KOCHIA CONTROL IN SUGARBEET AND CROPS IN SEQUENCE WITH SUGARBEET

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Summary

1. Identify the weed challenges in your fields and prepare for sugarbeet by planting crops with effective weed control herbicides.
2. Kochia control in sugarbeet is greatest when Roundup PowerMax postemergence (POST) follows ethofumesate preemergence (PRE) applied at 6 or 7.5 pt/A or two or three applications of Roundup PowerMax + ethofumesate POST applied to kochia less than 3-inches tall during the season.
3. Kochia control from Ultra Blazer is inconsistent; likely due to kochia size at required Ultra Blazer application timing in sugarbeet.
4. Successful kochia control requires a program approach throughout the crop sequence, including sugarbeet production.

Introduction

Glyphosate-resistant (GR) kochia is reemerging as a weed control challenge for sugarbeet growers in Minnesota, North Dakota, and eastern Montana. Kochia is unique from other weed control threats in that there are few effective weed control options in sugarbeet. Kochia typically emerges in April and May, but some kochia biotypes emerge as late as June. Kochia is most severe when drought conditions reduce both sugarbeet stands and early season growth and development. Finally, kochia interferes with sugarbeet root yield by virtue of its rapid growth, resulting in sugarbeet suffocation due to enormous growth potential.

Herbicides are a major component of kochia control programs. The outcome of relying on herbicides, along with kochia's competitive characteristics and high genetic diversity, are population shifts and evolution of herbicide-resistant populations in many regions in Minnesota, North Dakota, and eastern Montana. Kochia has evolved resistance to at least four herbicide sites of action. They are (ALS) inhibitors, synthetic auxins, photosystem II (PSII) inhibitors, and EPSP synthase inhibitors or glyphosate, which are also herbicides effective for kochia control in crops in sequence with sugarbeet. Glyphosate-resistant kochia is widespread and concerning to farmers since glyphosate is relied upon in many cropping systems. The objectives of this research were to 1) evaluate non-glyphosate herbicide options in sugarbeet or crops grown in sequence with sugarbeet and; 2) provide kochia control options in Minnesota and North Dakota fields when corn, soybean, or wheat are seeded in sequence with sugarbeet.

Kochia control in crops in sequence with sugarbeet. Researchers from Colorado, Kansas, Nebraska, South Dakota, and Wyoming selected their favorite programs for kochia control in corn, soybean, sugarbeet, spring wheat and fallow in 2010 and 2011 (Sbatella et al., 2019). Overall, preferred programs were a combination of soil residual followed by (fb) POST herbicides applied singly or in repeat applications. Kochia control was arranged by crop and location across years (Figure 1). Herbicide programs approved for kochia control in corn or soybean demonstrated greater overall control with less variability across environments compared with fallow, wheat, and sugarbeet (Sbettala et al. 2019). The potential for a kochia control failure was relatively low in corn, regardless of the herbicide program evaluated, whereas in sugarbeet, there was no herbicide program evaluated that provided greater than 86% kochia control at any field location. The median kochia control was 40% in sugarbeet across all sites (Figure 1).

Effective, long-term kochia management in sugarbeet will likely depend on programs used within a crop rotation including corn, soybean, spring wheat, and spring barley. However, some kochia control herbicides create challenges as their crop rotation restrictions do not allow sugarbeet to be planted the following year. Corn, wheat, and to an extent, soybean, create dense canopies formed early in the growing season that compete with kochia. In contrast, sugarbeet is a poor competitor because of slow growth and development and relatively short stature.

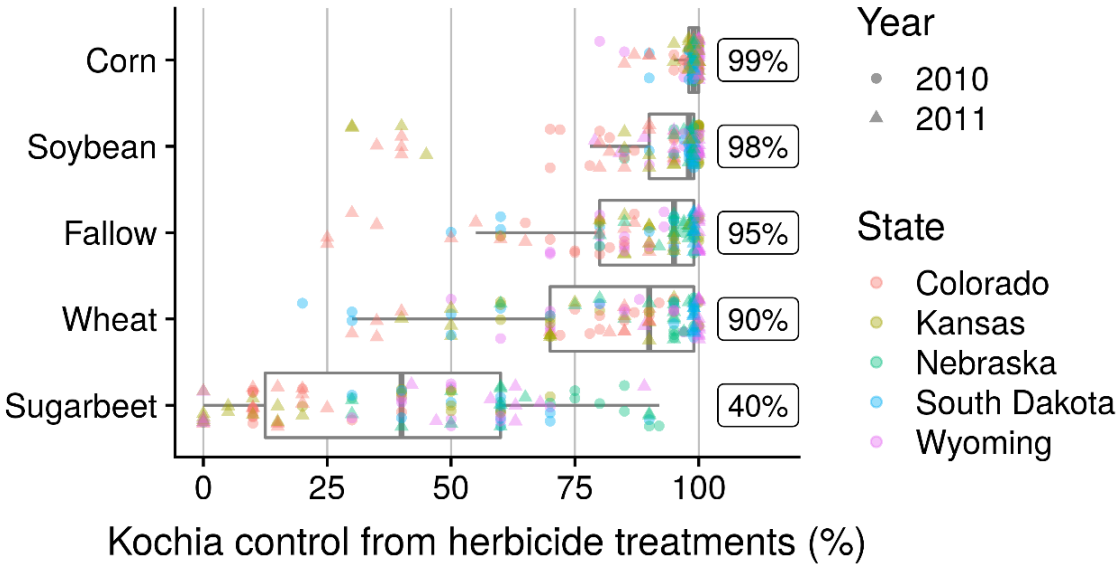

Figure 1. Kochia control, 30 days after final application of herbicide treatment, labeled for corn, soybean, fallow, wheat, and sugarbeet. Each point represents a plot in a field. Percentages are the median kochia control from herbicide treatments within each crop.

Eastern North Dakota and Minnesota. Dr. Joseph Ikley, North Dakota Extension Weed Control Specialist, lists his preferred kochia control programs in corn, soybean, and wheat. Recommendations are presented as product per acre. Please use the North Dakota Weed Control Guide to verify herbicide rates and crop rotation restrictions for soils and crop sequences on your farm.

1. Spring
   a. Corn
      i. Verdict (16-18 fl oz) + atrazine[1] (0.38 to 0.5 lb) or Harness MAXX (2 qt) + atrazine (0.38 to 0.5 lb) PRE fb PowerMax + Status (5 fl oz) POST (requires RR corn)
      ii. Acuron[2] (1.25 qt) or Acuron Flexi (1.25 qt) fb Acuron (1.25 qt) or Acuron Flexi (1.25 qt) + PowerMax (requires RR corn)
      iii. Capreno (3 fl oz) + PowerMax + atrazine (0.38 to 0.5 lb) EPOST (V2 to V4 corn, (less than 3-inch kochia) (requires RR Corn)
   b. Soybean
      i. Authority Edge[3] (full rate for soil type) fb PowerMax + dicamba or Liberty (dicamba use requires Xtend or XtendFlex soybeans, Liberty requires Enlist, LibertyLink, LLGT27, or XtendFlex soybeans)
      ii. Fierce MTZ[4] (full rate for soil type) fb PowerMax + dicamba or Liberty (dicamba use requires Xtend soybeans, Liberty requires Enlist, LibertyLink, LLGT27, or XtendFlex soybeans)
      iii. Authority MTZ[5] (full rate for soil type) fb PowerMax + dicamba or Liberty (dicamba use requires Xtend soybeans, Liberty use requires Enlist, LibertyLink, LLGT27, or XtendFlex soybeans
   c. Spring Wheat
      i. Huskie FX[6] (full rate)
      ii. Starane NXT[7] (full rate)
      iii. Talinor[8] (full rate)

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[1]Atrazine requires a second cropping season after herbicide application crop rotation restriction to sugarbeet.
[2]Acuron/Flexi requires an 18 month after application crop rotation restriction to sugarbeet.
[3] Authority Edge requires up to 36 months after application crop rotation restriction to sugarbeet.
[4] Fierce MTZ requires up to 18 months after application crop rotation restriction to sugarbeet.
[5] Authority MTZ requires up to 24 months after application crop rotation restriction to sugarbeet.
[6] Huskie FX requires a 9 month after application crop rotation restriction to sugarbeet.
[7] Starane NXT requires a 9 month after application crop rotation restriction to sugarbeet.
[8] Talinor requires a 15 month after application crop rotation restriction to sugarbeet.

Sidney Sugars, Western North Dakota and Eastern Montana. Kochia management in western North Dakota is complicated by irrigation practices on some acres. The following are a series of activities recommended by Dr. Brian Jenks for corn, soybean and wheat production in sequence with sugarbeet.

1. Fall. After fall ridging and before corn, soybean or spring wheat.
    a. Valor[1] at 3 oz/A after fall ridging
    b. We recommend no spring re-ridging since tillage will disturb the herbicide layer.
    c. Plan for fall Valor reducing spring kochia emergence 70%
1. Spring. Corn, soybean or small grains.
    a. Corn
        i. Verdict (10 fl oz minimum 15 fl oz is better) + atrazine[2] (0.38 lb) + AMS + MSO applied POST to emerged kochia and PRE to corn
        ii. Sharpen[3] (2-3 fl oz) + atrazine to reduce cost, applied POST to emerged kochia and PRE to corn
        iii. Roundup PowerMax + Status (5 fl oz) POST (requires RR corn). Glyphosate will get grasses but Verdict offers a different mode of action.
    b. Soybean
        i. Gramoxone or dicamba (XtendFlex soybeans are required) for burndown control of emerged kochia.
        ii. Fierce EZ[4] (full rate for soil type) fb Roundup PowerMax + dicamba or Liberty (dicamba or Liberty requires XtendFlex soybeans)
        iii. Fierce EZ may not get emerged kochia in spring burndown and twelve months may not be enough time to sugarbeet in dry conditions.
        iv. Liberty (requires Enlist, LibertyLink, LLGT27, or XtendFlex soybean) must be applied on less than 3-inch kochia and requires warm temperatures, sun, and humid conditions.
    c. Spring Wheat
        i. Gramoxone or a Gramoxone + Sharpen mix in the spring burndown.
        ii. Starane NXT[5] (full rate) or Huskie FX[6] (full rate) (the goal is to apply 1.5 to 2 oz/A fluroxypyr per acre)
        iii. Cleansweep D or Kochiavore (both have Starane + bromoxynil + 2,4-D). First choice is Huskie FX.

Kochia control in sugarbeet. Ethofumesate should be applied preplant incorporated (PPI) or PRE at 6 to 7.5 pt/A in sugarbeet fields when kochia, especially GR kochia, is a weed control challenge (Peters and Lueck 2016; Peters and Lystad 2021). Ethofumesate at less than 6 pt/A provided inconsistent kochia control, even when incorporated into the soil. Herbicide applications POST should be timed to kochia growth stage rather than sugarbeet growth stage. Kochia control POST is greatest in sugarbeet, even with glyphosate products, when it is less than 3-inches tall. The addition of Betamix improved kochia control from Roundup PowerMax + ethofumesate POST. However, Betamix rate must be carefully selected based on sugarbeet growth stage to ensure sugarbeet safety, especially when Betamix follows soil applied (PPI or PRE) ethofumesate.

Material and Methods

Field experiments. Field experiments were conducted on natural kochia populations that were a mixture of glyphosate susceptible and glyphosate resistant biotypes near Horace, ND and Manvel, ND in 2021 (Table 1). Soil residual herbicides were applied before and after planting. The entire experimental area was tilled using a Kongskilde s-tyne cultivator with rolling baskets once preplant soil residual herbicides were applied to remove variability with tillage treatments. Sugarbeet was seeded in 22-inch rows at about 61,000 seeds per acre with 4.7 inch spacing between seeds. Treatments were applied with a bicycle sprayer through appropriate nozzles and CO_2 pressured to deliver 17 GPA spray solution to the center four rows of six row plots, 35 feet in length. Experiments were conducted to evaluate soil applied applications of ethofumesate PRE and POST applications of Betamix, Ultra Blazer, and ethofumesate rates and timings to maximize kochia control and minimize sugarbeet injury.

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[1] Valor requires up to 10 months after application crop rotation restriction to sugarbeet; tillage effects restriction.
[2] Atrazine requires a second cropping season after herbicide application crop rotation restriction to sugarbeet.
[3] Sharpen requires 5-6 months after application crop rotation restriction to sugarbeet (depending on rate used).
[4] Fierce EZ requires up to 12 months after application crop rotation restriction to sugarbeet.
[5] Starane NXT requires a 9 month after application crop rotation restriction to sugarbeet.
[6] Huskie FX requires a 9 month after application crop rotation restriction to sugarbeet.

Table 1. Herbicide treatment, rate, and application timing, Horace and Manvel ND, 2021.

Treatment	Rate (fl oz/A)	Kochia (inches)
Etho[1] / RU PowerMax[2]	64 / 28	PPI / 3
Etho / RU PowerMax	96 / 28	PPI / 3
Etho / RU PowerMax	120 / 28	PPI / 3
Etho / RU PowerMax	64 / 28	PRE / 3
Etho / RU PowerMax	96 / 28	PRE / 3
Etho / RU PowerMax	120 / 28	PRE / 3
Etho + RU PowerMax[3] / Etho + RU PoweMax	4 +28 / 4 + 28	1 / 3
Ultra Blazer[4]	16	3
Ultra Blazer + RU PowerMax + Etho	16 + 28 + 4	3

[1] etho = ethofumesate.

[2]Roundup PowerMax applied with Prefer 90 NIS at 0.25%v/v and Amsol Liquid AMS at 2.5% v/v.

[3]Roundup PowerMax + ethofumesate applied with Destiny HC HSMOC at 1.5 pt/A and Amsol Liquid AMS at 2.5 % v/v.

[4]Ultra Blazer applications applied with Prefer 90 non-ionic surfactant at 0.125% v/v.

Visible sugarbeet growth reduction was evaluated using a 0% to 100% scale, (0 is no visible injury and 100 is complete loss of plant / stand) at the 2-lf sugarbeet stage and 7, 14, and 21 days after 2-lf stage application. Visual percent kochia control was evaluated using a 0% to 100% scale (0 is no control and 100 is complete control) at the 2-lf stage and 7, 14, 21 and 28 days after the 2-lf sugarbeet stage or when kochia was approximately 1-inch tall.

All evaluations were a visual estimate of percent fresh weight reduction in the four treated rows compared with the adjacent untreated strip. Experimental design was randomized complete block with four replications. Data was analyzed with the ANOVA procedure of ARM, version 2021.2 software package.

Greenhouse experiment. An experiment was conducted in the greenhouse to determine kochia control from Ultra Blazer. Kochia was grown in a flat containing a general-purpose greenhouse growing media (PRO-MIX BX, Quackertown, PA) and transplanted to 4 × 4-inch greenhouse pots. Herbicide treatments (Table 2) were applied when kochia reached 4-inches tall using a DeVries Generation III spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a TeeJet 8001XR nozzle calibrated to deliver 10.5 GPA spray solution at 40 psi and 3 mph. Visual percent kochia control was evaluated using a 0% to 100% scale (0 is no control and 100 is complete control) 14 and 21 days after application (DAA). Data was analyzed with the ANOVA procedure of ARM, version 2021.2 software package.

Table 2. Herbicide treatment, rate, and application timing, greenhouse, 2021.

Treatment	Rate (fl oz /A)	Kochia (inches)
Ultra Blazer	16	4
Ultra Blazer + NIS	16 + 0.25% v/v	4
Ultra Blazer + PowerMax + AMS + NIS	16 + 28 + 2.5% v/v +0.25% v/v	4
Untreated Control		4

Results and Discussion

Ethofumesate followed by Roundup PowerMax. A rain event to incorporate ethofumesate occurred 19 and 13 DAA at Horace and Manvel, respectively, in 2021. At Horace, kochia control was similar from Roundup PowerMax following ethofumesate averaged across rates and application method (Table 3). At Manvel, kochia control tended to be greater from Roundup PowerMax following ethofumesate applied PRE and average across rates as compared with kochia control from Roundup PowerMax following ethofumesate applied PPI. Incorporation moves ethofumesate into the soil. However, caution must be taken to ensure incorporation does not move ethofumesate too deep into the soil. Kochia control across locations tended to increase when ethofumesate was applied at 6 or 7.5 pt/A as compared with kochia control from ethofumesate at 4 pt/A. Kochia population was glyphosate-susceptible at both sites, so there were only modest differences across treatments following glyphosate application. Kochia control is greatest in sugarbeet when Roundup PowerMax follows ethofumesate and is applied to small kochia escapes or when Roundup PowerMax alone (not presented) or tank mixed ethofumesate is repeated three times during the growing season, beginning when kochia is less than 3-inches tall.

Table 3. Visible kochia control in response to herbicide treatment, Horace and Manvel ND, 2021.[1]

		Kochia Control			
		Horace		Manvel	
Treatment	Rate	28 DAT	42 DAT	7 DAT	21 DAT
	---fl oz/A---	----------%----------			
Etho[2] / RU PowerMax[3]	64 / 28	85 b	70 d	73 b	78 abc
Etho / RU PowerMax	96 / 28	90 ab	83 bc	73 b	79 abc
Etho / RU PowerMax	120 / 28	97 a	94 a	80 ab	82 ab
Etho / RU PowerMax	64 / 28	86 b	73 cd	93 a	92 a
Etho / RU PowerMax	96 / 28	94 a	88 ab	80 ab	86 ab
Etho / RU PowerMax	120 / 28	92 ab	76 cd	88 ab	94 a
Etho + RU PowerMax[4] / Etho + RU PowerMax	4 +28 / 4 + 28	85 b	70 d	85 ab	75 bc
Ultra Blazer[5]	16	25 c	10 e	50 c	32 d
Ultra Blazer + RU PowerMax + Etho	16 + 28 + 4	91 ab	73 cd	80 ab	66 c
LSD (0.10)		**8**	**11**	**16**	**13**

[1]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[2]etho = ethofumesate.
[3]Roundup PowerMax applied with Prefer 90 NIS at 0.25%v/v and Amsol Liquid AMS at 2.5% v/v.
[4]Roundup PowerMax + ethofumesate applied with Destiny HC HSMOC at 1.5 pt/A and Amsol Liquid AMS at 2.5 % v/v.
[5]Ultra Blazer applications applied with Prefer 90 non-ionic surfactant at 0.125% v/v.

Kochia control with Ultra Blazer. Kochia control from Ultra Blazer across locations and years has been inconsistent (Table 4). Some of the inconsistency is attributed to kochia size at application since Ultra Blazer application must be timed to sugarbeet growth stage. Ultra Blazer application for control of glyphosate-resistant kochia must be used in a program approach with products providing partial kochia control.

Table 4. Visible kochia control in response to herbicide treatment, Horace and Manvel ND, 2020 and 2021.[1]

		Horace		Manvel	
Treatment[2]	Rate	2020	2021	2020	2021
	---fl oz/A---	----------%----------			
Ethofumesate PRE / RU PowerMax	120 / 28	75 a	92 a	80 b	94 a
Ultra Blazer	16	25 b	25 b	83 b	33 c
Ultra Blazer + RU PowerMax	16 + 28	86 a	91 a	96 a	66 b
LSD (0.10)		**10**	**8**	**11**	**13**

[1]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[2]All POST treatments applied with Prefer 90 NIS at 0.25%v/v and Amsol Liquid AMS at 2.5% v/v.

Ultra Blazer plus Roundup PowerMax with AMS and NIS improved visible kochia control compared with Ultra Blazer alone (Table 4, Table 5) and tended to provide greater fresh weight reduction compared with Ultra Blazer alone with or without NIS (Table 5). The greenhouse experiment was a two-replication demonstration experiment, so the results were variable. Kochia control was less 21 DAA as compared with 10 DAA, due to incomplete kochia kill and regrowth following herbicide treatment.

Table 5. Visible kochia control and kochia fresh weight reduction in response to herbicide treatment, 10, 18, and 21 DAT, greenhouse, 2021.[1]

Treatment	Rate	Visible Kochia Control		Fresh Weight Reduction
		10 DAT	18 DAT	21 DAT
	--fl oz /A--	----------%----------		
Ultra Blazer	16	55 a	30 c	23 b
Ultra Blazer + NIS	16 + 0.25% v/v	55 a	55 b	37 ab
Ultra Blazer + RU PowerMax + AMS + NIS	16 + 28 + 2.5% v/v + 0.25% v/v	78 a	80 a	68 a
Untreated Control	-	0 b	0 d	-
LSD (0.20)		**22**	**15**	**41**

[1]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.

Kochia was grown up to 4-inches tall before application in the greenhouse to ensure treatment differences. Previous research, along with our own field observations, reinforce the importance of kochia size at Ultra Blazer application. Wicks (Wicks et al. 1997) reported kochia control was dependent on size at Ultra Blazer application (Figure 2). In general, their results suggest kochia size should be less than 2-inches to achieve 60% or greater kochia control at 32 fl oz/A. Ultra Blazer at 16 fl oz/A is the maximum rate in sugarbeet.

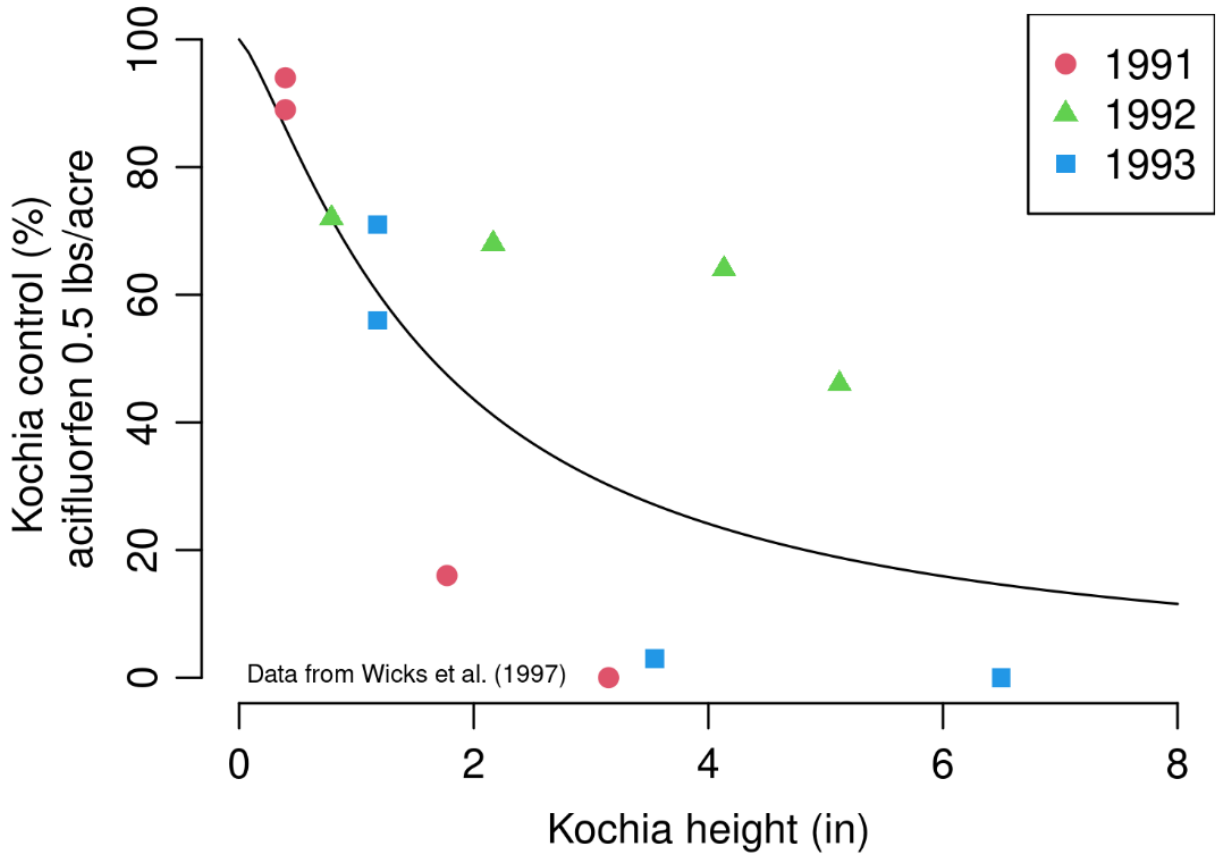

Figure 2. Visible kochia control (%) in response to Ultra Blazer at 2 pt/A at various kochia height (in), 1991, 1992, and 1993. Figure adapted by Kniss using data from Wicks et al. 1997.

Recommendations in sugarbeet

Eastern North Dakota and Minnesota. Ethofumesate at 6 pt/A or greater followed by glyphosate alone or repeat glyphosate plus ethofumesate applications, beginning when kochia is less than 3-inches tall, provides the greatest kochia control in sugarbeet. At this point, we do not have sufficient information to support kochia control in sugarbeet with Ultra Blazer or Ultra Blazer plus glyphosate.

Sidney Sugars, Recommendations in Sugarbeet. The biotype in western North Dakota appears to be resistant, or glyphosate control is influenced by environmental conditions at application. We recommend spraying small kochia with full glyphosate rates and adjuvants. We recommend a program approach including ethofumesate (fall or spring applied) followed by glyphosate. At this point, we do not have data to support Ultra Blazer use in sugarbeet in Williams or McKenzie counties in North Dakota or eastern Montana.

1. Fall. After fall ridging and before sugarbeet.
    a. Ethofumesate (Nortron, Ethotron, Nektron, or Ethofumesate 4SC) at 4 to 6 pt/A depending on organic matter (OM) and soil texture.
    b. Up to 3 pt/A if spring ethofumesate application follows fall application. We recommend no spring re-ridging since tillage will disturb the herbicide layer.
2. Spring. Sugarbeet plant.
    a. Ethofumesate PRE at 3 to 6 pt/A depending on OM and soil texture.
        i. Apply ethofumesate as early as possible to, and in advance of, spring rains.
    b. Glyphosate plus ethofumesate, POST. A total of 12 fl oz/A ethofumesate can be applied in sugarbeet.
        i. Use full rates of glyphosate products with adjuvants depending on formulation.
        ii. Apply to 3-inches or less kochia with water volumes to achieve good coverage.

Acknowledgements

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