glyphosate should not be used alone to delay the development of more glyphosate-resistant weeds.

GROUP 2-RESISTANT PALE SMARTWEED
(persicaria lapathifolia)

Pale smartweed, also known as lady's thumb, can grow to be a large plant with deep roots. It can grow to three feet tall and almost as wide, which is why this weed is a serious threat. It is also difficult to fully control as, some studies have shown, it can take over 16 years to completely rid the soil of germinating seed.

It has been noted in parts of Western Canada that pale smartweed is showing resistance to Group 2 herbicides and is having an effect on pulse and cereal crops.

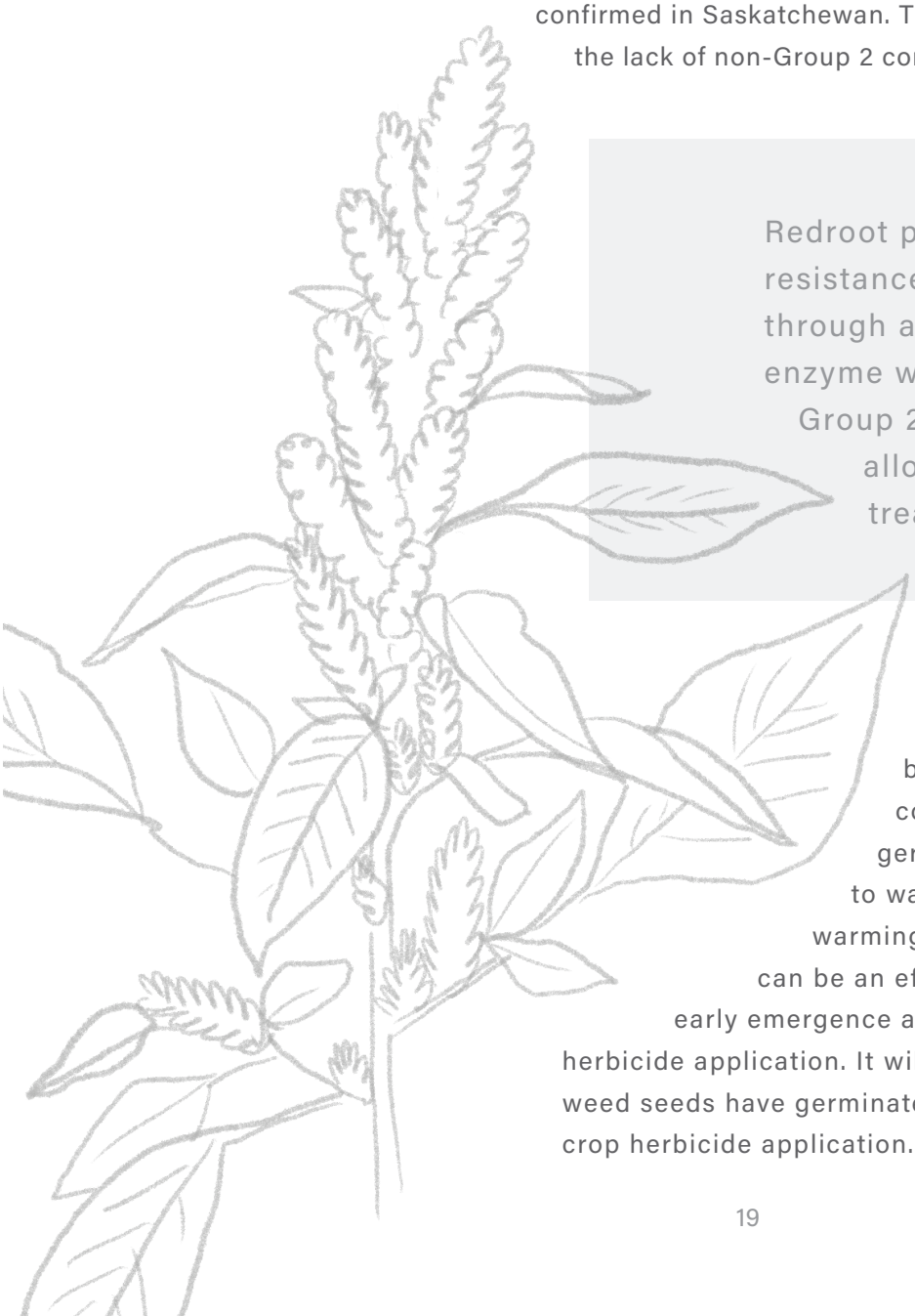
Pale smartweed is resistant to Group 2 herbicides through its target-site mutation of the ALS enzyme rendering Group 2 herbicides ineffective in causing plant death.

GROUP 2-RESISTANT REDROOT PIGWEED

(amaranthus retroflexus)

Redroot pigweed is a dicot weed in the Amaranthaceae family. Each plant's ability to produce up to 100,000 seeds if left alone through the growing season, means it can produce large infestations in a short period of time. Their 100,000 seeds can also lay dormant for up to five years, creating potential for future infestations when you aren't expecting it.

Group 2-resistant redroot pigweed was first confirmed in Manitoba in 2002. While the 2016 weed survey only detected one of 22 fields with Group 2-resistant redroot pigweed, focused sampling of suspicious patches has indicated that there are many more fields across Manitoba that have Group 2-resistant pigweed. Group 2-resistant redroot pigweed has also been confirmed in Saskatchewan. This is particularly concerning due to the lack of non-Group 2 control options in pulse crops.



Redroot pigweed developed a resistance to Group 2 herbicides through a mutation of the ALS enzyme which blocks the effect of Group 2 herbicides on the plant, allowing it to survive the treatment.

Redroot pigweed germinates when the crop is up, so a spring burnoff application won't help control them. However, pigweed germinates when the soil starts to warm, so darkening the soil and warming it early using tillage equipment can be an effective tool in encouraging early emergence allowing for an effective pre-seed herbicide application. It will also ensure that most of the weed seeds have germinated and emerged in time for an in-crop herbicide application.

GROUP 2-RESISTANT STINKWEED
(thlaspi arvense)

Stinkweed is an economically-important weed in the Canadian prairies, ranking on average 7th in abundance across Alberta, Saskatchewan, and Manitoba, with the most seen in Alberta. Stinkweed is a hardy winter annual with a persistent seed bank. In 2000, its resistance to Group 2 herbicides was first noticed near Lethbridge, Alberta.

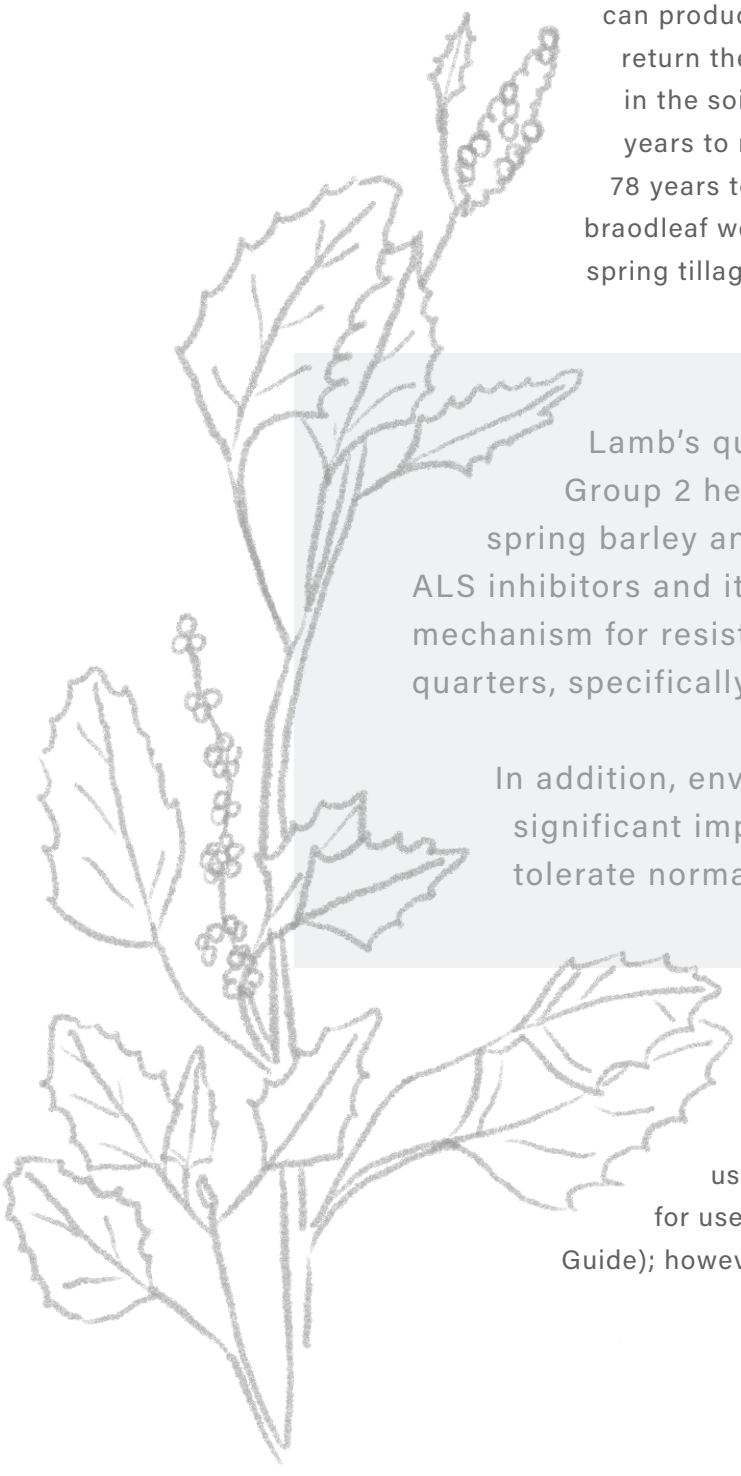
Known for its unpleasant aroma, stinkweed can produce up to 15,000 seeds per plant that remain viable up to six years in the tillage zone. Densities of 750 plants per square metre can reduce wheat yields by 20%. With its resistance to Group 2 herbicides on the rise, early control of stinkweed is crucial.

Stinkweed's Group 2 resistance was caused by the target-site mutation of the acetolactate synthase (ALS) enzyme, rendering Group 2 herbicides ineffective in causing plant death.

Stinkweed germinates in the fall or late summer and sets seed early in the spring, before in-crop herbicides are applied; therefore, Group 2-resistant stinkweed should be controlled in the fall with tillage and a non-Group 2 herbicide (see page 32).

GROUP 2-RESISTANT LAMB'S QUARTERS
(chenopodium album)

Lamb's quarters is a dicot weed in the Chenopodiaceae family (now considered a subfamily of the Amaranth family) and has been ranked as one of the five most widely distributed weeds in the world. An average lamb's quarters plant can produce more than 70,000 seeds, ensuring the weed will return the following spring. Seeds can also remain dormant in the soil for several decades and it will take at least 12 years to reduce seed in the soil seedbank by 50% and 78 years to reach 99%. Lamb's quarters is one of the first braodleaf weed to emerge in the spring and often before any spring tillage or burndown application.



Lamb's quarters has shown resistance to Group 2 herbicides in Western Canada affecting spring barley and wheat. Group 2 herbicides are ALS inhibitors and it has not been determined what the mechanism for resistance of these herbicides is in lamb's quarters, specifically.

In addition, environmental conditions can have a significant impact on the ability of lamb's quarters to tolerate normally lethal doses of herbicide.

Group 9-herbicide resistance hasn't been determined in lamb's quarters yet, but it's being looked for and farmers should be wary of over-using glyphosate. There are still herbicides available for use on lamb's quarters (see the Defy Resistance Guide); however, they need to be used efficiently.

GROUP 1- AND 2-RESISTANT YELLOW FOXTAIL
(setaria pumila)

Yellow foxtail has been an underestimated weed for many years, rated 30th in relative abundance in a 2002 AAFC weed survey. More recently, however, in a 2016 survey it made a surprising jump to 6th place.

Yellow foxtail is a heat-loving plant which may be increasing in abundance due to higher temperatures across the Prairies. It is an annual grassy weed that reproduces by seed with a longevity in the seed bank of up to 10 years, compared to most grasses which last three to six years. Yellow foxtail is now showing resistance to Group 1 and 2 herbicides.

GROUP 1- AND 2-RESISTANT GREEN FOXTAIL
(setaria viridis)

Unlike yellow foxtail, green foxtail has been seen as a troublesome weed for a long time, ranking in the top three in all Agriculture and Agri-Food Canada weed surveys since the 1970s.

Green foxtail has a late spring germination peaking with temperatures above 20 degrees Celsius. This timing means it is often missed by pre- and post-emergent herbicide applications, so a herbicide application during the one to three leaf stage is critical to minimize yield reductions.

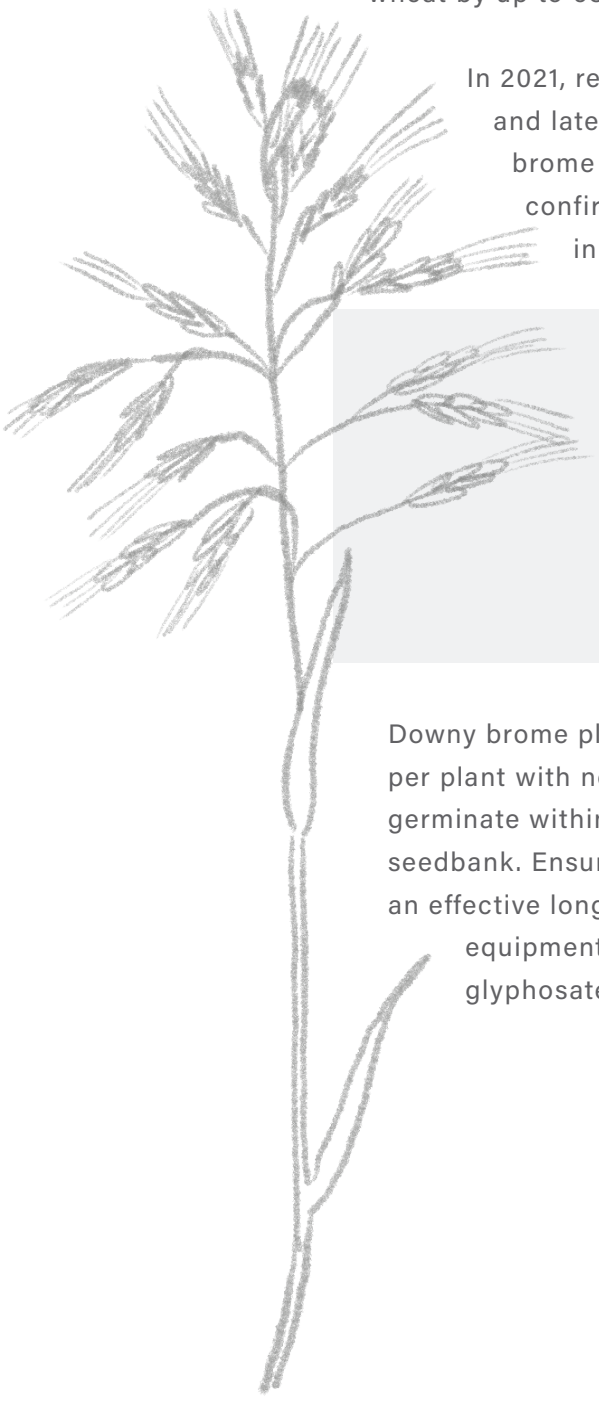
> As of 2014, green foxtail has shown resistance to Groups 1 and 2 herbicides and have likely become more prevalent since. Which mechanism the plant uses for resistance for each group hasn't yet been determined.

Because green foxtail is a poor competitor, it can be controlled by a strong crop stand produced by early seeding and a healthy crop to shade out the weed. Barley and canola are good candidates for this job, but the suppressed plants may still produce enough seed to infest the field in subsequent years.

GROUP 9-RESISTANT DOWNY BROME

(bromus tectorum)

Downy brome is a weed that has invaded North American crops since its introduction to the continent back in 1861. It is abundant in durum, barley, oats, lentils, canola, and spring wheat, but it is mainly an issue for winter wheat since their life cycles are very similar (fall germination and overwintering). Downy brome has the potential of reducing yields of winter wheat by up to 68%.



In 2021, resistance to Group 9 herbicide glyphosate was suspected and later confirmed when a lack of control was observed in a downy brome population in Alberta. This occurrence represents the first confirmation of a glyphosate-resistant grass weed in Canada.

The likely mechanism for Group 9 resistance in downy brome is 5-enolpyruvylshimate-3-phosphate synthase (EPSPS) gene amplification, which is similar to the mechanism of glyphosate resistance in kochia.

Downy brome plants reproduce by seed and can produce up to 6,000 seeds per plant with no competition, and while on average 98% of the seeds germinate within one year, the seed will only last up to 3 years in the soil seedbank. Ensuring those seeds don't return to the soil seedbank can be an effective long-term strategy for downy brome populations. Cleaning of equipment and seed products will be critical to limiting the spread of glyphosate-resistant downy brome.

RESISTANT WATERHEMP
(amaranthus tuberculatus)

Waterhemp is a problematic resistant weed in the midwestern United States, and in 2014 was found in Ontario with herbicide resistance. Waterhemp populations have now been detected in Manitoba and have been confirmed with resistance to Group 2, 9, and 14 herbicides. Since Waterhemp is not native to Manitoba, it is classified as a Tier 1 noxious weed and there is a concerted effort to eliminate the weed in that geography. It has not yet been detected in Saskatchewan or Alberta.

Waterhemp is a weed species with separate male and female plants (dioecious). As a result, it provides variability within populations due to cross pollination, which is evident from differences in plant characteristics. Waterhemp can produce up to one million seeds per plant, which can rapidly shift the response of a population to a herbicide, increasing the risk of herbicide resistance.

Because of waterhemp's genetic variability, it has a relatively high frequency of mechanisms that can impart resistance to herbicides, allowing waterhemp's resistance to develop more rapidly than most weeds. In the U.S. there are many different biotypes, but single plants have been identified with resistance to Groups 2, 5, 9, 14 and 27, with several other groups suspected and waiting to be confirmed.

Waterhemp is an extremely small seed easily transported through water, wildlife, machinery, or contamination of other small seeded crops.

A diversified integrated weed management plan is required to manage waterhemp, including crop rotation, multiple herbicide modes of action every year, cover crops, and a strategic use of tillage. Increasing the competitiveness of the crop through planting rates, row widths, etc. is key.

RESISTANT PALMER AMARANTH

(amaranthus palmeri)

Palmer amaranth, a noxious weed known in the U.S. to be impactful to yields, was confirmed to be present for the first time in September 2021. Seeds are able to travel through foot traffic, wildlife, or waterways, so transmission to Manitoba was expected once cases were found in North Dakota.

Palmer amaranth is described in the U.S. as one of their largest weed problems due to fast growth, large size, and significant yield impact – it can drop soybean production by 79% or corn production up to 91%. The plant can grow up to three inches a day to a maximum of eight feet tall and a single plant can produce up to a million seeds.

Herbicide resistance is also a common struggle in the U.S. with palmer amaranth.

As of January 2021, a U.S. study showed palmer amaranth had a six-way metabolic resistance in a single population.

Palmer amaranth is an important weed to note when considering resistance because of its devasting potential. The key to managing this weed will be to catch it before it takes hold and spreads. With one detection in 2021, more incidences are likely and early detection and eradication are critical to keeping it in check. Timely field scouting is being encouraged by weed specialists.

VOLUNTEER ROUNDUP READY® CANOLA (GROUP 9)

(brassica napus)

Canola has become a staple crop in Western Canada, but volunteer canola is a different story. Volunteer canola in a canola field does not make a positive contribution to yield. Volunteer plants do not have a seed treatment and can introduce seedling diseases and increase flea beetle pressure. In non-canola fields, volunteer canola can provide a host for blackleg and clubroot, reducing the effectiveness of crop rotation for managing these issues in canola the following year. Volunteer canola can reduce crop yield by 10%.

As glyphosate-tolerant traits in canola became the norm for canola growers across Western Canada, the instances of volunteer glyphosate-resistant canola have risen, creating an issue for volunteer canola management.

Group 9 herbicides, or glyphosate, inhibit 5-enolpyruvylshimate-3-phosphate synthase which leads to depletion of the aromatic amino acids: tryptophan, tyrosine, and phenylalanine, all amino acids needed for protein synthesis leading to growth. Group 9 volunteer glyphosate-resistant canola contains a modified EPSPS enzyme to ensure the production of the essential amino acids and further growth.

The best management practice for volunteer glyphosate-tolerant canola may be a two-pass strategy – a pre-emergent herbicide application and a post-emergent herbicide application. Crop rotation is also key, providing the ability to use a canola-controlling herbicide to clean the site before going back to a canola crop.

VOLUNTEER LIBERTYLINK® CANOLA (GROUP 10)
(brassica napus)

As the volunteer glyphosate-tolerant canola issue has been growing, the Group 10 volunteer glufosinate canola issue is growing as well.

Group 10 herbicides, or phosphinic acids, inhibit activity of glutamine synthetase, the enzyme that converts glutamate and ammonia to glutamine. If ammonia is left unconverted, its accumulation in the plant will destroy cells. A Group 10-resistant plant will possess a mutation to the glutamine synthetase enzyme to ensure the ammonia gets converted and the plant will live.

VOLUNTEER CLEARFIELD® CANOLA (GROUP 2)
(brassica napus)

Clearfield herbicides (Group 2) are in the Imidazolinone (IMI) class of herbicides which function by binding strongly to the active site of the ALS enzyme, thereby inhibiting the branched-chain amino acid biosynthesis pathway.

To help control volunteer Clearfield canola in cereals, Group 2 products may be applied with Group 4 products.

Volunteer canola, regardless of the herbicide tolerance platform, has become one of the top problem weeds in Western Canada. Controlling the volunteer plants in the rotational crop is critical to reduce the population and disease pressure on the volunteer plants as growers prepare for subsequent canola crops. Best practice is to rotate canola herbicide tolerance platforms to ensure volunteer canola can be effectively managed.

ROTATING CANOLA PLATFORMS

We've all heard that crop rotation is the key to managing herbicide resistance, and it is, but it may be necessary to take it a step further than simply rotating crops.

Rotating your canola hybrids and trait platforms will affect what control measures can be added to your crop, and being able to change them more often from year to year will help delay herbicide resistance.

In many parts of Western Canada the two crops in rotation are canola and cereals, with some areas adding in pulses, corn, or forages. Keeping a three-year break between all canola and cereal crops is a theoretical recommendation for a crop rotation to optimize weed control strategies and after that three years, if you can choose a variety with a platform you didn't use three years ago, especially a variety with different herbicide-tolerant traits allowing for different pest control applications, you are putting yourself and crop further ahead and potentially stopping new resistances from forming.

However, alternating between glufosinate and glyphosate in canola can be hugely valuable in delaying the onset of resistance.

RESISTANCE TESTING

There are two methods of testing for herbicide resistance in weeds. One is testing the seed collected from the suspect area prior to harvest, and the other is the collection of live plant samples during the season. Sending these samples to a laboratory for testing can determine whether they can survive a herbicide treatment and which ones.

For seed testing, collect seeds from several plants in areas where plants have survived the herbicide application. Make sure seeds are collected from a large enough number of plants so the sample isn't biased. If the resistance is widespread, collect seeds across the problem area in a W-shaped formation. A minimum of 25 grams of mature seeds per herbicide group must be collected and submitted without any stems or foreign material. At the lab, they will be grown and sprayed with the specific herbicides to determine resistance. This process can take up to 3-4 months.

Alternatively, leaf samples can be tested, which will eliminate the problem of seed dormancy and enables a much quicker turnaround time, possibly 2-3 weeks, and can be done in season allowing for effective management decisions to be made in the same growing season. However, there is currently a limited number of plant species available to test via this method.

HERBICIDES

When planning a weed control program, where possible, products should be chosen from herbicide groups with different modes of action to control the same weed either in successive applications or in mixtures. General guidelines for the rotation of chemical groups are:

1. Avoid continued use of the same herbicide or herbicides having the same mode of action in the same field.
2. Limit the number of applications of a single herbicide or herbicides having the same mode of action in a single growing season.
3. Where possible, use Multiple Effective Modes of Action herbicides or tank-mixes, which apply more than one mode of action for the same target weeds.
4. Use non-selective herbicides to control early flushes of weeds (prior to seeding). When using glyphosate, combine with other herbicides for Multiple Effective Modes of Action control of key target weeds.

herbicide mixtures

Herbicide mixtures can be a useful tool in managing or delaying resistant weed establishment. For herbicide mixtures to be effective, they should:

1. Include active ingredients which both give high levels of control of the target weed; and,
2. Include active ingredients from groups with different modes of action.

The grower should also:

1. Know which weeds infest the fields or non-crop area, and, where possible, tailor the weed control program according to weed densities and/or economic thresholds;
2. Follow label use instructions carefully; this especially includes recommended use rates and application timing for the weeds to be controlled;
3. Routinely monitor results of herbicide applications, being aware of any trends or changes in the weed populations present;
4. Maintain detailed field records so that cropping and herbicide history is known;
5. Grow a highly competitive crop, set up for rapid growth and vigour of early seedlings to out-compete weeds and increase the effectiveness of the herbicides used.

WEED	CROP	SOIL ZONE	PRE-SEED HERBICIDE	IN-CROP HERBICIDE
Group 1 Herbicde-Resistant Wild Oats	Canola	Brown		**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**Simplicity**, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**Simplicity**, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Simplicity**, **Rexade, Tandem** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Wild Oats	Canola	Brown		**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**Liquid Achieve SC**, **Avenza** + MCPA
		Dark Brown	**Korrex II** + glyphosate	**Liquid Achieve SC**, **Avenza** + MCPA, **Rezuvant XL** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Liquid Achieve SC**, **Rezuvant XL** + MCPA or 2,4-D
Group 15 Herbicide-Resistant Wild Oats	Canola	Brown		**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Ares SN**, **Amity WDG** (Clearfield canola); **glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**Simplicity**, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D, **Liquid Achieve SC**, **Avenza** + MCPA
		Dark Brown	**Korrex II** + glyphosate	**Simplicity**, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D, **Liquid Achieve SC**, **Avenza** + MCPA, **Rezuvant XL** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Simplicity**, **Rexade, Tandem** + MCPA or 2,4-D, **Liquid Achieve SC**, **Rezuvant XL** + MCPA or 2,4-D

Group 2 Herbicide-Resistant Kochia	Canola	Brown		**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tridem** + 2,4-D
		Dark Brown	**Paradigm PRE or Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tridem** + 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D, **Rezuvant XL** + MCPA or 2,4-D
Group 4 Herbicide-Resistant Kochia	Cereal	Brown		**OnDeck**
		Dark Brown		**OnDeck**
		Black		**OnDeck**
Group 9 Herbicide-Resistant Kochia	Canola	Brown		**Interline** (glufosinate tolerant)
		Dark Brown		**Interline** (glufosinate tolerant)
		Black		**Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL**, **Stellar XL, Avenza** + MCPA, **Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL**, **Stellar XL, Avenza** + MCPA, **Tridem** + MCPA or 2,4-D
		Black		**Pixxaro, Prestige XL, Prominex** + MCPA or 2,4-D, **Rezuvant XL** + MCPA or 2,4-D
Group 14 Herbicide-Resistant Kochia	Canola	Brown		**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown		**OnDeck**
		Dark Brown		**OnDeck**
		Black		**OnDeck**

WEED	CROP	SOIL ZONE	PRE-SEED HERBICIDE	IN-CROP HERBICIDE
Group 2 Herbicide-Resistant Cleavers	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Wild Mustard	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA**, Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza + MCPA, Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D
Volunteer Roundup Ready® Canola (Group 9)	Canola	Brown	**Glyphosate**	**Ares SN, Amity WDG** (Clearfield canola)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Ares SN, Amity WDG** (Clearfield canola)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Ares SN, Amity WDG** (Clearfield canola)**, Interline** (glufosinate tolerant)
	Cereal	Brown	**PrePass** + glyphosate, **Korrex II** + VP 480	**OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Dark Brown	**PrePass** + glyphosate, **Korrex II** + VP 480	**OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Black	**PrePass** + glyphosate, **Korrex II** + VP 480	**Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
Volunteer LibertyLink® Canola (Group 10)	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)

Volunteer LibertyLink® Canola (Group 10)	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Black	**PrePass XC** + glyphosate, **Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D**, Tandem** + MCPA or 2,4-D
Volunteer Clearfield® Canola (Group 2)	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
	Cereals	Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D**, Tandem** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Pale Smartweed	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
	Cereal	Brown	**Glyphosate**	**OnDeck**
		Dark Brown	**Glyphosate**	**OnDeck, Prominex** + MCPA or 2,4-D
		Black	**Glyphosate**	**OnDeck, Prominex** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Redroot Pigweed	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant canola)**, Interline** (glufosinate tolerant)
	Cereals	Brown	**Korrex II** + glyphosate	**OnDeck, OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OnDeck, OcTTain XL, Stellar XL, Prominex** + MCPA or 2,4-D**, Avenza** + MCPA**, Tandem** + MCPA or 2,4-D**, Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, OnDeck, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D**, Tandem** + MCPA or 2,4-D

WEED	CROP	SOIL ZONE	PRE-SEED HERBICIDE	IN-CROP HERBICIDE
Herbicide-Resistant Palmer Amaranth	Canola	Dark Brown	**Prospect** + glyphosate	
		Black	**Prospect** + glyphosate	
	Cereals	Brown		**Prominex** + MCPA or 2,4-D
		Dark Brown		**Prominex** + MCPA or 2,4-D
		Black		**Cirpreme XC, Exhilarate, Pixxaro, Rexade, Prominex** + MCPA or 2,4-D, **Rezuvant XL** + MCPA or 2,4-D
Herbicide-Resistant Waterhemp	Canola	Dark Brown	**Prospect** + glyphosate	
		Black	**Prospect** + glyphosate	
	Cereals	Brown		**Prominex** + MCPA or 2,4-D
		Dark Brown		**Prominex** + MCPA or 2,4-D
		Black		**Cirpreme XC, Exhilarate, Pixxaro, Rexade, Prominex** + MCPA or 2,4-D, **Rezuvant XL** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Stinkweed	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant), **Interline** (glufosinate tolerant)
	Cereal	Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OcTTain XL, Stellar XL, Avenza** + MCPA, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D, **Rezuvant XL** + MCPA or 2,4-D, **Tandem** + MCPA or 2,4-D
Group 1 Herbicide-Resistant Yellow Foxtail	Cereals	Brown		**OnDeck**
		Dark Brown		**OnDeck**
		Black		**OnDeck**

Group 2 Herbicide-Resistant Yellow Foxtail	Cereal	Brown		**OnDeck**
		Dark Brown		**OnDeck, Rezuvant XL** + MCPA or 2,4-D
		Black		**OnDeck, Rezuvant XL** + MCPA or 2,4-D
Group 1 Herbicide-Resistant Green Foxtail	Cereals	Brown		**OnDeck**
		Dark Brown		**OnDeck**
		Black		**OnDeck**
Group 2 Herbicide-Resistant Green Foxtail	Cereals	Brown		**OnDeck**
		Dark Brown		**OnDeck, Rezuvant XL** + MCPA or 2,4-D
		Black		**OnDeck, Rezuvant XL** + MCPA or 2,4-D
Group 2 Herbicide-Resistant Lamb's Quarters	Canola	Brown	**Glyphosate**	**Glyphosate** (glyphosate tolerant)**, Interline** (glufosinate tolerant)
		Dark Brown	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant)**, Interline** (glufosinate tolerant)
		Black	**Prospect** + glyphosate	**Glyphosate** (glyphosate tolerant)**, Interline** (glufosinate tolerant)
	Cereals	Brown	**Korrex II** + glyphosate	**OnDeck, OcTTain XL, Stellar XL, Avenza** + MCPA, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Dark Brown	**Korrex II** + glyphosate	**OnDeck, OcTTain XL, Stellar XL, Avenza** + MCPA, **Tandem** + MCPA or 2,4-D, **Tridem** + MCPA or 2,4-D
		Black	**Paradigm PRE** + glyphosate	**Cirpreme XC, Exhilarate, OnDeck, Pixxaro, Prestige XL, Rexade, Prominex** + MCPA or 2,4-D**, Rezuvant XL** + MCPA or 2,4-D**, Tandem** + MCPA or 2,4-D
Group 9 Herbicide-Resistant Downy Brome	Cereals	Dark Brown		**Simplicity, Rexade**
		Black		**Simplicity, Rexade**

RESOURCES

This guide has been compiled of information and research provided by the following reputable institutions, organizations, and publications:

Canadian Agronomist

Canadian Journal of Plant Science, Canadian Science Publishing

Charles M. Geddes

Crop Extension, Iowa State University

Department of Crop Sciences, University of Illinois

Department of Agronomy, Kansas State University

Government of Saskatchewan, Ministry of Agriculture

Government of Western Australia, Department of Primary Industries and Regional Development, Agriculture and Food

GrainNews

gov.mb.ca, Government of Manitoba, Agriculture

Iowa State University

Manage Resistance Now

Manitoba Pulse and Soybean Growers

Ontario Ministry of Agriculture, Food, and Rural Affairs

Saskatchewan Pulse Growers

Scientific Report, nature.com

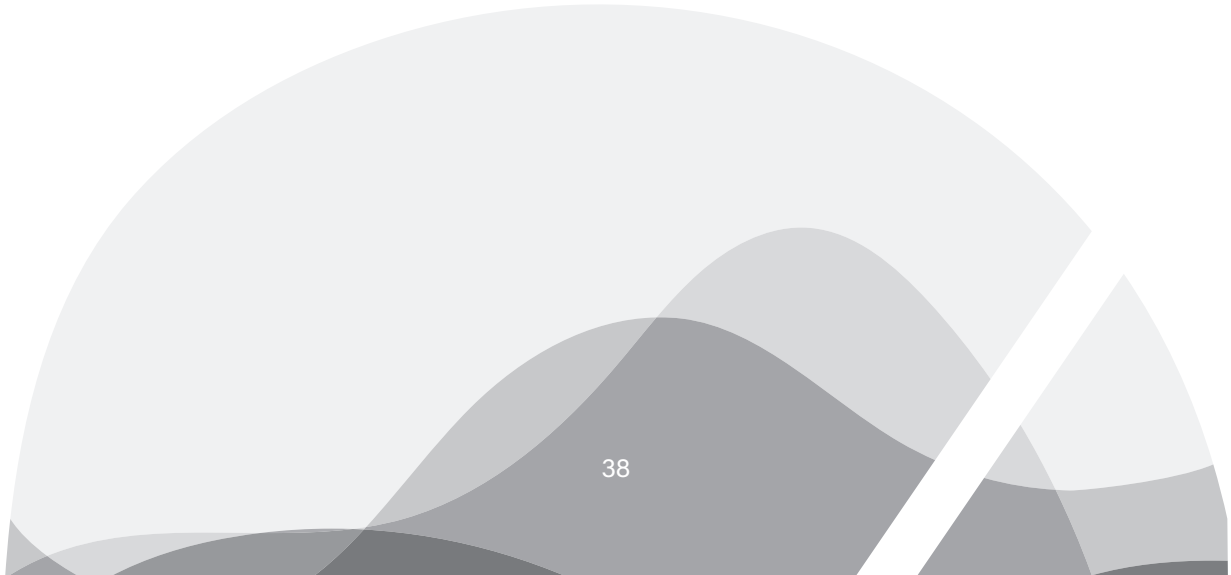
The Western Producer

Top Crop Manager

University of Manitoba

University of Saskatchewan, College of Agriculture and Bioresources

Weed Science Society of America



IT'S TIME TO GET SERIOUS

ARE YOU TAKING HERBICIDE RESISTANCE SERIOUSLY?

herbicide resistance is a growing problem that can only be stopped by serious strategic action to halt its progress.

your defy resistance dealer is ready to work with you to create a strategy that employs the proper use of herbicides as well as practices to ensure your resistant weeds can be killed and anything else will not develop resistance.

there is still hope, but it's time to get serious about defying resistance.

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