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Herbicide Options for Control of Glyphosate-Resistant Weeds in Sugar Beet

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Since the commercialization of glyphosate-resistant sugar beet in 2008, weed control practices have changed and glyphosate-resistant weeds have become a major challenge. In the Western Sugar Cooperative production region of Colorado, Montana, Nebraska, and Wyoming, there are currently three known glyphosate-resistant weeds: volunteer corn, kochia (*Bassia scoparia*), and Palmer amaranth (*Amaranthus palmeri*). These weeds can have a tremendous impact on sugar beet yields. If left uncontrolled, one volunteer corn plant every four feet of row can cause up to 25% sugar beet root yield loss. At the same density, kochia could cause up to 45% yield loss, and Palmer amaranth is expected to cause nearly 70% yield loss (Figure 1). To avoid the yield loss shown in Figure 1, it is important to control the weeds early in the growing season.

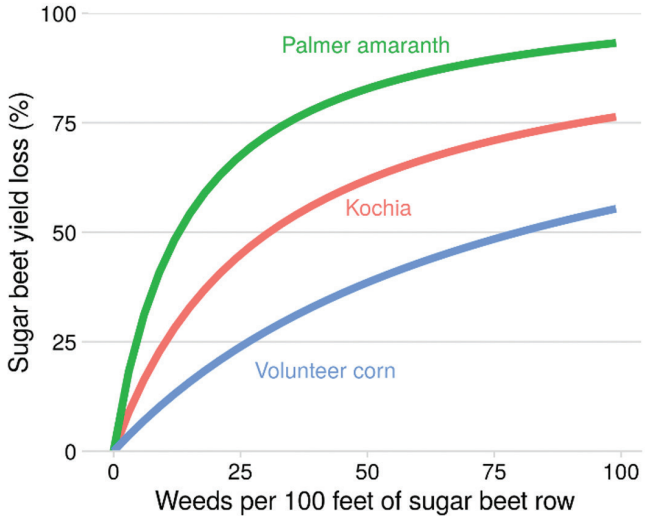

Figure 1: Sugar beet yield loss in competition with kochia, Palmer amaranth, and volunteer corn.

How do we control (group 9) glyphosate-resistant weeds?

Volunteer corn

Available Group 1 herbicides are more effective when applied to volunteer corn less than 12" in height. Quizalofop (Assure® II), sethoxydim (Poast Plus®), or clethodim (Select Max®) provide greater than 90% control of volunteer corn when applied at the two true leaf (2 TL) sugar beet stage. However, if application is delayed until the 8 TL stage, control can be as low as 60%.

All of these products can be tank-mixed with glyphosate, but applicators should be mindful of how adjuvants may impact the efficacy of glyphosate. Methylated seed oil (MSO) and crop-oil concentrate (COC) can make glyphosate less effective. Ammonium sulfate (AMS), urea ammonium nitrate (UAN, either 28% or 32%), and nonionic surfactant (NIS) are commonly recommended adjuvants that work well with both quizalofop and clethodim. However, sethoxydim provides better control when used with MSO or COC. Therefore, if you are going to mix a grass-control herbicide with glyphosate, quizalofop or clethodim are better options.

Table 1. Ethofumesate rate, and observed kochia density and kochia control.

Nortron® SC rate (fl oz per acre)	Kochia density (plants per 100 ft row)	Kochia control (%)
0	376	-
16	257	32
24	168	55
32	162	57
40	114	70

Figure 2. Failed control of herbicide-resistant kochia in a research plot at the PHREC near Scottsbluff, Nebraska.

Kochia

Glyphosate and the Group 2 triflusulfuron-methyl (UpBeet®) are the only two herbicides available for POST control of kochia in sugar beet. However, kochia is resistant to both UpBeet® and glyphosate across most of the Western Sugar Cooperative growing region. If kochia is resistant to both glyphosate and UpBeet®, there are no effective herbicides to control kochia that has already emerged. The only herbicide that provides some level of control is ethofumesate (Group 16) (Nortron® SC) applied before the kochia has emerged (Table 1). If applied before kochia emergence, ethofumesate can suppress kochia, but complete control is unlikely.

Palmer amaranth

The only registered products in sugar beet that control Palmer amaranth are the Group 15 herbicides: acetochlor (Warrant®), dimethenamid-P (Outlook®), and *S*-metolachlor (Dual Magnum®). All three products work by controlling Palmer amaranth *before* seedlings emerge from the soil. They will not control Palmer amaranth if applied after seedling emergence. These Group 15 herbicides cannot

Table 2. Comparison of Group 15 herbicides in sugar beet.

Herbicide Product	Cost (per acre)A	Rate (per acre)B	Number of applicationsC	Last application date
Warrant®	$10.50–$33.00	1.25–2 qts	2 to 3, do not exceed 4 qt	8 TL
Outlook®	$15–$17.5	12–14 fl oz	2	Before 12 TL
Dual Magnum®	$15.75–$25	1–1.6 pts	2, do not exceed 2.6 pt	60 days before harvest

[A] Costs as reported in the *Guide for Weed, Disease, and Insect Management in Nebraska* (EC130). All costs are approximations, and do not include application costs.

[B] Lower rates are for coarse-grained (light) soils with less than 1% organic matter (OM), higher rates are for fine-grained (heavier) soils or those with greater than 1% OM.

[C] The maximum number of applications for Warrant® and Dual Magnum® is dependent on the herbicide rate. Please refer to the label for more information.

be applied until the sugar beet is at 2 TL stage or later. Because Palmer amaranth emergence occurs throughout much of the growing season, generally from early May to late August, control with these herbicides is limited. Further, there are currently no known herbicides available to control Palmer amaranth that emerges between sugar beet emergence and the 2 TL stage. Research at the UNL Panhandle Research and Extension Center near Scottsbluff, Nebraska, suggests these three Group 15 herbicides are equally effective at controlling Palmer amaranth, but only when applied after the sugar beet reaches 2 TL stage. Which product you choose should be based on cost and application timing (Table 2).

What about Betamix®?

U.S. Environmental Protection Agency registration of all desmedipham-containing products (including Betamix®) expired on March 13, 2014, and the product is no longer being sold in the U.S. market. Despite no longer being available for purchase, existing stocks of Betamix® may still

Figure 3. Palmer amaranth (left) and sugar beet (right), two weeks after a tank-mix application of Betamix®, Stinger®, and Nortron® SC, applied in late April to cotyledon-sized Palmer amaranth. Palmer has fully recovered from injury, and the sugar beet remains injured.

Table 3: Summary of herbicide options for control of glyphosate-resistant weeds:

Volunteer corn:	Kochia:	Palmer amaranth:
ACCase inhibiting herbicides (Group 1) should be applied shortly after the corn emerges (before it reaches 4-inches in height). Group 1 herbicides: • quizalofop (Assure® II) • sethoxydim (Poast Plus®) • clethodim (Select Max®)	Ethofumesate (Group 16) applied before kochia emergence is the only option growers have for chemical suppression. Labeled rates depend on product and soil type, but applying less than 1 pound/acre of ethofumesate (32 fl. oz/ac of Nortron® SC) will reduce kochia suppression substantially.	Every POST application of glyphosate up to sugar beet canopy closure should include a Group 15 herbicide. Most Group 15 herbicides are limited to two applications per season, so products should be rotated to ensure compliance with label restrictions—for example, an application of Warrant® at 2 TL and again at 8 TL, followed by an application of Dual Magnum® at canopy closure.

Table 4. Herbicides labeled for glyphosate- and ALS-resistant kochia and Palmer amaranth control in sugar beet and common rotation crops within the Western Sugar Cooperative production region of Colorado, Montana, Nebraska, and Wyoming.

Corn before Corn	Corn before Dry Bean	Corn before Sugar Beet	Small Grains before Dry Bean & Sugar Beet	Dry Beans	Sugar Beet
What Does Not Work					
• Group 2: Permit®, Resolve® Q, etc. • Group 9: glyphosate	• Group 2: Resolve® Q, etc. • Group 9: glyphosate	• Group 2: Permit®, Resolve® Q, etc. • Group 9: glyphosate	• Group 2: Harmony® SG, etc.	• Group 2: Raptor®, Pursuit®, • Group 6: Basagran® • Varisto® (6+2)	• Group 2: UpBeet® • Group 9: glyphosate
What Works					
PRE					
• Group 15: Warrant®, Dual Magnum®, Outlook®, etc . . . • Group 3: Prowl® H2O • Group 5: atrazine • Group 14: Sharpen®, Valor®	• Group 15: Warrant®, Dual Magum®, Outlook®, etc . . . • Group 3: Prowl® H2O • Group 14: Sharpen®, Valor®	• Group 15: Warrant®, Dual Magnum®, Outlook®, etc . . . • Group 3: Prowl® H2O • Group 14: Sharpen®, Valor®		• Group 15: Outlook®, Dual Magnum® • Group 8: Eptam® • Group 3: Sonalan®, Prowl® H2O	• Group 16: ethofumesate[A]
PRE & POST					
• Group 27: Balance® flexx· Callisto®· • Acuron® (15+5+27), DiFlexx® DUO (27+4), Resicore® (14 +15)	• Acuron® (15+5+27)[C], DiFlexx® DUO (27+4)[C]	• DiFlexx® DUO (27+4)[C]			
POST					
• Group 4: dicamba, fluroxypyr, 2,4-D • Group 27: Armezon®, Laudis®	• Group 4: dicamba, fluroxypyr, 2,4-D • Group 27: Armezon®[C]	• Group 4: dicamba, fluroxypyr, 2,4-D • Group 27: Armezon®[C]	• Huskie® (27 + 6)		• Group 15[B], as a layby

[A]Ethofumesate does not have activity on Palmer amaranth.

[B]Group 15 herbicides do not have substantial activity on kochia.

[C]Must be applied under a center-pivot irrigation if rotating to dry bean or sugar beet

be used in accordance with the label. In greenhouse trials at the PHREC in 2019, Betamix® controlled Palmer amaranth if sprayed at the cotyledon growth stage, and so may be helpful if sprayed as soon as Palmer begins emerging. However, Betamix® did not control Palmer amaranth that was 2" or taller, so it will not be effective for controlling Palmer amaranth that has escaped glyphosate application.

Leveraging the crop rotation

Because of the limited herbicide options available to control kochia and Palmer amaranth in sugar beet, it is important to consider weed control throughout the entire crop rotation. Choosing competitive crops (corn, wheat, and/or barley) to rotate with sugar beet will help suppress kochia seed production, which will benefit weed control in the sugar beet crop. Diverse crop rotations also allow using a more diverse mixture of herbicide modes of action (Table 3). Herbicide mixtures, if chosen carefully, can significantly delay evolution of herbicide-resistant weeds. Selection of crops and herbicides in preparation for sugar beet are among the most important decisions farmers can make with respect to successful weed management. However, it can be difficult to determine which herbicide combinations will provide effective broad-spectrum weed control while also providing effective proactive resistance management.

The co-authors of this paper, along with Albert Adjesiwor from the University of Idaho, created a web-

application to help growers developing multi-year crop rotation and herbicide programs that are cost-effective and reduce potential for herbicide-resistant weed evolution. The website allows users to select a four-year crop rotation, and evaluate different herbicide options within each crop. The website will then provide herbicide-cost and weed-control efficacy estimates, along with a resistance risk score for each herbicide mode of action used in the rotation. The herbicide-resistance risk calculator can be found online at: http://bit.ly/HerbRisk

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