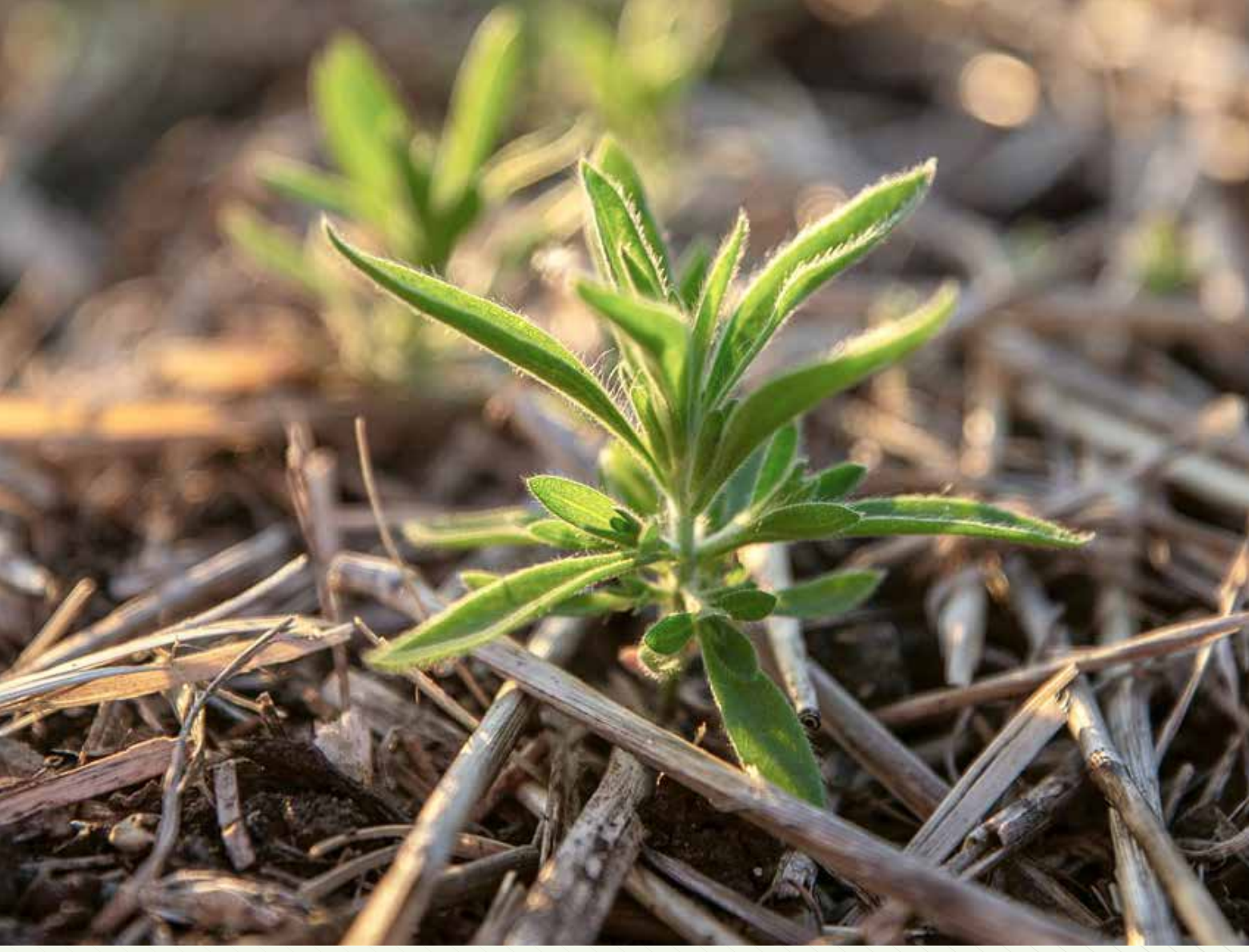

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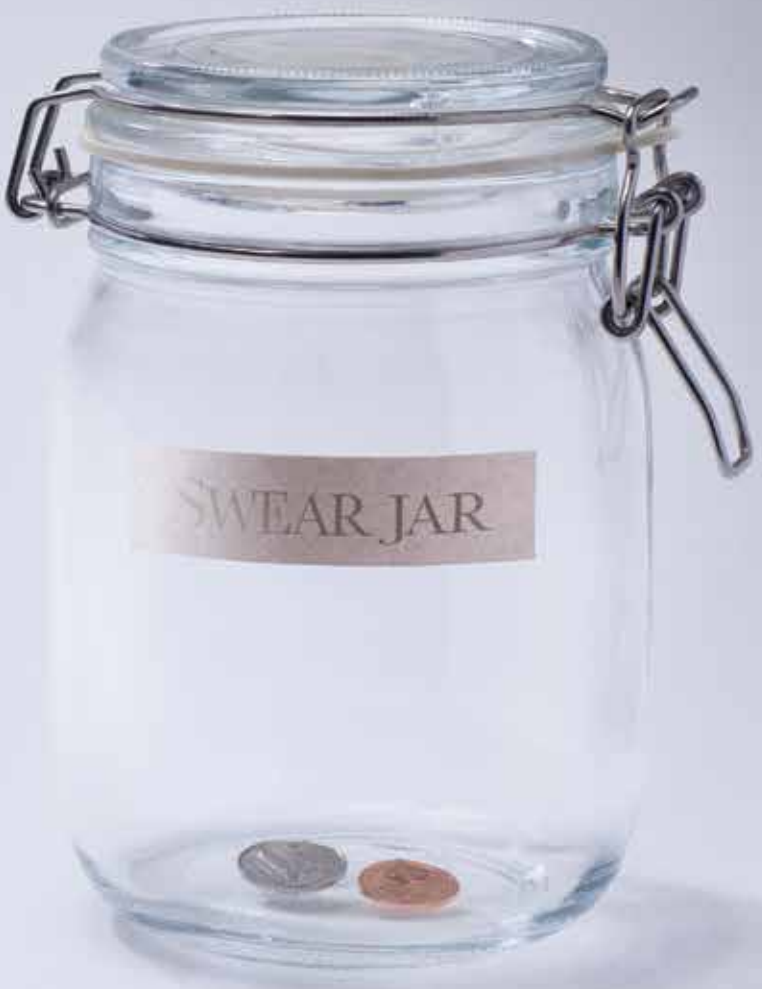

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MESSAGE FROM

FMC An Agricultural Sciences Company

Kochia, including resistant kochia, continues to be a serious threat to crop production in Western Canada.

In recent research, Agriculture and Agri-Food Canada Weed Scientist Charles Geddes points to three factors behind kochia's geographic spread and greater impact: climate change, increased resistant populations and pollen-mediated gene flow/protogynous flowering. Other scientists agree.

At this point, completely controlling or eradicating kochia isn't a realistic goal. For growers, it's now a matter of managing the population and delaying the onset of more or different herbicide-resistant biotypes.

Success against kochia will demand multiple tactics as part of an integrated pest management strategy. Available tactics include but are not limited to crop rotation, using unique modes of action and mechanical means such as harvest weed seed destructors.

This publication looks at the kochia situation from several angles, providing growers with current information and useful advice.

FMC Canada is pleased to collaborate with this publication to help give growers a much-needed edge against the rising threat of kochia. ■

HERBICIDE-RESISTANT KOCHIA CONTINUES TO SPREAD

The prolific weed has been found across the Prairies with resistance to Group 2, Group 9 and now Group 4 herbicides

BY ALEX MCCUAIG | MEDICINE HAT BUREAU

Producers looking for good news out of the latest Alberta survey of kochia resistance on the Prairies are going to be disappointed.

The stubborn weed continues to show how tough it is against any herbicide.

Group 2 herbicide-resistant kochia first showed up on the Prairies in 1988 and has since become so widespread that all populations are assumed not to be susceptible.

"Group 2 resistance showed us just how quickly a herbicide-resistant trait can spread throughout kochia populations in the prairie provinces," said Charles Geddes, a research scientist at Agriculture Canada specializing in weed ecology. "It took only about two decades to go from the first confirmation to essentially all populations being Group 2 resistant."

That trend continued in 2011 when the first Group 9 glyphosate-resistant kochia was found in southern Alberta, which by 2017 was found to be the case in half the population. That year also saw the emergence of Group 4 dicamba resistance, and populations with triple resistance to Group 2, 4 and 9. Since then, the numbers have continued to rise across the Prairies during the survey, which alternates between Alberta, Manitoba and Saskatchewan. The results of the 2021 survey included the discovery of fluroxypyr resistance.

"It's pretty surprising to see how this is even possible," said Geddes of the speed of herbicide resistance in the kochia populations.

The dry conditions on the Prairies in recent years have seen kochia populations thrive, spreading their scourge as tumbleweeds blowing across the plains. Additionally, Geddes said kochia pollen is also a source for herbicide resistance due to the plant's unique flowering.

Dry conditions on the Prairies in recent years have seen kochia populations thrive, while the weed's pollen has also been found to be a source for herbicide resistance through its unique flowering. FILE PHOTO

PHOTO: GETTY IMAGES

"The female part of the flower matures before the male part of the flower so it is actually receptive to pollen from neighbouring plants before it can self-pollenate," said Geddes.

That, combined with the weed's ability for long-distance seed dispersal, is now equating to a plant with the seeming ability to cancel just about anything that's thrown at it and a perfect recipe for herbicide resistance.

"With 78 percent of the population having glyphosate resistance, we're at the point where it's pretty safe to assume if you are dealing with kochia, it's quite likely glyphosate resistant kochia," said Geddes.

Triple resistance for glyphosate, dicamba and fluroxypyr was found in 10 percent of the kochia tested during the 2021 survey in Alberta.

"It's safe to assume that those populations are also Group 2 resistant," said Geddes.

With herbicide options becoming exhausted, Geddes said there isn't any single tool available to deal with kochia, "and it is unlikely there will be one in the near future."

Alternative kochia management techniques will be needed, "as you're not going to be able to spray your way out of resistance," he added.

Herbicides are still going to be part of management but will continue to be challenged in their effectiveness unless non-chemical techniques are also incorporated. Kochia for cattle feed is one option if cut before the weed produces seed.

Other options being researched include ways to exploit the weed's weak point — that it's seed isn't viable in the soil beyond one or two years.

"Kochia tends to respond to crop competition," said Geddes. "The way it responds is it reduces its biomass, reduces its seed production so anything you can do to promote competitive crops is going to go a long way to helping to prevent that kochia seed production."

Geddes said research into crop row spacing and seeding rates have shown some promise.

"Both decreasing row spacing and increasing seeding rates were effective strategies," said Geddes. "But when you combine those two together, we actually saw an 80 percent reduction overall in kochia biomass."

That reduction rate is on par with control rates of herbicides but it doesn't come without a cost.

"Some of these cultural tools can be as effective as a new herbicide mode of action," he said. "It's an investment of equipment and also an investment in increasing crop seeding rates."

Geddes said while some of the herbicide resistance in kochia is relatively low in populations, the trend has shown it will increase the more the weed is exposed to chemical treatments. ■

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(This story originally appeared Oct. 13, 2022 in The Western Producer. Reprinted with permission,

KOCHIA BECOMES MAJOR PROBLEM ACROSS WESTERN CANADA

BY THOM WEIR, PAg | AGRONOMY PRECISELY COLUMN

Kochia can displace a crop in the field very rapidly, such as this cereal, and once it is established it is difficult to manage and can heavily reduce crop yields.
THOM WEIR PHOTO

A couple of years ago I wrote a number of articles under "The Weed of The Week" heading.

This column might be headed "The Weed of the Year." From what I have seen in the fields, and from phone calls and texts I have received, kochia, which I have previously referred to as the scourge of the south, is showing up across most of the south and large areas of the dark brown and black soil zones.

Enquiries have varied from "what is this weed?" to "how do I control it in XXX crop?"

The first is easy. Descriptions include an olive mat of weeds to a velvety green blanket of weeds. The second question is easy as well because some crops — flax, Clearfield canola or sunflowers do not offer any in-crop alternatives. Your choice for control in these crops include tillage, burn off with glyphosate and Heat, or cutting for feed. None of these are options a grower wants to hear, especially with today's commodity prices.

Kochia (Kochia scoparia) like many of our weeds, is native to Asia and central Europe. Unlike most weeds, though, it was introduced to Canada as an ornamental planting by European immigrants. It is still sold by seed companies as burning bush and in nurseries selling annual plants. I saw it in a nursery where I buy my annuals this year.

What sets kochia apart from most weeds is firstly, its prolific seed production. Kochia reproduces from seeds, it typically produces around 15,000 seeds per plant. Seeds are dispersed in the fall when the plant matures. If left undisturbed, it becomes a tumbleweed.

Often, though, it is put through the combine that acts as a very good distributor of the seed. As well, sometimes areas are swathed and then harrowed up into a pile for burning. Some seeds may be left in the harrows and transported to another area of the field.

I can't count the times I have discovered kochia in a field that was previously clean and have the farmer say "Oh yeah, last year I moved over from Mike's Dad's quarter and must have dragged it over."

On the positive side, kochia seeds are somewhat short-lived in the soil. They last only two to three years, so if you can control them for a couple of years, the seed supply will play out.

The second factor is that kochia is tolerant to drought and has a high tolerance to saline soils. That is usually where you see it in a field, in that saline ring around a slough or along the headlands next to a ditch. Over the last couple years, populations have increased due to both of these factors, a wide ranging drought and increasing salt affected or saline soils.

The third factor that makes kochia a concern is that, not only does it produce a huge amount of seeds, it is also outcrossed. This means that it required pollen from another plant to be pollenated and produce seed.

Kochia produces a large amount of pollen. Because of this, and a high amount of genetic variability, it is a prime candidate for becoming resistant to herbicides. It quickly became resistant to Group 2 ALS inhibiting herbicides in the 1990s and more recently, to glyphosate or Group 9s and to dicamba, a Group 4 herbicide.

A kochia survey in southern Alberta in 2017 found that all kochia populations were resistant to Group 2s, 50 percent of populations were resistant to Group 9 glyphosate, and 18 percent of populations resistant to Group 4 (dicamba) herbicides. More shocking was that there were kochia populations with triple resistance to Group 2, Group 4, and Group 9 modes of action found in 10 percent of the 305 populations collected and tested.

Now is the time to plan around a potential kochia problem in 2022. The first thing to do is map where the patches or fields are that are infested. Job Two is to use this information when planning your 2022 crops.

Kochia is a lot easier to control in cereals than many other crops. There are a number of herbicides available that do an excellent job at controlling kochia in crop.

This year, Authority 480 herbicide was labelled for wheat. It provides residual control of kochia and a few other weeds. It can be applied pre-plant or up to three days after seeding and it can be applied alone or with glyphosate.

In addition to kochia, Authority controls redroot pigweed, lamb's-quarters, cleavers and wild buckwheat. Authority is also registered for use in field peas, chickpeas, flax, soybeans and sunflowers. This is also important because there are no effective in-crop alternatives for flax, sunflowers or chickpeas.

Another product that will provide good to excellent control of kochia is Edge (ethalfluralin) and is registered on canola, field peas, lentils, fababeans, yellow mustard, dry edible beans, sunflowers, alfalfa (establishment), soybeans, chickpeas, dry common beans and industrial hemp.

Canola should be of interest to growers as there are no in-crop herbicides for kochia control in Clearfield canola. As well, if Roundup Ready canola is grown in an area where Group 9 resistant kochia is suspected, there will be no control options.

Finally, manage the problem areas this year. This may include spraying out patches of uncontrolled kochia in fields, tilling them up or mowing before seed set in early July. Burning in the fall also works but avoid harrowing.

If you use pre-harvest weed management with glyphosate, make sure you notice any kochia that seems to be unaffected. ■

Thom Weir PAg is a certified crop advisor and professional agrologist in the Yorkton, Sask., region. You can reach him at thom.weir@farmersedge.ca.
(This story originally appeared June 24, 2021 in The Western Producer.

Here are some control strategies for crops with limited control alternatives:

- **Seed in fields that showed good control of kochia in the previous year's crop.**
- **Use a burn down up to emergence.**
- **Products containing sulfentrazone (Authority) have excellent kochia control and can be used in many crops in reduced tillage and no-till systems.**
- **Ethalfluralin control of kochia is rated as fair but can perform very well. Best results when applied in the fall.**
- **Use a registered pre-emergent option for crops such as flax or Clearfield canola.**

RAPID TEST AVAILABLE FOR RESISTANT WEEDS

BY ROBERT ARNASON | WINNIPEG BUREAU

Glyphosate-resistant kochia is spreading across southern Manitoba. So this spring more kochia weeds will survive the first herbicide treatment and more growers will want to know: did the sprayer miss this patch of weeds, or are they resistant to glyphosate?

A rapid test is now available to answer that question.

"I just spent money to do this (test) two days ago," said Rob Gulden, a University of Manitoba weed scientist.

Gulden explained that Pest Surveillance Initiative (PSI), a Winnipeg company, uses a DNA-based test to determine if kochia is resistant to glyphosate.

A grower sends in a sample of a weed and the result helps the producer decide, during the growing season, what to do next.

"If your glyphosate fails on kochia (and) you're not sure if it was an application issue or it was resistance ... you can get that confirmed before you go out with a second application of glyphosate and make the whole situation even worse," Gulden said from his U of M office. "(It) allows you to get a result within a few days (or longer) and you can figure out what's going on."

Glyphosate-resistant kochia first appeared in Manitoba's Red River Valley several years ago and the pest has spread to many other fields.

Most of the municipalities in the Red River Valley and south-central Manitoba now have it, along with two rural municipalities in the southwestern corner of the province.

One thing growers should be doing is scouting for kochia plants that may be resistant, said Manitoba Agriculture weed specialist Tammy Jones (now an agronomist with Corteva). If there is a patch in a field, producers should hand-pull the kochia or consider spot tillage to remove the weeds.

The test used at PSI is part of a new suite of molecular tests for herbicide resistance. Scientists are using molecular markers, or fragments of DNA found at certain locations in the genome, to confirm if a weed is resistant. This winter Agriculture Canada announced that such tests are being used in Quebec to combat herbicide resistance.

"With just a few fresh leaves from a weed plant, a technician can determine whether resistance genes are present in less than two weeks," said Martin Laforest, a scientist at the Ag Canada research centre in Saint-Jean-sur-Richelieu, Que. The DNA-based tests are helpful but they have limitations.

For instance, the test for kochia is only for kochia and only looks for a particular mechanism, in the plant, which causes resistance to glyphosate.

So, the same test can't be used for a different herbicide or a different weed.

"They are very specific to species (of weed) and specific to resistance mechanism," Gulden said.

That means scientists still need the old method of testing — where weed samples are grown in a greenhouse and then sprayed with a particular product — to see if a herbicide kills a weed or not.

"(The old test) will help us in detecting new mechanisms (for resistance)," Gulden said. "These new tools are really nice, in season, to look at what's going on ... before the weeds produce seed." ■

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(This story originally appeared March 28, 2019 in The Western Producer. Reprinted with permission, all rights reserved.)

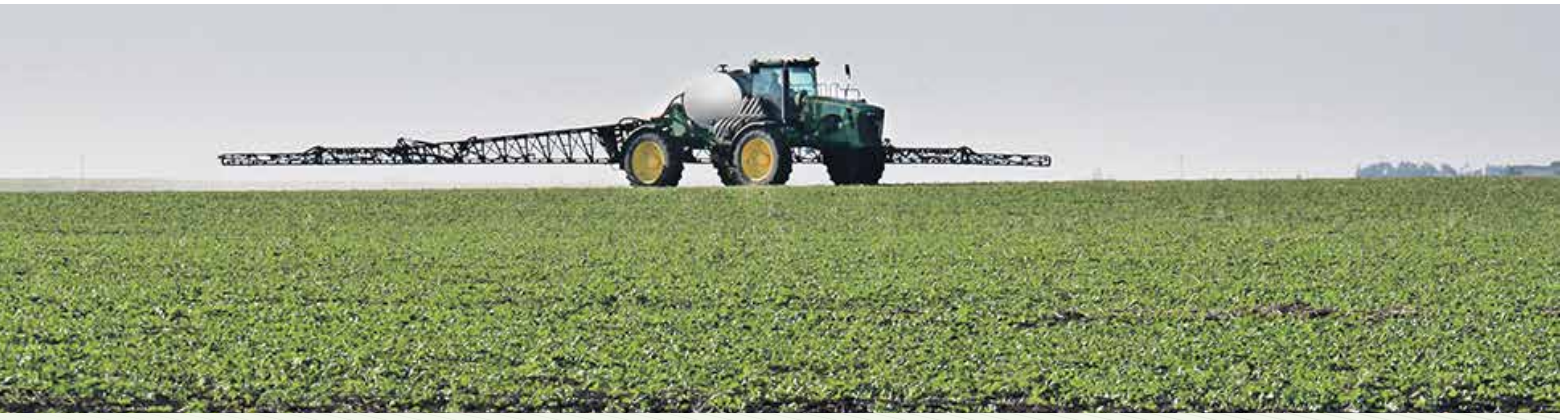
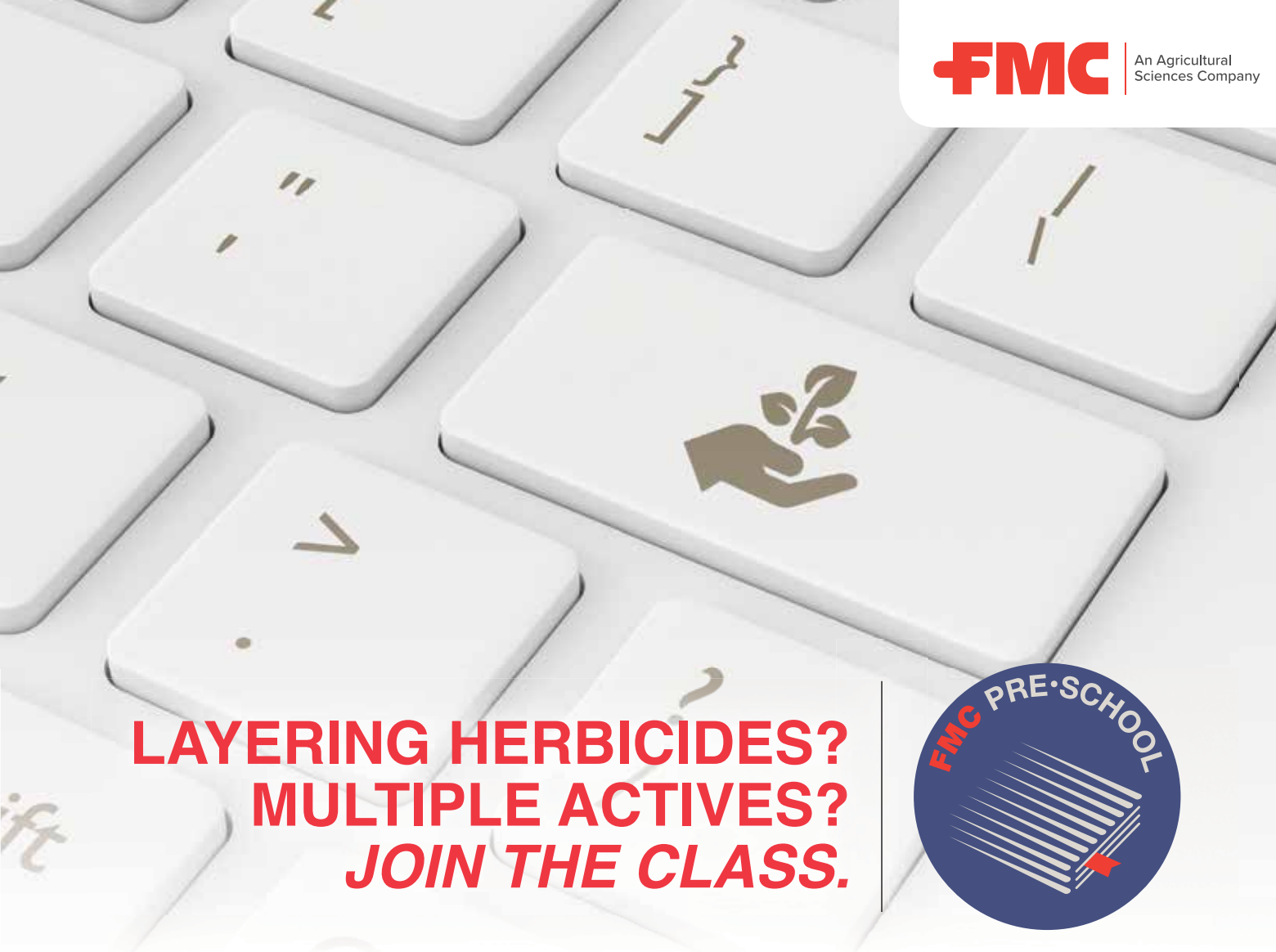


PHOTO: MIKE RAINE



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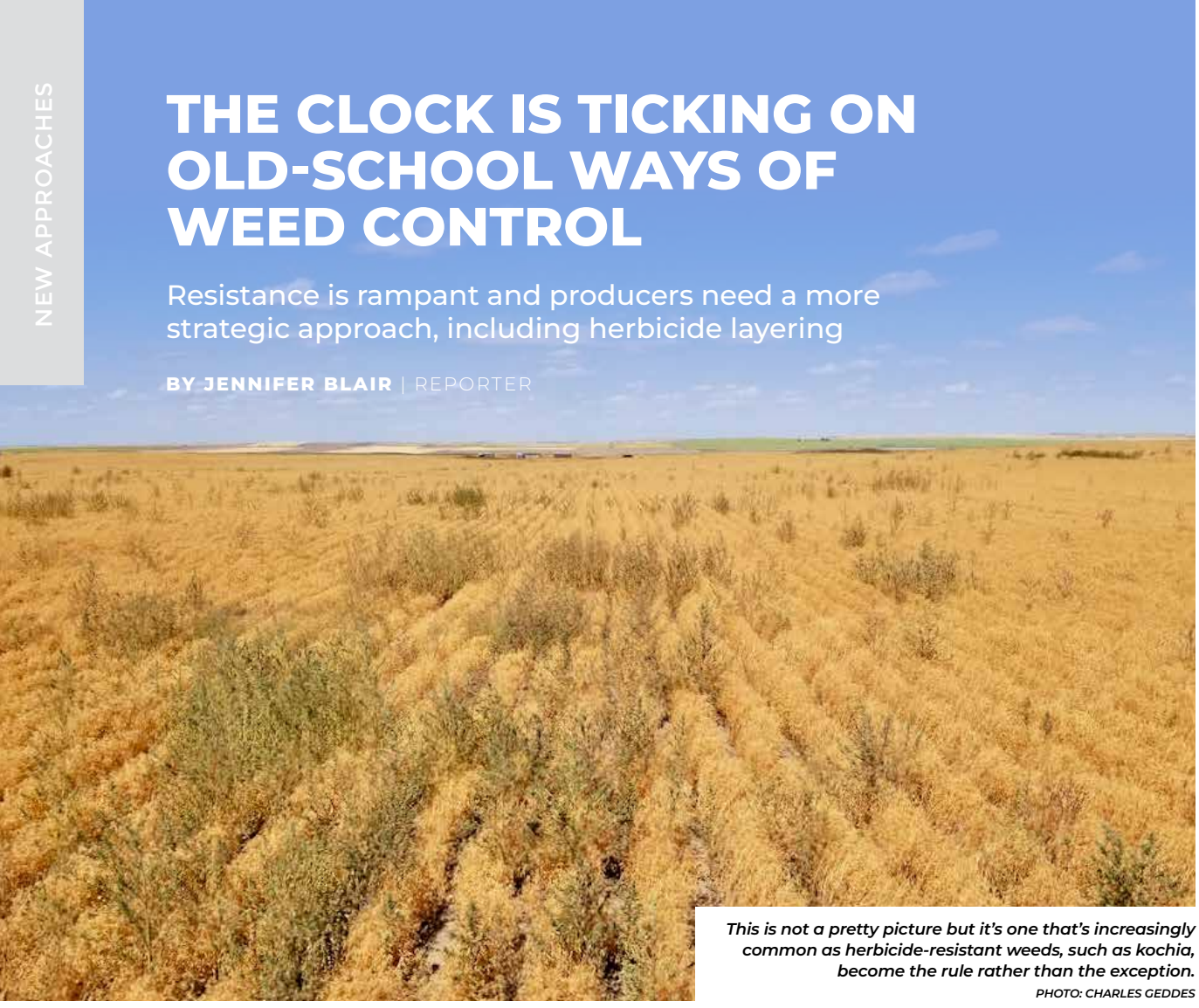
THE CLOCK IS TICKING ON OLD-SCHOOL WAYS OF WEED CONTROL

Resistance is rampant and producers need a more strategic approach, including herbicide layering

BY JENNIFER BLAIR | REPORTER



This is not a pretty picture but it's one that's increasingly common as herbicide-resistant weeds, such as kochia, become the rule rather than the exception.
PHOTO: CHARLES GEDDES

Time's just about up.

Crop growers won't be able to spray their way out of problem weeds for much longer if herbicide resistance continues to spread, says one of the country's top weed scientists.

"We're seeing multiple-herbicide resistance show up in a few different weed species on the Prairies," said federal research scientist Charles Geddes. "The number of herbicides we have to manage these biotypes are dwindling, and we need to come up with more creative approaches to help manage these biotypes effectively."

Canada is No. 3 in the world when it comes to herbicide-resistant weeds, with about 75 unique species resistant to certain herbicide modes of action, Geddes said at Farming Smarter's recent virtual field school. Alberta is No. 2 in the country, with 26 resistant weed biotypes.

Managing these weeds coupled with reduced yield costs producers around $13 an acre.

"About 35 per cent of the farmland cropped in the Prairie region contains at least one herbicide-resistant weed biotype," he said. "The most recent estimate is that herbicide-resistant weeds cost Prairie farmers about $530 million annually, which equates to a fairly large impact on the Prairie and Canadian agricultural sector."

Wild oat is the biggest headache for Alberta growers with the most recent survey (from four years ago) finding more than half the fields having Group 1-resistant wild oat, and Group 2 resistance increasing as producers rely more on those herbicides.

"Essentially, all of these types of resistance are fairly widespread across the Prairie region, making wild oat one of the biggest herbicide-resistant weed

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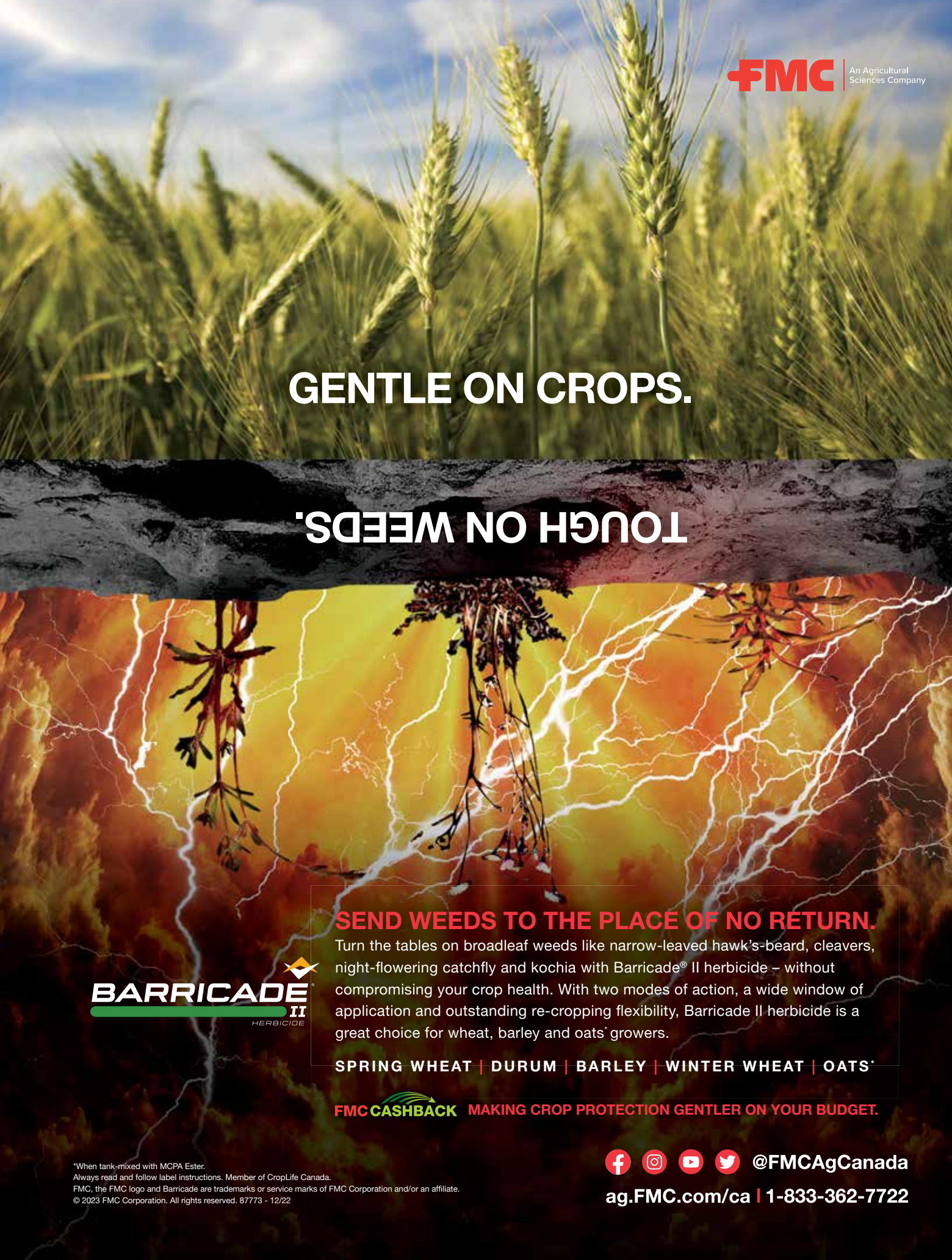
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problems that Prairie growers have to deal with," said Geddes.

Kochia is not that far behind.

"We consider all kochia populations found on the Prairies Group 2-resistant," he said. "It's at the point where it's not even worth testing for resistance anymore."

Glyphosate-resistant kochia was first found in 2011 and in just five years, half of the population of that weed in the province was resistant to the Group 9 herbicide.

"This is a very rapid spread of herbicide resistance," said Geddes, adding that in 2017, dicamba (Group 4) resistance was also found in about 18 per cent of the populations.

"That made about 10 per cent of the population triple-resistant to Group 2 herbicides as well as Group 4 and Group 9."

And there's no saviour on the horizon.

"In the past three decades, we really have not seen a new herbicide mode of action released that would be used in Prairie agriculture," said Geddes. "So we're seeing an increase in the number of herbicide-resistant weed biotypes but a stagnation in the release of new herbicide modes of action available for their management.

"We need to come up with new ways to help manage these biotypes and also mitigate the selection for new types of herbicide resistance."

One method is herbicide layering.

"It is using effective multiple active ingredients and herbicide groups to control the same weed at different application timings, using soil-applied products to control weeds while they are emerging and utilizing tank mix strategies to control already emerged weeds," said Nolan Kowalchuk, technical sales manager at FMC Corporation.

An effective strategy limits the application of a single mode of action and the use of the same herbicide or tank mix repeatedly. But producers must answer a few questions first, he said, including: What weeds are being targeted? What products or modes of action will offer the greatest efficacy? Do you have products that offer high control of resistant weeds? What application timing will control those target weeds?

"It's answers to these areas that are critical in the approach you choose to manage resistance," said Kowalchuk.

And in the case of layering, more is better.

"Use as many different herbicide groups as possible. Four would be great," he said, adding that timing will play a role in how you layer.

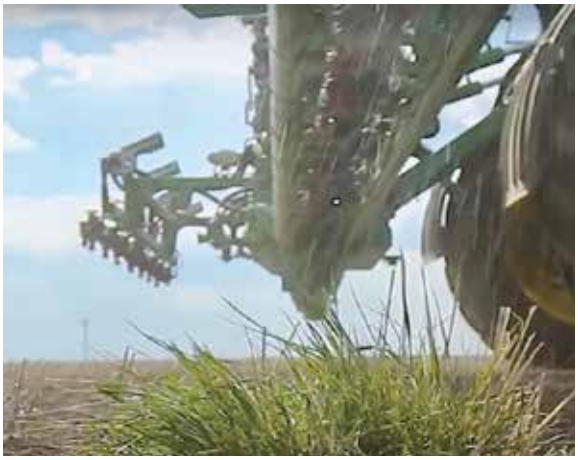

PHOTO: CROPLANDS EQUIPMENT

"In the past three decades, we really have not seen a new herbicide mode of action released that would be used in Prairie agriculture... So we're seeing an increase in the number of herbicide-resistant weed biotypes but a stagnation in the release of new herbicide modes of action available for their management."

"Ensure your pre-seed and in-crop herbicide applications include different chemical groups. This will ensure you do not select for resistance to another group or increase selection pressure to a group you may already have some resistance to."

Pre-seed herbicides should offer extended control to help reduce weed pressure prior to the in-crop herbicide, he added.

"Utilizing an extended-control herbicide-layering product will be key in controlling these early flushes, not only reducing weed pressure for the in-crop but allowing one to pick an in-crop that is better suited for what new weeds may emerge," he said.

And there's no cookie-cutter approach.

"There's no silver bullet answer or strategy that will work for all," said Kowalchuk. "However, proactive planning will allow you to develop a practical working strategy for helping prevent herbicide resistance from developing or being able to actively manage it if it has already developed." ■

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(This story originally appeared August 2021 in The Alberta Farmer Express.

KEEPING AHEAD OF KOCHIA CAN BE A CHALLENGE

Managing the tough, adaptable weed takes all the tools that are available in farmers' integrated pest management toolkit

BY ROBIN BOOKER | SASKATOON NEWSROOM

It is possible to reclaim fields where herbicide-resistant kochia has the upper hand, but it takes long-term planning for crop and herbicide rotations, as well as patch management.

Group 2 resistant kochia was first found on the Prairies in the late 1980s and within two decades it spread across the region.

"That type of resistance spread to the point where we consider all kochia populations found in the Prairies Group 2 resistant, to the point where it's not even worth testing for resistance anymore," said Charles Geddes, research scientist at Agriculture Canada during a virtual presentation at a Farming Smarter digital event held at the end of June.

Geddes leads the Weed Ecology and Cropping Systems research program, which focuses on discovery, monitoring, and management of herbicide-resistant weeds in Western Canada.

He said the first case of glyphosate-resistant kochia was first found in Alberta in 2011, then a 2012 survey found about five percent of the kochia population at the time contained glyphosate-resistant biotypes.

"This survey was repeated five years later and after only five years, glyphosate resistance had spread from five percent of the populations to now 50 percent of the populations. This is a very rapid spread of herbicide resistance," Geddes said.

"Also in 2017, dicamba resistance was documented as well in about 18 percent of those populations. So that made about 10 percent of the populations triple resistant, to Group 2 herbicides, as well as Group 4 and Group 9."

He said kochia with triple-herbicide resistance limits herbicide options available for a chemical management program, including the herbicide layering approach. Another herbicide-resistant survey is being conducted this summer in Alberta.

Some of the more recent work Geddes is involved with examined kochia resistance to synthetic auxins in Alberta, which found that dicamba resistance is typically found in southern Alberta while kochia with fluroxypyr resistance is more common in western Alberta.

Geddes said a goal of the research is to document whether the populations were broadly cross-resistant to multiple synthetic auxins. Dicamba and fluroxypyr are the most commonly used synthetic-auxin active ingredients used in small grain cereal crops for kochia management.

"What we found in our additional screening was that about 13 percent of the populations in 2017 were fluroxypyr resistant. But interestingly, only four percent of the population actually overlapped. Meaning that many of the populations were actually resistant to either dicamba or fluroxypyr, but only four percent of the populations had both biotypes."

Therefore, if dicamba-resistant kochia is present in your fields, fluroxypyr may still be effective, and vice versa, he said.

To help understand what options producers have left to control herbicide-resistant kochia, Geddes led a study in Lethbridge that examined how herbicide layering throughout the rotation combined with increased seeding rates and narrow row spacing can affect yield loss due to herbicide-resistant kochia.

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PHOTO: GETTY IMAGES

"We actually planted glyphosate-resistant kochia into the plots at the beginning of the experiment. And then basically, our challenge is to try and manage the herbicide-resistant weed, using both a chemical management program but then also adding in cultural management to help get an additional edge."

Auxinic-resistant kochia plants were not planted, however the use of auxinic herbicides were limited in the study because of the resistance to this chemistry is building in the kochia population. The study used a four-year rotation of wheat, canola, wheat and lentils. In both wheat crops, a glyphosate pre-plant was used with carfentrazone, and for the in-crop herbicides pinoxaden, pyrasulfotole, and bromoxynil were used.

For the canola rotation ethalfluralin was used the fall before, glyphosate was used pre-plant, and glufosinate and clethodim were used in-crop.

For lentils, glyphosate and saflufenacil and pyroxasulfone were used pre-plant, and imazomox was used in-crop. Liberty Link canola was used because Geddes said glufosinate has good activity on kochia.

"We had all of these phases present within every year, and then in addition we also have this entire rotation using either wide-row spacing versus narrow spacing, as well as either seeding these crops at the recommended densities versus double the recommended densities."

He said it was easy to see plots with cultural management of decreased row spacing and increased seeding rates because they had better success competing with the kochia. In the first two years of the study, 2018 and 2019, crop density did not have an effect but in 2020 crop density had a significant effect with a 74 percent reduction in kochia biomass when a higher seeding rate was used.

When it comes to row spacing, this practice had a consistent effect throughout each year of the study.

"Growing the crops with a wide-row spacing versus the narrow spacing, we have about 60 percent reduction in the (kochia) biomass," Geddes said.

"We're really seeing better performance of those herbicides, and then also increased competition with the kochia plants that remained unmanaged."

In 2018, in the plots where herbicide-resistant kochia was present, there was a 26 percent increase in crop yield in all crops and crop rotation phases in the plots with narrow-row spacing. A separate study published in 2021 that was conducted by Geddes and others examined ways to control glyphosate-resistant kochia.

Of the 20 treatments examined, the three most effective herbicide treatments were: sulfentrazone applied pre-emergence had 99 percent control, fluroxypyr/bromoxynil/2,4-D applied post-emergent had 94 percent control, and pyrasulfotole/bromoxynil applied post-emergent had 92 percent control of the glyphosate-resistant kochia.

The study suggests that layering the pre-emergence sulfentrazone with either the fluroxypyr/bromoxynil/2,4-D or the pyrasulfotole/bromoxynil post-emergent application will give excellent control of glyphosate-resistant kochia.

Geddes said a common site in the fall is kochia patches that have been harvested around because they are too green to put through the combine.

So he designed a study to find the best way to manage these patches.

"In order to do this, we wanted to focus on seed production because essentially seed entering the soil seed bank is going to be the source from which the population establishes in subsequent years," Geddes said.

He said kochia can emerge late in the growing season and still produce viable seed because it needs about 2,000 growing degree days, which typically happens in the middle of August.

Viable seed production from kochia plants that emerged earlier in the year also starts in mid August. Geddes said if these two timings are put together an optimal management time can be found.

There is a period of time in the middle of August where the kochia patches can be managed before they produce viable seeds and there is not enough time for new plants to emerge and seed out.

"If we came in and managed those patches in mid-August, say cut those patches and maybe perhaps also treated the re-growth with a herbicide. That would go a long way to preventing the production of seed back into the soil seed bank," Geddes said.

"This is really important with a weed species like kochia that has very short seed longevity in the soil seed bank."

He said some of the research he's conducting focuses on the impact of pre- versus post-harvest herbicides applied the previous fall when it comes to the best time to manage kochia patches.

"Preliminary results are showing that we can extend this period a bit later in growing season as well if we decide to use either pre- or post-harvest herbicide," Geddes said. ■

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TAKE A LAYERED APPROACH TO HERBICIDES

Develop an effective herbicide layering strategy — it could be one of your most powerful tools in the fight against herbicide resistance

BY JIM TIMLICK

It's no secret that herbicide-resistant weeds are making life increasingly difficult for many crop growers in Western Canada, but the situation is far from hopeless, says an agricultural expert.

Canada currently ranks third in the world for herbicide-resistant weeds, trailing only the United States and Australia in that category. Studies have shown there are currently 77 resistant weeds in this country, with kochia leading the way as the largest threat to crop production, especially in Western Canada.

Nolan Kowalchuk, technical sales manager for FMC Canada, says as problematic as the situation may be, growers do have some options when it comes to mitigating the pressures of herbicide resistance.

One of the most effective tools in that fight, he says, is herbicide layering. Herbicide layering is the use of multiple active ingredients and herbicide groups at different application timings. In a pre-seed burn-off timing, it incorporates soil-applied products to control target weeds while they are emerging along with utilizing tank-mix strategies with glyphosate to control already emerged weeds.

Growers then have the potential to use other available modes of action as in-crop, pre- or post-harvest applications. The more effective modes of action that can be introduced at different application timings help to ensure control of a resistant weed so it does not mature and return seed to the seed soil bank for future years.

The importance of herbicide layering, Kowalchuk explains, is it minimizes the selection pressure for resistance that can occur with the application of a single mode of action product or the repeated use of the same herbicide or tank mix continually.

"The thing with weed resistance is there's no silver bullet answer that works for all," he says. "It all comes down to proactive planning and developing a practical, working strategy for helping prevent herbicide resistance from developing or managing it as if it has already developed. It's all about developing an overall weed resistance management strategy."

Where to begin

In order to develop an effective herbicide layering strategy, Kowalchuk says producers must first ask themselves some questions. For example, what weeds are growers targeting? When do those weeds germinate (early or later spring)? Are they annuals (e.g. kochia, lamb's quarters or Russian thistle) or are they perennials (e.g. dandelions) or winter annuals (e.g. narrow-leaved hawk's-beard)? Going through this process, he says, will allow growers to determine what modes of action, what timing and which products could potentially be used to provide the highest level of efficacy.

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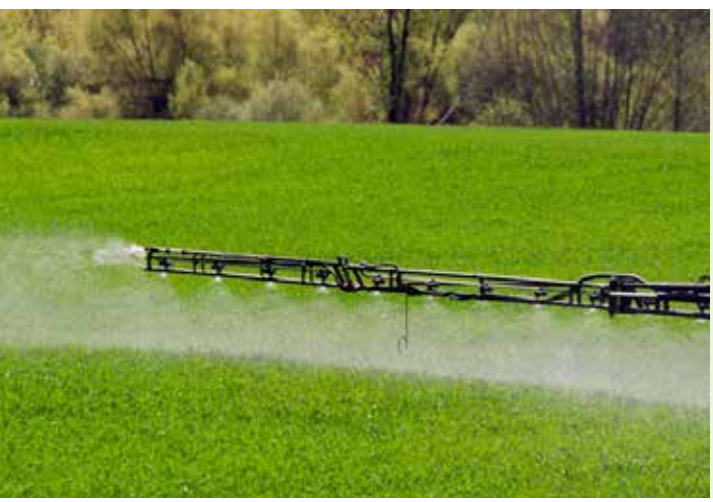

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A herbicide layering strategy uses a pre-seed treatment on emerged weeds while using soil-applied products simultaneously to control weeds that emerge a couple of weeks after the initial application. The pre-seed treatment helps to remove early-emerged weed pressure while the soil-applied application, when activated by moisture, provides extended control to help reduce weed pressure prior to the application of an in-crop herbicide. This type of strategy not only helps with early weed removal and allowing the crop to establish and take advantage of the nutrients and moisture available, but it also provides farmers more options for an in-crop application that will best target the later-emerging weeds that have to be dealt with.

It's all part of developing an effective strategy. Kochia, Russian thistle and lamb's quarters tend to germinate quite early in the spring, so applying a soil-applied active in the fall or early spring (when the soil is not frozen), would be beneficial because the products are in the soil, in place, working as these weeds are germinating. Some weeds that germinate in later spring (wild oats, green and yellow foxtail, barnyard grass) can still be controlled from an early-spring treatment or may best be targeted with a soil-applied product that is applied a bit later in the spring or after seeding, to prolong the control later into the growing season.

The second thing for growers to consider is what application timing will best control the weeds they are targeting (pre-emergent, post-emergent, in-crop, pre-harvest, post-harvest). Perennials (dandelion) and winter annuals (narrow-leaved hawk's-beard) are best controlled in the fall with post-harvest applications of glyphosate and systemic products, like Group 2 herbicides. Application of these modes of action at a post-harvest timing allows the chemistry to take advantage of the biology of the weeds and moves down, as these plants start to move carbohydrates down to their root systems, in preparation for winter.

When it comes to resistance management, "Ultimately the goal is preventing that specific weed from going to seed, so it's not returning more resistant-weed seeds into the seed bank population," Kowalchuk adds.

More is better

In the case of layering, more is better, he says. Ideally, growers should use as many different modes of action they can when it comes to managing herbicide resistant weeds. Four is considered ideal.

"The biggest thing is to utilize an effective mode of action in the tank-mix combination. Even if one mode is not effective, the other mode will be. If you're targeting resistant kochia and you know that you've got Group 2 and 9 resistance, you need some other mode of action in that tank mix other than Group 2 or 9 to control that," Kowalchuk says.

"Sometimes four (modes) isn't totally realistic. The important thing is to make sure you have an effective mode of action in the tank in combination with a mode of action that the target weed is resistant to. That way the effective mode of action is controlling the resistant weed and you still get the benefit from the other modes of action on the weeds that it is strong on."

The important part of a herbicide layering strategy is the use of a pre-seed treatment on emerged weeds while using soil-applied products simultaneously to control weeds that can emerge in a couple of weeks after the initial application. Kowalchuk explains a pre-seed treatment helps to remove early-emerged weed pressure while the soil-applied application (once activated by moisture) is invaluable in offering extended control to help reduce weed pressure prior to the application of an in-crop herbicide. This type of strategy not only helps with early weed removal and allowing the crop to establish and take advantage of the nutrients and moisture available, but it also allows the farmer more options to choose an in-crop application that will best target the later-emerging weeds that have to be dealt with.

"That's really the essence of an effective herbicide layering program," he says. "The more you can eliminate the emerged and emerging weeds, the better. If you're using soil-applied chemistry in conjunction with chemistries targeting emerged weeds, the dual-pronged approach will do a nice job of minimizing weeds, allowing your crop to establish that much more weed-free. That's important, especially in drier years. If you can take care of that early weed pressure in drier springs, you don't have that weed competition using up precious moisture and nutrients and so forth in the spring."

Integrated weed management program

One of the country's top weed scientists agrees that herbicide layering can be an effective approach to herbicide-resistant weed control as part of an integrated weed management program.

"We tend to see an additive management or synergistic management when we're adding cultural weed management with an optimal herbicide program as well," Agriculture and Agri-Food Canada weed ecology and cropping systems research scientist Charles Geddes said during a recent virtual presentation for the Farming Smarter Field School on tackling resistance through herbicide layering and patch management. "Adding in cultural management can actually go a long way when we're talking about herbicide-resistant weed management."

It's estimated herbicide-resistant weeds cost Prairie farmers more than $500 million annually. Geddes noted during his presentation that the problem will become even more costly unless growers come up with more creative approaches to dealing with the issue.

"We're seeing multiple herbicide resistance show up in a few different weed species in the Prairies," he said. "In order to manage them effectively, we now need to focus on the biology and ecology of those weeds and come up with targeted management strategies because the number of herbicides we have to manage these biotypes are dwindling and we need to come up with more creative approaches to help these biotypes effectively." ■

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GLYPHOSATE-RESISTANT KOCHIA CONTROL IN SPRING WHEAT

SOURCE: CANADIAN AGRONOMIST

The most effective and consistent treatments for glyphosate-resistant (GR) kochia management included Authority (sulfentrazone) applied pre-emergence, post-emergent Enforcer D (fluroxypyr/bromoxynil/2,4-D) at the high label rate, and post-emergent Infinity (pyrasulfotole/bromoxynil).

Glyphosate-resistant (Group 9) kochia has rapidly spread across Alberta since it was first discovered in 2011 in chemical fallow fields located in Warner County. Previously, all populations were considered resistant to Group 2 herbicides. In a 2017 survey, GR kochia had grown to 50% of kochia populations in Alberta– and that resistance is spreading across the Prairies.

Field experiments were conducted near Lethbridge, Alberta in 2013 to 2015, and Coalhurst, Alberta in 2013 and 2014. Plots were split between GR kochia and glyphosate-susceptible (GS) kochia. The kochia populations did not have any Group 4 resistant biotypes, which an Alberta survey in 2017 found 18% of populations tested were dicamba-resistant, and 10% were triple-resistant to Group 2, 4 and 9 modes of action.

AC Lillian spring wheat was seeded 1.4 inches (3.5 cm) deep at a target rate of 30 seeds/ft2 (300 seeds/m2). Kochia was seeded simultaneously at 1/10th of an inch deep at the same target seeding rate. A pre-plant burndown was conducted prior to seeding.

The herbicide treatments included an untreated control and 19 herbicide treatments that were either registered for kochia management in spring wheat, or had potential for kochia control with minimal wheat injury. All herbicide treatments were applied post-emergent at the 4 to 5 leaf stage of wheat, except for Authority (sulfentrazone) which was applied pre-emergence 1 to 2 days before or after seeding.

Wheat injury and yield

Wheat visible injury was considered minor among the herbicide treatments at the majority of site-years. Injury ratings from 0 to 10% are considered acceptable. Wheat visible injury was not acceptable in Coalhurst in 2014 and Lethbridge 2015 for some treatments where dicamba was applied alone or in mixture with other Group 4 active ingredients.

Visible injury ranged from 11% to 21% in Coalhurst 2014 for dicamba + 2,4-D, Pulsar (dicamba/fluroxypyr), Target (MCPA/mecoprop-p/dicamba), and both high and low rates of Dyvel DSp (dicamba/2,4-D/mecoprop-p).

Treatments including higher rates of dicamba (2x and 4x label rate) applied alone were tested in 2015 only, and the 4x label rate was the only herbicide treatment in this environment that resulted in crop injury considered unacceptable (21% injury), while injury from dicamba applied at 2X label rate was considered just acceptable (10% injury).

Wheat yield remained the same among GR and GS kochia, herbicide treatments, and the untreated weedy control in each of the environments tested. The researchers thought that the lack of yield difference following herbicide treatments compared with that of the untreated weedy control could suggest that spring wheat yield loss occurs from kochia competition or interference prior to the 4 to 5 wheat leaf stage. It should be noted that a weed-free control was not included in the study, however.

Despite the lack of wheat yield response, the true benefit of herbicide application in wheat is the reduction in kochia growth inhibiting harvest operations, and reduced seed production and lower seed return to the soil seedbank.

Herbicide effectiveness

The most effective and consistent treatments for GR kochia management included Authority (sulfentrazone) applied pre-emergence, post-emergent Enforcer D (fluroxypyr/bromoxynil/2,4-D) at the high label rate, and post-emergent Infinity (pyrasulfotole/bromoxynil). All of these treatments resulted in ≥ 90% visible control in all environments and ≥ 90% kochia biomass reduction compared with the untreated control in Lethbridge 2014 and 2015.

Optica Trio (MCPA/dichlorprop-p/mecoprop-p), Dyvel DSp (dicamba/2,4-D/mecoprop-p) at the high label rate, and Pulsar (dicamba/fluroxypyr) resulted in acceptable control among environments resulting in ≥ 80% visible control in all environments and ≥ 80% kochia biomass reduction in Lethbridge 2014 and 2015; however Dyvel DSp and Pulsar caused unacceptable (> 10%) wheat visible injury in Coalhurst 2014.

The majority of herbicides evaluated in the current study were mixtures of Group 4 synthetic auxins. Dicamba, fluroxypyr, 2,4-D, MCPA, clopyralid,

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dichlorprop-p, mecoprop-p, and halauxifen are examples of Group 4 herbicides. Not all of these would have acceptable activity on susceptible kochia when applied alone, which is why most auxins are mixed either together or with another mode of action.

While Group 4 herbicides continue to play an important role in control of GR kochia in spring wheat, including alternative modes of action in herbicide programs like Group 14 herbicides applied pre-emergence, or a Group 6 or 27 herbicide post-emergently will be important. The current research suggests that optimal control of glyphosate and ALS inhibitor-resistant kochia in spring wheat may be achieved in a layering approach with a combination of Authority applied pre-emergence with Enforcer D (Groups 4 + 6) or Infinity (Groups 6 + 27) applied post-emergence.

The sustainability of remaining herbicides for kochia control will depend on the successful implementation of integrated weed management including alternative crop life cycles (e.g., winter-annuals or perennials), competitive crop cultivars, cover crops, field scouting, resistance diagnostic testing, strategic and site-specific tillage, and potentially also harvest weed seed control.

Since this research was conducted, pre-plant Fierce herbicide (Group 14 flumioxazin and Group 15 pyroxasulfone) and Authority herbicide (Group 14 sulfentrazone) applied pre-plant or pre-emergent were registered for control of kochia before spring wheat. ■

This research was supported by the Alberta Barley Commission, Alberta Canola Producers Commission, Alberta Crop Industry Development Fund, Alberta Wheat Commission, BASF Canada, Dow AgroSciences, Nufarm Canada, Valent Canada, and Western Grains Research Foundation.

TABLE 5. Visible control 3 weeks after post-emergence herbicide application, density, and aboveground biomass of glyphosate-resistant (GR) and glyphosate-suseptible (GS) kochia in wheat in one environment near Lethbridge, AB in 2015.

Herbicide treatment [a]	Rate (g a.e./a.i.•ha^{-1})	Lethbridge		
		Visible control %	Density (plants•m^{-2})	Biomass (g•m^{-2})
Untreated	–	–	246a	208a
Dicamba +2, 4-D	110+420	68g	210a	23b-d
Bromoxynil/2,4-D	280/280	71fg	235a	29bc
Fluroxypyr/2,4-F	40/160	79d-f	210a	33ab
Florasulam/Fluroxypyr+MCPA	2.5/100 + 350	79d-f	230a	27bc
Dicamba/Fluroxypyr	80/104	86b-d	219a	12b-g
Fluroxypyr+Clopyralid/MCPA	100+75/420	79d-f	217a	42ab
Fluroxypyr/Bromoxynil/2,4-D	48/114/144	73e-g	188a	18b-e
Fluroxypyr/Bromoxynil/2,4-D	96/228/288	94ab	212a	3e-g
MCPA/Dichlorprop-P/Mecoprop-P	395/765/320	89bc	198a	1g
MCPA/Mecoprop-P/Dicamba	275/62.5/62.5	72fg	227a	15b-f
Pyrasulfotole/Bromoxynil	30/170	92ab	216a	2fg
Dicamba/2,4-D/Mecoprop-P	93/251/68	78d-f	243a	2g
Dicamba/2,4-D/Mecoprop-P	124/331/90	89bc	227a	5b-g
Dichlorprop-P/2,4-D	368/702	71fg	177a	11b-g
Sulfentrazone	105	99a	1b	1d-g
Fluroxpyr/Halauxifen+MCPA	77/5+350	71fg	199a	42ab
Fluroxpyr/Halauxifen+MCPA	100/6.5+455	81de	198a	37ab
Dicamba	300	83cd	231a	5c-g
Dicamba	600	94ab	221a	2d-g

Note: Values are LS means. Within columns, different letters indicate significant differences based on Tukey's HSD (α = 0.05).
[a] All herbicides were applied post-emergence at wheat 4-5 leaf stage except for sulfentrazone, which was applied pre-emergence.

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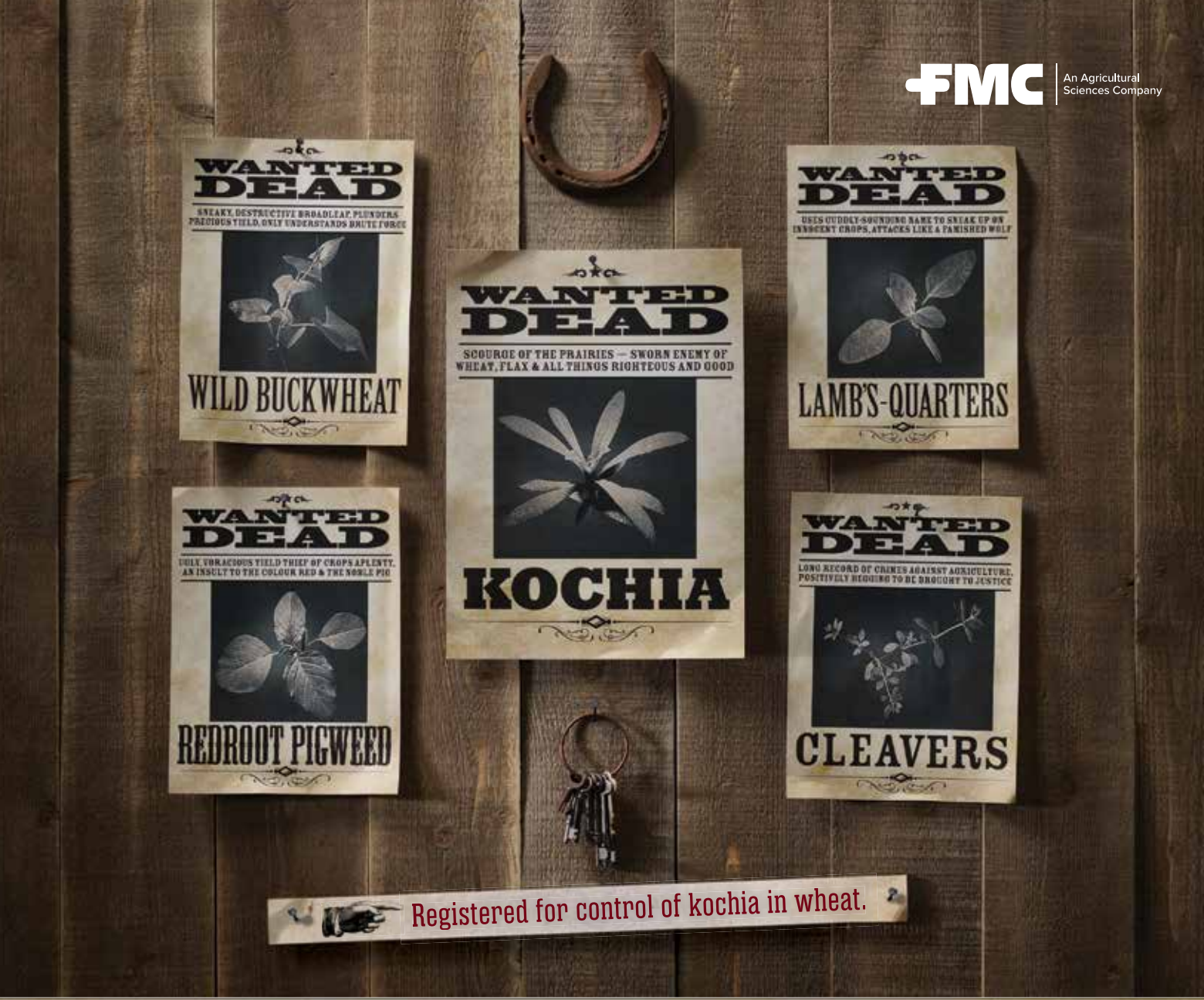

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