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Herbicide-Resistant Weeds in Nebraska

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Seven weed species now are resistant to several groups of herbicides in Nebraska. This is further proof that repeated herbicide applications with the same mode-of-action is unsustainable for weed control.

What Is a Herbicide-Resistant Weed?

Intensive and continuous use of the same herbicide(s) over the last few decades has caused the evolution of several herbicide-resistant weeds. Herbicide-resistant weeds are those uncontrolled at a labeled rate of a specific herbicide applied repeatedly, whereas before the weed was controlled by the same herbicide and application rate.

For example, a herbicide provides excellent weed control in a crop or non-crop situation for several years, until one year there are more weed escapes than usual. The assumption may be that it was due to a spraying error; so the next time spraying is monitored even more closely but there are even more weed escapes. This is likely because the weed has reduced susceptibility to that particular herbicide, and in that situation the weed may now be herbicide resistant.

How Do Herbicide-Resistant Weeds Develop (Evolve)?

Weed resistance to herbicides is not a new phenomenon, rather it is an evolutionary process. Since the report of triazine-resistance in the mid-1960s, over 390 weed species have evolved resistance to one or more herbicide classes. A heritable change occurs within a weed population following a repeated application of an herbicide, and that change or mutation confers resistance to the weed species. Changes can occur in response to herbicide use and other management decisions. Changes in weed populations begin when a small number of plants within a species, called a "biotype," have a different genetic diversity that allows them to resist or survive a particular herbicide application. As a grower continues to use a single herbicide with the same mode-of-action, or doesn't use any other cultural practices, the resistant biotype continues to survive and produce seeds. Subsequent populations of the resistant biotype will continue to increase until they are the dominant weed in the field. This is referred to as herbicide selection pressure. It is not possible to predict exactly which weed species will have biotypes resistant to certain herbicides, due to complex biology of different weed species and environmental interactions.

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Characteristics of a weed that can facilitate evolution of herbicide resistance:

1. Large amount of seeds produced per plant
2. High level of germination
3. Several weed flushes per season
4. Short life cycle
5. High frequency of resistant genes
6. Easily dispersed such as with wind
7. Competitive in nature and
8. Ability to regenerate from stem or plant fragments.

Management factors that are often present in areas where herbicide-resistant weeds have evolved:

1. Limited or no crop rotation
2. Limited or no-tillage production practices
3. A high dependency on a single herbicide or herbicides with the same mode-of-action
4. Limited or no use of soil-applied herbicides
5. Not using herbicide tank mixtures
6. Application of herbicide at reduced rates
7. The lack of follow-up treatments when needed and
8. Using herbicide(s) application practices that reduce the efficacy of the weed management system.

Status of Herbicide-Resistant Weeds in Nebraska

Seven weed species have evolved resistance to several groups of herbicides in Nebraska (*Table 1*). Out of seven weed species, five are resistant to acetolactate synthase (ALS) inhibiting-herbicides (Classic®, FirstRate®, Pursuit®, Raptor®). Four weed species including common waterhemp, kochia, marestail, and giant ragweed are confirmed resistant to glyphosate in Nebraska.

Table 1. Confirmed case of herbicide-resistant weeds in Nebraska (as of September, 2013)

Weed species	Type of resistance	Example herbicides
Common waterhemp	Triazine	AAtrex
	HPPD-inhibitor	Callisto, Laudis, Impact
	ALS-inhibitor	Pursuit, Classic
	Growth regulator	2,4-D
	Glycine	Roundup, Touchdown
Palmer amaranth	ALS-inhibitor	Pursuit, Classic, FirstRate
	HPPD-inhibitor	Callisto, Impact, Laudis
	Triazine	AAtrex
	Photosystem-II-inhibitor	Buctril
Kochia	Growth regulator	2,4-D
	Triazine	AAtrex
	Glycine	Roundup
	ALS-inhibitor	Glean
Shattercane	ALS-inhibitor	Accent, Beacon
Marestail	ALS-inhibitor	Pursuit, Classic, FirstRate
	Glycine	Roundup
Giant ragweed	Glycine	Roundup
Redroot pigweed	Triazine	AAtrex

What is Herbicide Mode-of-Action and Why It Is Important for Management of Herbicide-Resistant Weeds?

The mode-of-action is the pathway in which a herbicide kills the treated vegetation. More specifically, it is the description of a biological process that a herbicide interrupts in order to inhibit weed growth. Each herbicide has a specific mode-of-action to control vegetation. For example, glyphosate (Roundup®, Touchdown®) inhibits a specific enzyme called **EPSPS** (5-enolpyruvylshikimate-3-phosphate synthase). Without that enzyme, plants are unable to produce proteins essential to growth, so they turn yellow and die over the course of several days.

Understanding herbicide mode-of-action is also very useful in diagnosing herbicide injury. Although a large number of herbicides are available commercially, several have similar chemical properties and herbicidal activity. Herbicides with a common chemistry are grouped into “families.” For example, sulfonylurea (Classic, Permit®) and imidazolinone herbicides (Raptor, Scepter®, Pursuit®) belong to a different chemical family; however, their mode of action is the same because they are acetolactate synthase (ALS)-inhibiting herbicides. (Group 2 herbicide is based on mode-of-action classification by the Weed Science Society of America.)

Herbicide families are a convenient way of organizing information about herbicides. Two or more herbicide families may have the same mode-of-action within the plant and thus express the same herbicide activity and injury symptoms. Herbicides have been classified into seven major modes-of-action groups: growth regulation, amino acid synthesis inhibition, lipid synthesis inhibition, seedling growth inhibition, photosynthesis inhibition, cell membrane disruption, and pigment inhibition. Understanding herbicide mode-of-action is useful in selecting and applying the best herbicide(s) for weed control problems and for reducing selection pressure of herbicide-resistant weeds. It is important to include herbicides with different mode-of-action in herbicide programs to control resistant weeds or to reduce chances of evolution of herbicide-resistant weeds.

Figure 1. Common waterhemp competition in a soybean field.

Biology and Occurrence of Herbicide-Resistant Weeds in Nebraska

Common Waterhemp

Common waterhemp (*Figure 1*) is a summer annual broadleaf weed of the pigweed family. It grows aggressively and is capable of producing more than 500,000 seeds per plant. Several flushes of common waterhemp occur during the growing season. The extended germination window of common waterhemp (May to August) increase in a no-tillage crop production system, and ability of waterhemp to evolve resistance to herbicide(s) have contributed to widespread occurrence of this weed species. Furthermore, it is a dioecious species, meaning male and female flowers occur on separate plants and reproduction requires pollen movement. The resistant gene can be spread long distances via pollen and outcrossing.

Common waterhemp populations resistant to triazine and acetolactate synthase (ALS)-inhibiting herbicides are common in Nebraska due to a widespread and a repeated use of ALS-inhibiting herbicides (Pursuit, Classic, FirstRate) and atrazine (AAtrex®). A common waterhemp population from a native-grass seed production field in southeast Nebraska has been reported as resistant to 2,4-D. The dose response study confirmed that the waterhemp biotype was 10-fold resistant to 2,4-D at rates ranging from 0.25 to 64 quarts per acre. The field experiment conducted on the site suggested that plants treated with 64 quarts per acre of 2,4-D were stunted and had injury symptoms, but were beginning to recover from the initial injury; by 84 days after treatment, plants had recovered and produced seeds. Additionally, common waterhemp was confirmed resistant to HPPD-inhibiting herbicides (Callisto®, Laudis®, Impact®). The resistance occurred in a seed corn production field where HPPD-inhibiting herbicides were repeatedly used for five years.

Several complaints were received from growers in 2011-12 about control failure of common waterhemp despite the repeated application of glyphosate (Roundup) in Roundup Ready® soybean. Seeds were collected from 10 Nebraska counties and a dose response study was conducted. The results confirmed glyphosate-resistance common waterhemp in at least six Nebraska counties (Antelope, Dodge, Lancaster, Pawnee, Seward, and Washington). The evolution of glyphosate-resistance means it will require an effective integrated weed management program to achieve acceptable control. Continuing to rely solely on glyphosate will speed up the evolution of glyphosate-resistant weeds and diminish the effectiveness of glyphosate-resistant crops and weed control programs.

Giant Ragweed

Giant ragweed (*Figures 2a and 2b*) is an early emerging summer annual weed typically found throughout the Midwest and eastern Corn Belt. In Nebraska, giant ragweed historically was found on heavier "bottom grounds" and/or close to canals and waterways; however, in the last decade it has become a common weed in crop production fields of eastern Nebraska. One reason for increased prevalence in crop production fields is the ability of giant ragweed to evolve resistance to herbicides. Before the introduction of glyphosate-resistant crops, ALS-inhibiting herbicides were widely used to control giant ragweed. However, repeated use led to the evolution of ALS-resistant giant ragweed even prior to commercialization of glyphosate-resistant crops.

Glyphosate-resistant giant ragweed biotypes have been reported in 11 states in the United States and in Ontario, Canada. In Nebraska, glyphosate-resistant giant ragweed was confirmed in Butler, Nemaha, Richardson, and Washington counties. Glyphosate-resistant

Figure 2. Giant ragweed seedlings in a field at Clay Center, Nebr. (a). Glyphosate-resistant giant ragweed in a field near Clay Center, Nebr. (b).

populations were from fields with corn-soybean rotations and with history of repeated use of glyphosate. There have been confirmed reports of multiple-resistant giant ragweed to glyphosate and ALS-inhibiting herbicides in Ohio and Minnesota.

Kochia

Kochia (*Figure 3*) is an annual broadleaf weed in crop production systems and non-crop areas in semiarid to arid regions of North America, including western Nebraska. Kochia is a well-adapted weed because of rapid growth rate, and tolerance to drought and salinity. In addition, kochia produces abundant seeds and has capacity to distribute seed from tumbling across the landscape. Therefore, it is also known as "tumble weed." In Nebraska, kochia is more prevalent in the western half of the state where the plant has a competitive advantage in the semiarid climate. Kochia has been reported as a problematic weed as far east as Grand Island.

Figure 3. Kochia seedlings in early spring.

Kochia emergence starts as early as mid-March in central Kansas and by late March begins to emerge in Nebraska and Wyoming. Most of the seed (70 to 95 percent) produced the previous year emerge during the first two weeks in the spring; however, some plants continue to emerge as late as July. Kochia seed viability is short, one to two years compared to pigweed and common lambsquarters, which can remain viable in the soil for 10 or more years. Burial of seed in the soil to depths of 4 inches does not reduce viability but can significantly reduce germination. Kochia seed viability declines rapidly the first year after production with only 5 to 10 percent of the seed viable the second year. Kochia in Nebraska has evolved resistance to five major herbicide families: triazines (atrazine, metribuzin), imidazolinones (Pursuit, Raptor), sulfonylureas (Ally®, Permit®, UpBeet®), growth regulator (2,4-D), and glyphosate (Roundup, Touchdown®). Because of this range in resistance, a kochia biotype may be resistant to two or three herbicide modes-of-action. Research in western Nebraska suggested if kochia is resistant to glyphosate, probably it may be resistant to imidazolinones and sulfonylureas as well.

Marestail (Horseweed)

Marestail (*Figures 4a, 4b, and 4c*) is a fast-growing broadleaf weed found in no-till production systems, landscapes, nurseries, pasture, roadsides, and rights-of-way. Marestail can cause repeated callbacks for Lawn Care Operators and challenges for corn and soybean growers. Marestail has simple, alternating leaves, and its stems are erect. Marestail is generally considered a winter annual; however, it can germinate in spring and also complete its lifecycle as a summer annual. The biology of marestail is shifting to more spring and summer germination as a result of cropping systems and herbicide use patterns in some places. Each plant can produce more than 200,000 seeds spread by wind over great distances. Given the widespread adoption of reduced and conservation tillage systems, marestail has become an economically important weed in the past 10 years. Glyphosate and ALS-inhibiting (Classic, FirstRate) resistance in marestail has been reported in Nebraska.

Palmer Amaranth

Palmer amaranth is a summer annual, difficult-to-control broadleaf weed that infests corn and soybean fields in south central to south western Nebraska. It can be characterized by rapid growth, high fecundity, competitive ability, extended emergence, and high water use efficiency. Palmer amaranth has been a problem weed in the southern U.S. for many years. Recently, Palmer amaranth has been

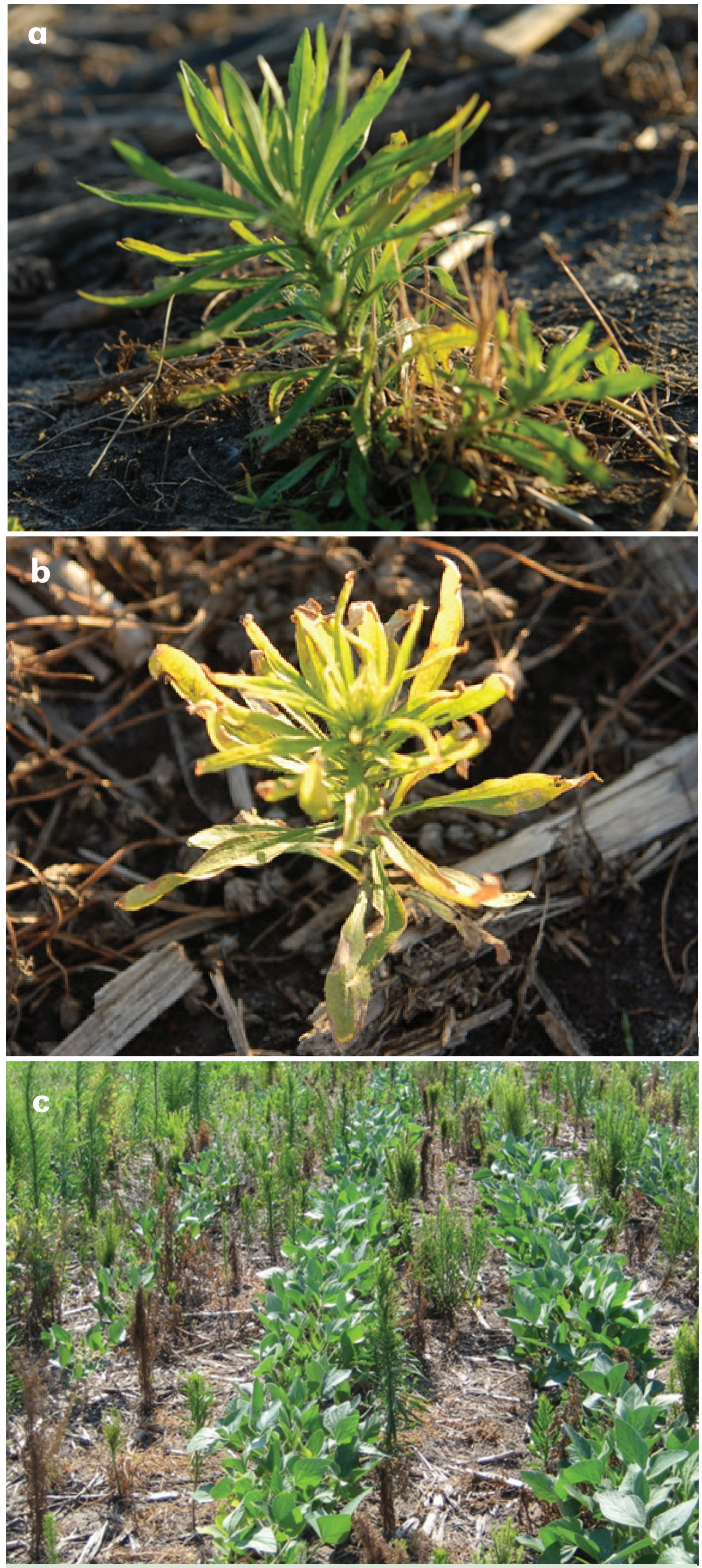

Figure 4. Marestail in a field near Clay Center, Nebr. (a). Glyphosate-resistant marestail surviving repeated application of glyphosate (b). Glylphosaste-resistant marestail in a soybean field near Lincoln, Nebr. (c).

found from the Panhandle, through the Sandhills to Antelope County in northeast Nebraska. Palmer amaranth's dissemination into several counties in Nebraska could be a tremendous hindrance to corn and soybean producers.

Palmer amaranth is known to evolve resistance to several groups of herbicides with different modes of action. Palmer amaranth biotypes resistant to ALS-inhibitors (Pursuit, Classic etc.), triazine (AAtrex), and photosystem-II-inhibiting herbicides (Buctril®) have been confirmed in Nebraska. A seed corn field in Fillmore County, Nebraska, had failed Palmer amaranth control despite application of atrazine and HPPD-inhibiting herbicides. The dose response studies confirmed a 4- to 23-fold level of resistance, depending upon the type of HPPD-inhibiting herbicide (Callisto, Laudis, Impact) used. This biotype also had at least a 10-fold level of resistance to atrazine (AAtrex) applied POST. An integrated management program will be required to control atrazine and HPPD inhibiting herbicide-resistant Palmer amaranth to sustain seed corn production in Nebraska. Additionally, glyphosate-resistant Palmer amaranth should be at the forefront of concerns for any grower who has it, due to the widespread problems of glyphosate-resistant biotypes in the southern United States.

Shattercane

Shattercane is an annual grass weed species that grows 4 to 12 feet tall. It is closely related to sorghum and also is known as weedy sorghum, black amber, chicken-corn, and wild cane. Shattercane has a large range of variability in morphology and growth habit. Flowering usually occurs 56 to 69 days after planting with seeds produced 10 days after anther appearance. Each shattercane panicle can produce 500 to 1,500 seeds with plants usually producing one to six panicles. Seed dispersal is primarily through shattering. The seeds typically mature and drop before the cultivated crop is harvested, leaving the seeds in the field. Shattercane seeds also survive digestion by livestock, allowing spread to new areas through manure. Shattercane is widespread wherever grain sorghum is grown in the United States. Acetolactate sysnthase (ALS) inhibiting-herbicides (Pursuit, Beacon®) have been commonly used for weed control in corn, soybean, and sorghum for many years. Therefore, ALS-inhibiting herbicide-resistant shattercane has been confirmed in several states, including Nebraska. However, it is unknown if ALS-resistance still occurs in shattercane populations found in these areas because Nebraska sorghum production has declined dramatically over the last decade, being replaced by glyphosate-resistant corn and soybean.

Conclusion

The confirmation of seven weed species resistant to several groups of herbicides in Nebraska as of 2013 is further evidence of an ever-evolving weed spectrum, and further proof that repeated herbicide applications with the same mode-of-action in any crop production systems is an unsustainable approach to weed management. In the face of herbicide selection pressure, several weed species such as common waterhemp, giant ragweed, kochia, marestail, etc. have repeatedly proven to be ecological survivors. The common denominator in all instances where resistance evolved was near continuous use of the same or similar herbicide management approach with little or no diversity in herbicide site of action and crop rotation for many years.

Glyphosate-resistant weeds continue to be an increasing problem in Nebraska. Glyphosate-resistant marestail (horseweed), kochia, and giant ragweed previously were confirmed in Nebraska and have become very problematic in certain areas. A recent confirmation of glyphosate-resistant common waterhemp will be an additional challenge to Nebraska growers. Resistance to any herbicide mode-of-action is troubling, but multiple-resistance (resistance in a weed population to more than one herbicide site of action) is of particular concern. Common waterhemp populations with resistance to multiple herbicides have been confirmed in Iowa and Illinois. This resistance stacking is alarming and limits herbicide options for managing weeds.

An integrated weed management program is based on a variety of weed control methods (see integrated weed management section of the *Guide for Weed Management in Nebraska,* EC130). The easiest way to start an integrated program is to rotate herbicides with different modes-of-actions. Using a variety of weed control methods reduces the reliance on a single tool, which suggests those tools may still be effective in the years to come. Using various methods keeps weeds off-balance and prevents them from adapting to management strategies.

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