ETHOFUMESATE

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Summary
1. Chemical properties of ethofumesate, including adsorptivity and water solubility, partially explain the inconsistent waterhemp control across environmental conditions.
2. Waterhemp control from ethofumesate is best following timely, adequate, and penetrating rainfall events.
3. Ethofumesate rate alone does not overcome sub-optimal environmental conditions.
4. The use of shallow tillage to incorporate ethofumesate in the top soil may improve the probability for waterhemp control.
5. Moisture in the soil solution is necessary for waterhemp control, even if ethofumesate moves into the soil during tillage.

Introduction
Ethofumesate or 'Nortron' was registered by Fisons Corporation in 1977 for control of small seeded broadleaves including common lambsquarters, waterhemp, and redroot pigweed control in sugarbeet (Edwards et al. 2005; Ekins and Cronin 1972). Ethofumesate is applied preplant incorporated (PPI) and preemergence (PRE) at use rates from 1.00 (2 pt/A) to 3.75 (7.5 pt/A) pound per acre (Kellogg 2011) and up to 0.38 (0.75 pt/A) pound per acre postemergence.

Weed control following PRE application requires timely and adequate precipitation to activate ethofumesate in the weed seedling layer due to low water solubility and strong adsorption to soil characteristics as compared to the chloroacetamide family of herbicides, dicamba, and trifluralin (Table 1; Shaner 2014; Schweitzer 1975). Ethofumesate rarely leaches in soil and provides up to 10 weeks of residual control to grass and broadleaf weed species (Ekins and Cronin 1972). Ethofumesate is absorbed through emerging roots and shoots when applied to soil (Eshel et al. 1978).

Table 1. Herbicides behavior in soil.

Common Name	Trade Name	Adsorptivity[a]	Water Solubility[b]
		K_{OC}	ppm[c]
acetochlor	Warrant	200	233
dimethenamid-p	Outlook	155	1,174
S-metolachlor	Dual Magnum	200	488
ethofumesate	Nortron	340	110
trifluralin	Treflan	7,000	0.3
dicamba	XtendiMax	2	4,500

[a]K value represents the ratio of herbicide bound to soil collides versus what is free in the water solution. The higher the K value, the greater the adsorption to soil colloids.
[b]Water solubility is a measure of the amount of chemical substance that can dissolve in water at a specific temperature. For example, milligrams per liter.
[c]ppm=Parts per million

Waterhemp control from ethofumesate has been an enigma (Merriam-Webster Dictionary definition: mysterious, puzzling, or difficult to understand) and it seems our interpretation of ethofumesate becomes more confusing with experiments in more environments. One of our first waterhemp experiments was near Herman, MN in 2014. We observed greater than 85% waterhemp control in July from ethofumesate alone or ethofumesate mixed with Dual Magnum PRE, but found ethofumesate did not provide season-long waterhemp control (Table 2). This outcome led to the development of a layered strategy in sugarbeet beginning with ethofumesate alone or ethofumesate mixtures with Dual Magnum PRE, followed by (fb) the split application of chloroacetamide herbicides at the V2 and V6 sugarbeet stage.

Table 2. Waterhemp control in response to herbicide treatment, Herman MN, 2014.

			Waterhemp Control			
Treatment[a]	**Application**	**Rate**	**Jun 23**	**Jul 2**	**Jul 10**	**Aug 27**
		---pt/A---	-----------------------%-----------------------			
Ethofumesate	PPI	6	78	90	86	74
Ethofumesate	PRE	6	88	88	86	70
Etho + Dual Magnum	PRE	3 + 0.5	99	99	97	94
Etho + Dual Magnum	PRE	4 + 0.5	98	97	97	94
Etho + Dual Magnum	PRE	3 + 1	98	100	100	98
Etho + Dual Magnum	PRE	4 + 1	100	100	100	98

[a]Treatments included repeat Roundup PowerMax applications POST at 28 fl oz/A followed by (fb) 28 fl oz/A fb 22 fl oz/A + Prefer 90 NIS at 0.25% v/v and N-Pak AMS at 2.5% v/v.

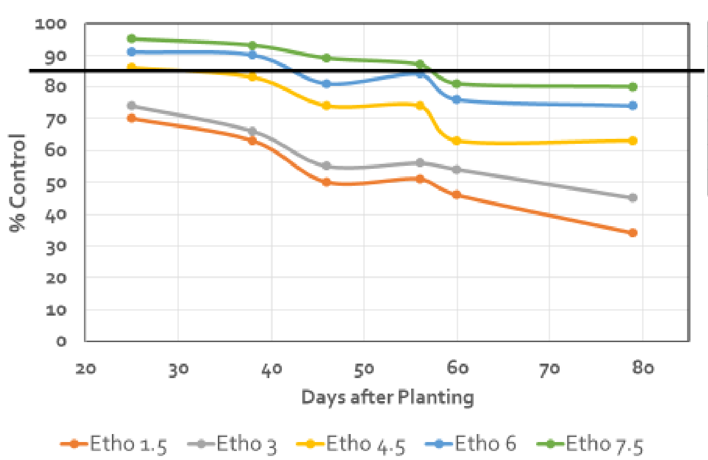
Ethofumesate alone or mixed with Dual Magnum PRE layered with chloroacetamide herbicides consistently controlled waterhemp in field experiments from 2015 to 2019. In general, sugarbeet were planted in May and received sufficient rainfall for activation of soil residual herbicides. However, our promising results did not reflect our historical knowledge, especially Dr. Dexter's research, which found incorporating ethofumesate improved the consistency of pigweed control from ethofumesate. Moreover, Dr. Dexter conducted several experiments over the years comparing preplant ethofumesate with preemergence ethofumesate (Table 3). Dr. Dexter's data suggests the importance of timely rainfall for activating ethofumesate. Finally, he conducted research on the appropriate depth to incorporate ethofumesate as well as comparing tillage equipment for optimal ethofumesate incorporation (Dexter et al., 1982).

Table 3. Comparing preplant incorporated and preemergence ethofumesate at 3.75 to 4.0 lb/A; 1973 to 1986.[a]

Nortron application	Redroot pigweed control at 4 of 7 locations	Redroot pigweed control at 3 of 7 locations
	---------------------------%---------------------------	
PPI	97	91
PRE	79	93
LSD (0.05)	**11**	**NS**

[a]Data taken from NDSU PLSC 350 class notes.

Growers frequently inquired about the maximum ethofumesate rate one can apply without injury to nurse crops. An experiment, first established in 2020, considered waterhemp control in response to ethofumesate rate (Figure 1 and Table 4). The experiment was established near Blomkest and at the ACS Technical Center, Moorhead, MN in 2020. Spring barley was drilled perpendicular to plots sprayed with ethofumesate at 1.5 to 7.5 pt/A. The primary objective was to find the threshold between spring barley safety and waterhemp control. Our second objective was to determine waterhemp control from ethofumesate at various application rates.



	Days after planting					
	25	38	46	56	60	79
Etho 1.5	70	63	50	51	46	34
Etho 3	74	66	55	56	54	45
Etho 4.5	86	83	74	74	63	63
Etho 6	91	90	81	84	76	74
Etho 7.5	95	93	89	87	81	80

Calendar date	Rainfall (inch)	Total Rainfall (inch)
May 9	0.7	0.7
May 26	1.7	2.4
June 10	0.3	2.7
June 25	1.3	4.0
July 10	3.8	7.8

Figure 1. Waterhemp control in response to ethofumesate PRE at 1.5 to 7.5 pt/A, Blomkest MN, 2020.

Our working hypothesis was ethofumesate provides greater than 85% waterhemp control for less than 30 days at 1.5, 3.0 and 4.5 pt/A and greater than 85% waterhemp control for more than 30 days at 6.0 and 7.5 pt/A. That is, complete waterhemp control but for short duration at rates less than 4.5 pt/A. To our surprise, the 1.5 and 3.0 pt/A rates did not accomplish 85% control at either Moorhead or Blomkest. The Moorhead experiment was completely overgrown with waterhemp by July 4, 2020 (Table 4). We attributed the Moorhead results to less than optimal results from ethofumesate in a season where ethofumesate activation by rainfall was compromised by below normal rainfall after planting.

Table 4. Waterhemp control in response to ethofumesate rate, Moorhead MN, 2020

		Waterhemp Control		
Herbicide	**Rate**	**May 26**	**June 15**	**June 28**
	--pt/A--	--------------------------------%--------------------------------		
Ethofumesate	0	8 e	0 d	3 d
Ethofumesate	1.5	38 d	35 c	13 cd
Ethofumesate	3	50 c	51 b	18 c
Ethofumesate	4.5	73 a	68 a	33 b
Ethofumesate	6.0	63 b	70 a	58 a
Ethofumesate	7.5	65 ab	76 a	53 a
LSD (0.20)		**9**	**9**	**14**

This experiment was repeated at two locations in 2021, a location near Hector International Airport, Fargo, ND and a second location at the ACS Technical Center, Moorhead, MN. We elected to include both preplant incorporation and preemergence application in the experimental design in 2021 in response to previous year results with below normal rainfall. We also elected to conduct the experiment at 2, 4, 6, 8, 10 and 12 pt/A ethofumesate. Unfortunately, 2021 was equally as dry as 2020. Conditions were so poor that the experiment at Moorhead was abandoned due to erratic emergence of spring barley. We observed very poor overall control of waterhemp at Fargo location. However, we observed that waterhemp escapes were either small or large plant, depending on treatment, suggesting control of either early or late emerging waterhemp. Ethofumesate PPI, averaged across treatments, provided no control of early emerging waterhemp, but 56% control of late emerging waterhemp (Figure 2). Conversely, ethofumesate PRE, averaged across treatments, provided 55% control of early emerging waterhemp, but only 28% control of late emerging waterhemp.

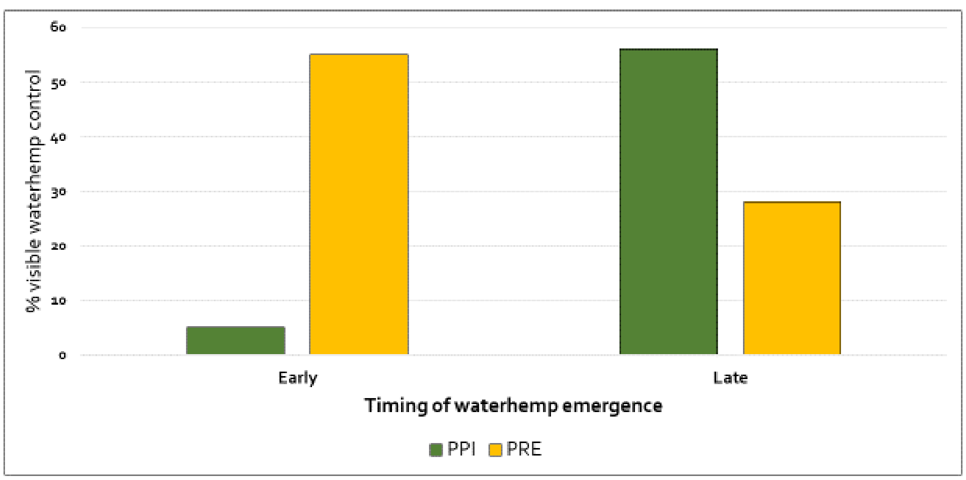


Figure 2. Early and late emerging waterhemp control in response to ethofumesate PPI or PRE, Fargo ND, 2021.

We hypothesize that ethofumesate incorporated into the soil was bound to soil colloids and unavailable for waterhemp uptake early in the season due to sub-optimal soil moisture conditions (Figure 3). However, ethofumesate moved into the soil solution following rain events in June and was partially effective at controlling later emerging waterhemp. Ethofumesate PRE, which likely was bound to the soil surface, may have moved into the soil following rainfall events on May 20 and June 7, providing some early season control. However, degradation likely reduced control of late emerging waterhemp.

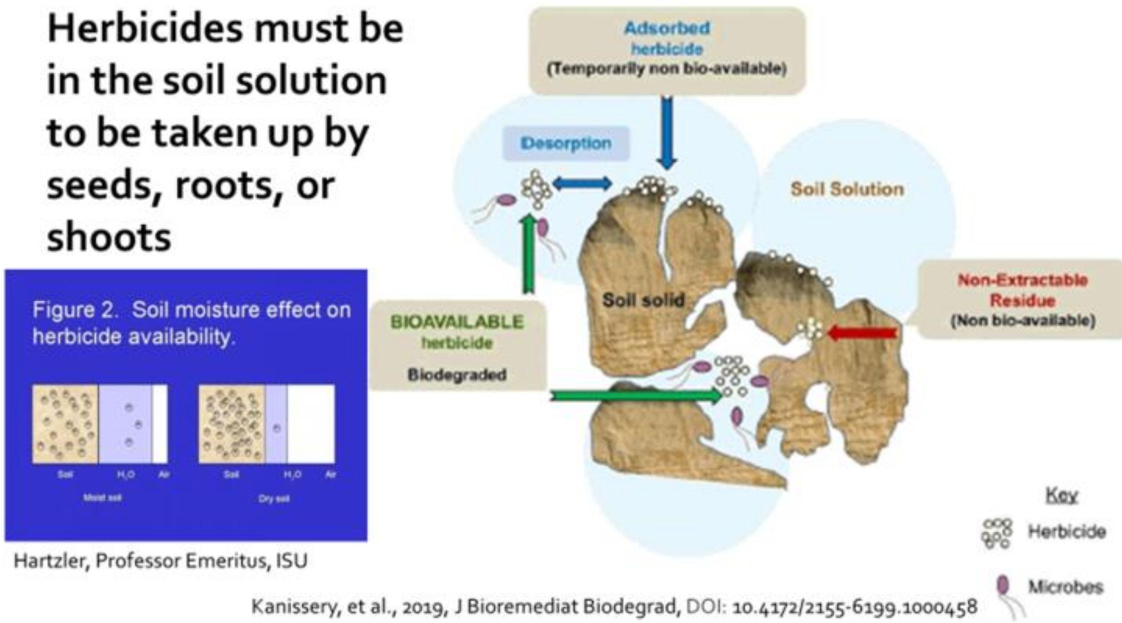


Figure 3. Illustration depicting ethofumesate bound to soil colloids when soil water content is low and in the soil solution when the soil water content is greater.

We believe soil moisture is a predictor of ethofumesate performance and at least partially explains the inconsistent results growers have experienced when ethofumesate has been applied preemergence in some fields in 2021 (and 2022). Likewise, waterhemp control from ethofumesate has been inconsistent even with effective incorporation, when soil moisture levels were sub-optimal such as conditions in some geographies in 2021.

Our working hypothesis is that ethofumesate controls waterhemp best following timely, adequate, and penetrating rainfall events to move ethofumesate off the soil surface and into the water solution and/or spaces between colloids. Ethofumesate rate does not overcome challenges caused by a dry spring. Finally, incorporating ethofumesate might be an effective way for improving waterhemp control, provided ethofumesate is not incorporated too deep, thereby diluting concentration.

The objective of this 2022 experiment was to 1) demonstrate crop safety to nurse crop barley and 2) determine the duration of waterhemp control from ethofumesate.

Materials and Methods

An experiment was conducted near Moorhead, MN in 2022. The experimental area was prepared for planting by fertilizing and conducting tillage across the experimental area. Sugarbeet was planted on May 25 at Moorhead, MN in 2022. Sugarbeet was seeded in 22-inch rows at approximately 62,000 seeds per acre with 4.6 inch spacing between seeds. Herbicide treatments are found in Table 5.

Treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 40 feet in length in 2022. Ethofumesate applied preplant was incorporated into soil using a Kongskilde s-tine field cultivator with rolling baskets set approximately 2-inch deep and operated at approximately 5 mph.

Table 5. Herbicide treatment, application timing, and rate, Moorhead, MN, 2022.

Herbicide Treatment	Application timing	Rate (pt/A)
Ethofumesate	Preplant	2
Ethofumesate	Preplant	4
Ethofumesate	Preplant	6
Ethofumesate	Preplant	8
Ethofumesate	Preplant	10
Ethofumesate	Preplant	12
Ethofumesate	Preemergence	2
Ethofumesate	Preemergence	4
Ethofumesate	Preemergence	6
Ethofumesate	Preemergence	8
Ethofumesate	Preemergence	10
Ethofumesate	Preemergence	12

Visible waterhemp control (0 to 100% control, 0% indicating no control, and 100% indicating complete control) was collected approximately 10 days after treatment (DAT). Experimental design was randomized complete block design with four replications in a factorial arrangement, with factors being herbicide rate and application timing. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Results and Discussion

Waterhemp control was evaluated on approximately ten-day intervals from June 16 to August 3, 2022. Figure 4 demonstrates waterhemp control × ethofumesate rate, averaged across application type, since waterhemp control from ethofumesate PPI (preplant incorporated) did not interact with ethofumesate PRE (P-Value = 0.8926, 0.7840, 0.6326, 0.4246, 0.2129 and 0.3762, approximately 20, 30, 40, 50, 60, and 70 DAP (days after planting) evaluation, respectively). Cumulative rainfall was 0.9, 2.6, and 4.5 inches, 14, 30 and 45 DAP and ethofumesate application, in 2022, which was enough to activate the herbicide, regardless of application method, and explains the lack of interaction. However, waterhemp control from ethofumesate at labeled rates failed to reach 85% control.

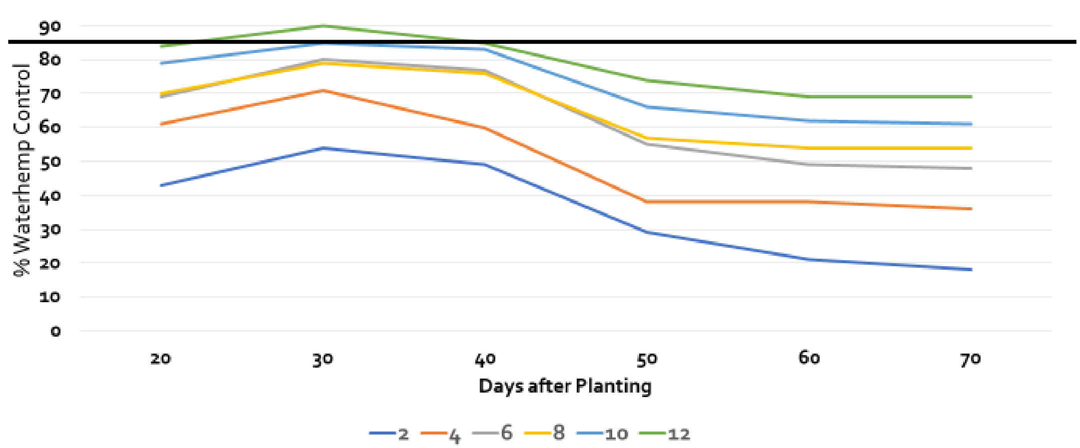


Figure 4. Waterhemp control in response to ethofumesate, averaged across PPI and PRE, Moorhead MN, 2022.

Ethofumesate PPI or PRE is a component in the waterhemp control strategy which includes PRE fb EPOST fb POST application of soil residual herbicides. Sugarbeet reach the 2-lf stage between 14 and 28 DAP, depending on planting date. Ekins and Cronin (1972) reported ethofumesate provides up to 10 weeks of residual broadleaf control. However, Ekins and Cronin did not research waterhemp control. Our 2022 result suggests no more than 6-weeks of waterhemp control (Figure 5) which seems to align with results from previous years.

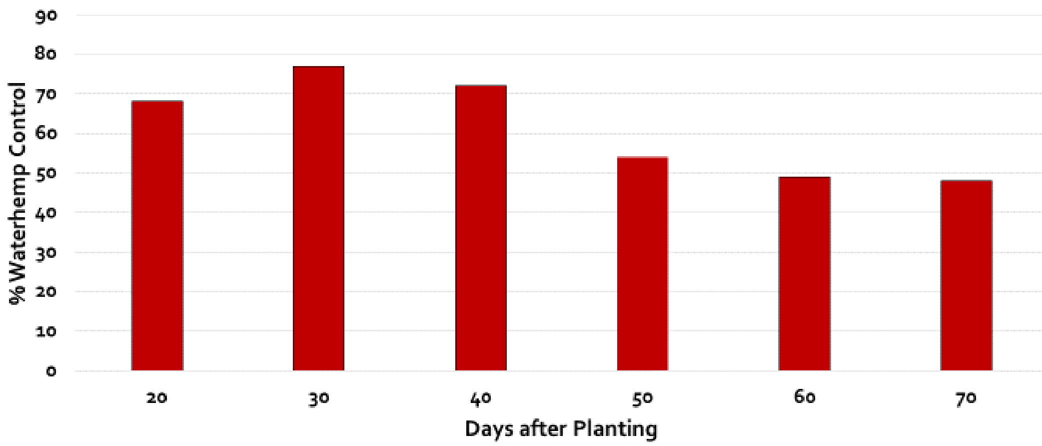


Figure 5. Waterhemp control in response to ethofumesate, averaged across ethofumesate rate and application type, Moorhead MN, 2022

Conclusion

Implementing the layered soil residual strategy is our best opportunity for season-long waterhemp control in sugarbeet. Our best opportunity for a clean start has been an early spring planting date along with an application of ethofumesate alone PRE or ethofumesate mixed with Dual Magnum PRE fb ample rainfall for activation. Our results suggest ethofumesate rate alone does not overcome environmental challenges when timely, adequate, and penetrating rainfall fails to occur. Thus, mixing Dual Magnum with ethofumesate is a strategy to reduce risk, as Dual Magnum adsorbs less to soil and is more water soluble, thus providing short duration control until sufficient rainfall occurs for ethofumesate activation. Incorporating ethofumesate is a risk-aversion strategy, provided ethofumesate is incorporated 0.5- or 1-inch (tillage at 1-inch or 2-inch) with tillage equipment that enables movement of ethofumesate into the soil, thereby maximizing pigweed control.

References

Dexter AG et al. (1981) Comparison of herbicide incorporation tools. Sugarbeet Res Ext Rep 12:49-56.

Edwards D et al. (2005) Reregistration eligibility decision for ethofumesate. Environmental Protection Agency. 738-R-05-010 https://www3.epa.gov/pesticides/chem_search/reg_actions/ reregistration/red_ PC-110601_1-Sep-05.pdf. Accessed: January 28, 2020

Ekins WL, Cronin CH (1972) NC 8438, a promising new broad spectrum herbicide for sugar beet. J Amer Soc Sugar Beet Technol 17:134–143

Entz MH (1982) Ethofumesate (Norton) layering—a comparison of different application times. Sugarbeet Res Ext Rep 13:76–79

Kellogg M (2011) Willowood ethofumesate 4SC. EPA. https://www3.epa.gov/pesticides/chem_search/ppls/087290-00001-20110411.pdf. Accessed: January 28, 2020

Schweizer EE (1975) Crop response to soil application of ethofumesate. Weed Sci 23:409–413

Shaner DL (2014) Herbicide Handbook. 10th edn. Lawrence, KS: Weed Science Society of America. 513 p

WATERHEMP CONTROL FROM SOIL RESIDUAL PREEMERGENCE AND POSTEMERGENCE HERBICIDES IN 2022

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Summary

1. Layering soil residual herbicides, beginning with preemergence (PRE) herbicide at planting, is our most effective strategy for controlling waterhemp in sugarbeet.
2. Differences in waterhemp control may occur, especially when rainfall is absent or not timely.
3. We do not completely understand the environmental conditions where ethofumesate fails to provide waterhemp control or why lack of control occurs.
4. Roundup PowerMax3 mixed with Ultra Blazer improved waterhemp control when soil residual herbicides failed due to lack of rainfall for activation.
5. Ultra Blazer mixed with Roundup PowerMax3 causes significant sugarbeet growth reduction injury which may cause loss of root yield compared with our soil residual waterhemp control standards, despite providing very good waterhemp control.

Introduction

Waterhemp control is our most important weed management challenge in sugarbeet according to the annual growers survey. Waterhemp is both common and troublesome in fields planted to sugarbeet for multiple reasons including full-season germination and emergence, prolific seed production, genetic diversity, and herbicide resistance. To date, waterhemp has shown resistance to herbicides from six classes, including Group 5 (e.g., triazines like atrazine), Group 2 (e.g., ALS-inhibiting herbicides like Pursuit), Group 14 (e.g., PPO-inhibiting herbicides like Ultra Blazer and Flexstar), Group 9 (e.g., glyphosate), Group 27 (e.g., HPPD-inhibiting herbicides like Callisto and Laudis), and Group 4 (e.g., 2,4-D).

The foundation of the waterhemp control program in sugarbeet is layered use of chloroacetamide (Group 15) herbicides PRE, early postemergence (EPOST), and POST, alone or in combination with glyphosate and ethofumesate, in sugarbeet (Figure 1). The goal is to have layered residual herbicides in the soil from planting through canopy closure, in late June or early July, to control waterhemp emergence.

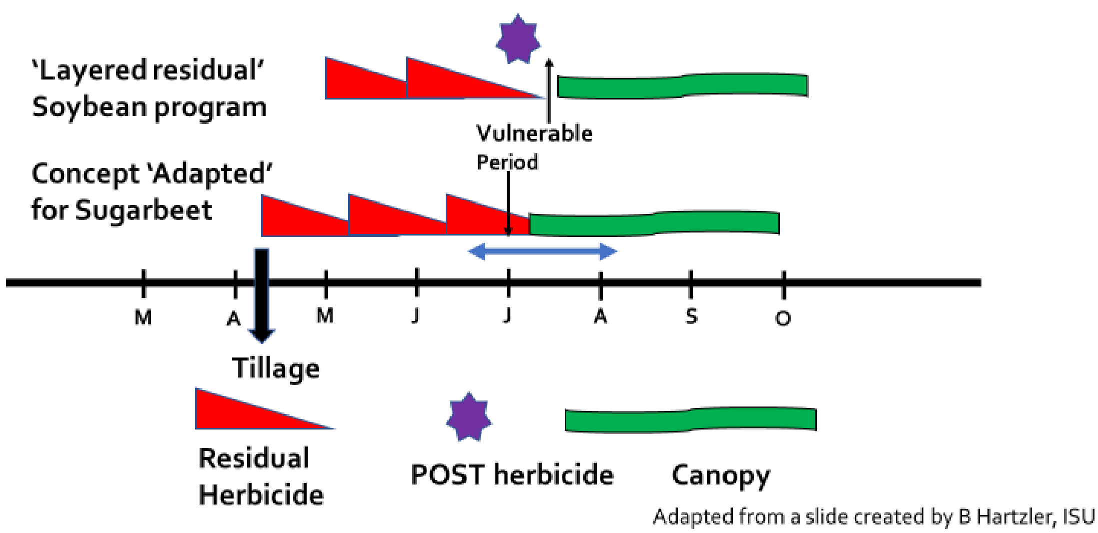

Figure 1. A demonstration of layered soil residual herbicides creating a herbicide barrier in soil from planting through canopy closure.

Calendar year 2022 created some unique challenges for sugarbeet growers. First, the spring was wet, resulting in average planting dates approximately 21 days later than the 20-year averages. Second, June and July rainfall were below normal in areas, compromising activation of soil residual herbicides (Figure 2).

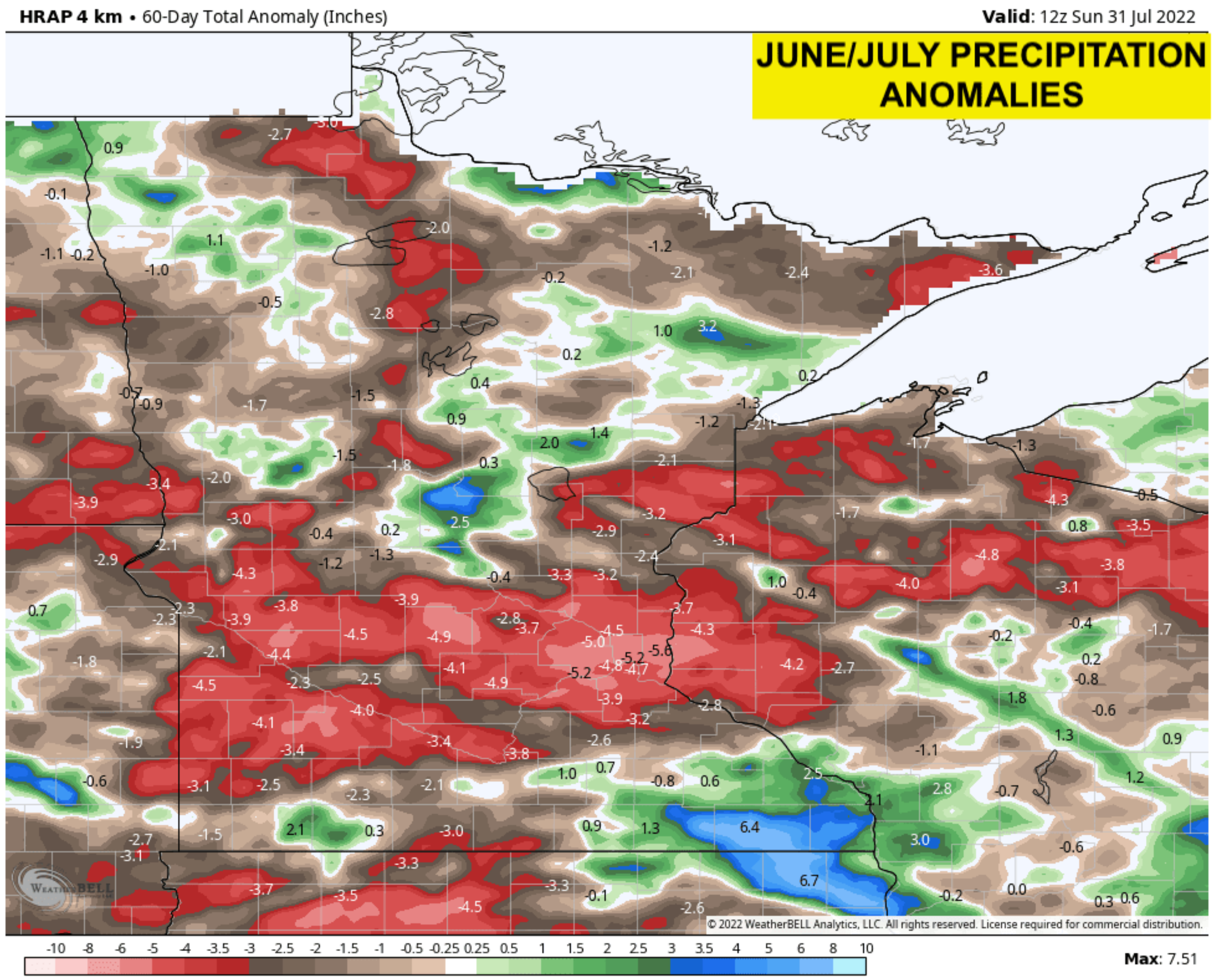

Figure 2. June and July, 2022 precipitation anomalies, Bring Me the News, Meteorologist Sven Sundgaard https://bringmethenews.com/minnesota-weather/july-2022-in-minnesota-was-hotter-windier-and-drier-than-normal.

The objectives of these experiments were 1) to demonstrate a weed control system for waterhemp control in sugarbeet, 2) to reinforce previous waterhemp control messages and practices for audiences with experience in waterhemp control, and 3) to examine differences in waterhemp control across experiments and investigate factors contributing to control.

Materials and Methods

Experiments were conducted near Blomkest, Moorhead, and Sabin, MN in 2022. Treatments are listed in Table 1. The experimental area was prepared for planting by fertilizing and conducting tillage across the experimental area. Sugarbeet was planted on May 27 at Blomkest, May 25 at Moorhead, and May 19 at Sabin in 2022. Sugarbeet was seeded in 22-inch rows at approximately 62,000 seeds per acre with 4.6 inch spacing between seeds. Treatments were applied with a bicycle sprayer in 17 gpa spray solution through XR8002 flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 40 feet in length.

Table 1. Herbicide treatment, rate, and application timing, Blomkest, Moorhead, and Sabin MN, 2022.

Herbicide Treatment PRE	Residual Herbicide Treatment POST[a]	Rate (fl oz/A)	Sugarbeet stage (lvs)
No	PowerMax3 + etho / PowerMax3 + Ultra Blazer[b]	25 + 6 / 25 + 16	2 / 6-8
No	Outlook / Outlook	12 / 12	2 / 6-8
No	Warrant / Warrant	48 / 48	2 / 6-8
No	Outlook / Warrant	12 / 48	2 / 6-8
No	Outlook / Warrant	12 / 64	2 / 6-8
Yes[c]	PowerMax3 + etho / PowerMax3 + Ultra Blazer	25 + 6 / 25 + 16	PRE/2 / 6-8
Yes	Outlook / Outlook	12 / 12	PRE/2 / 6-8
Yes	Warrant / Warrant	48 / 48	PRE/2 / 6-8
Yes	Outlook / Warrant	12 / 48	PRE/2 / 6-8
Yes	Outlook / Warrant	12 / 64	PRE/2 / 6-8

[a]Roundup PowerMax3 at 25 fl oz/A + ethofumesate at 6 fl oz/A + Destiny HC High Surfactant Methylated Oil Concentrate (HSMOC) at 1.5 pt/A and Amsol Liquid AMS at 2.5% v/v applied with every POST application that did not contain Ultra Blazer.
[b]Ultra Blazer applied with Roundup PowerMax 3 at 25 fl oz/A + Prefer 90 NIS at 0.25% v/v + Amsol Liquid AMS at 2.5% v/v.
[c]Ethofumesate + Dual Magnum at 2+0.5 pt/A PRE at Bloomkest and Sabin or ethofumesate at 6 pt/A PRE at Moorhead.

Visible sugarbeet growth reduction injury was evaluated using a 0 to 100% scale with 0% representing no visible injury and 100% as complete loss of plant / stand) approximately 7 and 14 days (+/- 3 days) following the 6-8 leaf application. Visible waterhemp control was evaluated using a 0 to 100% scale (0% indicating no control and 100% indicating complete weed control) and was collected 59, 90, and 94 days after planting. Experimental design was randomized complete block with four replications in a factorial treatment arrangement, factors being PRE and POST herbicide treatments. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

At harvest, sugarbeet was defoliated and harvested mechanically from the center two rows of each plot and weighed at Moorhead and Sabin, MN. An approximate 30-pound sample was collected from each plot and analyzed for sucrose content and sugar loss to molasses by American Crystal Sugar Company (East Grand Forks, ND).

Results

Experiments at Blomkest and Moorhead, MN were planted later than average due to continuous spring rainfall in 2022. As a result, sugarbeet stands were variable at both locations. At Moorhead, experiments were planted into a cloddy seedbed. It was extremely dry at planting at Blomkest. In addition, excessively strong winds on June 21 partially defoliated sugarbeet. Timely rainfall events were measured at Moorhead in June and July following herbicide applications and in July at Sabin, MN; however, rainfall was much less at the Blomkest location (Table 2).

Table 2. Cumulative rainfall the first 10 days following herbicide application, across locations, 2022.

Herbicide Treatment	Moorhead, MN[a]	Sabin, MN	Blomkest, MN[b]
	----------------	inch	----------------
PRE Application	1.0	0.5	0.9
EPOST Application	1.7	0.4	0.0
POST Application	1.8	2.4	0.5
Total:	**4.5**	**3.3**	**1.4**

[a]Moorhead and Sabin precipitation data collected from nearby weather stations operated by North Dakota Agricultural Weather Network (NDAWN)
[b]Blomkest precipitation data collected using weather station instrumentation by Campbell Scientific.

Sugarbeet injury from soil residual herbicides ranged from 0% to 29% across evaluations and experiments (Table 3). Sugarbeet injury from soil residual herbicides tended to be greatest at Sabin and was less at Bloomkest and Moorhead. Assessment of sugarbeet injury at Bloomkest was complicated by erratic stands due to dry conditions and strong winds, which partially defoliated sugarbeet. At Sabin, sugarbeet injury from soil residual herbicides was observed 7 days after treatment (DAT) and remained visible 14 DAT, especially from PRE / EPOST / POST treatments.

Sugarbeet injury from Ultra Blazer + Roundup PowerMax3 POST ranged from 35% to 53% across locations and was greater than sugarbeet injury from soil residual herbicides POST (Table 3). Applying ethofumesate or ethofumesate + Dual Magnum PRE did not impact sugarbeet injury from Roundup PowerMax3 + ethofumesate followed by (fb) Roundup PowerMax3 + Ultra Blazer. Sugarbeet injury from Ultra Blazer declined numerically between the first and second evaluation.

Table 3. Sugarbeet visible injury in response to PRE and POST treatment, across locations, 2022.[a]

Herbicide Treatment PRE[c]	Herbicide Treatment POST[d]	Rate	Sugarbeet Injury[b]					
			Sabin, MN		Moorhead, MN		Blomkest, MN	
			7 DAT	17 DAT	10 DAT	15 DAT	9 DAT	18 DAT
		-fl oz/A-	---%					
No	PowerMax3 + etho / PowerMax3 + Ultra Blazer[e]	25 + 6 / 25 + 16	44 d	38 d	50 c	34 b	53 b	46 b
No	Outlook / Outlook	12 / 12	11 a	4 a	0 a	0 a	0 a	6 a
No	Warrant / Warrant	48 / 48	9 a	0 a	0 a	3 a	0 a	11 a
No	Outlook / Warrant	12 / 48	29 c	14 bc	0 a	5 a	0 a	5 a
No	Outlook / Warrant	12 / 64	9 a	3 a	16 b	4 a	0 a	0 a
Yes	PowerMax3 + etho / PowerMax3 + Ultra Blazer	25 + 6 / 25 + 16	50 d	35 d	50 c	48 b	48 b	41 b
Yes	Outlook / Outlook	12 / 12	13 ab	8 ab	0 a	0 a	0 a	5 a
Yes	Warrant / Warrant	48 / 48	20 abc	20 c	11 b	5 a	0 a	3 a
Yes	Outlook / Warrant	12 / 48	24 bc	15 bc	0 a	5 a	0 a	4 a
Yes	Outlook / Warrant	12 / 64	19 abc	4 a	8 a	0 a	0 a	8 a
LSD (0.10)			**12**	**8**	**9**	**8**	**5**	**11**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[b]Sugarbeet injury evaluations were approximately 7 and 14 days after application C, Ultra Blazer.
[c]Ethofumesate + Dual Magnum PRE at 2 + 0.5 pt/A at Blomkest and Sabin. Ethofumesate PRE at 6 pt/A at Moorhead.
[d]Roundup PowerMax3 at 25 fl oz/A + ethofumesate at 6 fl oz/A + Destiny HC High Surfactant Methylated Oil Concentrate (HSMOC) at 1.5 pt/A and Amsol Liquid AMS at 2.5% v/v applied with every POST application that did not contain Ultra Blazer.
[e]Ultra Blazer applied with Roundup PowerMax 3 at 25 fl oz/A + Prefer 90 NIS at 0.25% v/v + Amsol Liquid AMS at 2.5% v/v.

Waterhemp (with some redroot pigweed) control ranged from 36% to 96% across treatments and locations (Table 4). The average control across all treatments was 52%, 93% and 95% for Blomkest, Moorhead and Sabin, respectively. At Sabin, repeat Warrant applications or Outlook fb Warrant tended to provide waterhemp control greater than repeat Outlook applications. Addition of ethofumesate mixtures with Dual Magnum PRE did not improve waterhemp control. Waterhemp control was greatest from Roundup PowerMax3 mixtures with soil residual herbicides at Sabin compared with other locations.

Waterhemp control from soil residual herbicides applied POST which contained Warrant, or Outlook followed by Warrant, provided similar waterhemp control at Moorhead and Sabin. PRE herbicides followed by POST herbicides tended to provide waterhemp control similar to POST treatments alone. The exception was at Moorhead where the absence of PRE herbicides resulted in reduced waterhemp control from repeat POST Outlook applications.

Ultra Blazer mixed with Roundup PowerMax3 following ethofumesate PRE provided or tended to provide waterhemp control similar to soil residual herbicides POST. However, control was less when Ultra Blazer and Roundup PowerMax3 were applied without PRE ethofumesate.

Table 4. Waterhemp control in response to PRE and POST treatment, across location, 2022.[a]

Etho or Etho+DM PRE[b]	Soil Residual Treatment POST[c]	Rate	Waterhemp Control Blomkest, MN 59 DAP[d]	Moorhead, MN 90 DAP	Sabin, MN 94 DAP
		--fl oz/A--	--------------------------%-----------------------		
No	PowerMax3 + etho / PowerMax3 + Ultra Blazer[e]	25 + 6 / 25 + 16	63 ab	63 c	84 c
No	Outlook / Outlook	12 / 12	36 e	89 b	97 ab
No	Warrant / Warrant	48 / 48	54 bc	99 a	98 ab
No	Outlook / Warrant	12 / 48	43 de	96 ab	98 ab
No	Outlook / Warrant	12 / 64	54 bc	99 a	99 a
Yes	PowerMax3 + etho / PowerMax3 + Ultra Blazer	25 + 6 / 25 + 16	71 a	98 a	90 bc
Yes	Outlook / Outlook	12 / 12	43 de	99 a	98 ab
Yes	Warrant / Warrant	48 / 48	49 cd	99 a	99 a
Yes	Outlook / Warrant	12 / 48	56 bc	93 ab	92 ab
Yes	Outlook / Warrant	12 / 64	49 cd	99 a	96 ab
LSD (0.10)			**9**	**9**	**9**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[b]Ethofumesate + Dual Magnum PRE at 2 + 0.5 pt/A at Blomkest and Sabin. Ethofumesate PRE at 6 pt/A PRE at Moorhead.
[c]Roundup PowerMax3 at 25 fl oz/A + ethofumesate at 6 fl oz/A + Destiny HC High Surfactant Methylated Oil Concentrate (HSMOC) at 1.5 pt/A and Amsol Liquid AMS at 2.5% v/v applied with every POST application that did not contain Ultra Blazer.
[d]DAP=Days after plant
[e]Ultra Blazer applied with Roundup PowerMax3 at 25 fl oz/A + Prefer 90 NIS at 0.25% v/v + Amsol Liquid AMS at 2.5% v/v.

Waterhemp control from PRE herbicides were inconsistent and unacceptable at Blomkest, MN. We credit trial inconsistency to variable weed pressure across the experiment due to dry conditions in June. An on-site rainfall collection device recorded 0.79 inches of rainfall May 30 or three days after PRE application (Table 5). This rainfall event should have been sufficient to activate ethofumesate and Dual Magnum PRE. However, sub-optimal weed control was observed on June 21 (data not included in this report) contributing to the overall lack of control, even from PRE herbicides at Blomkest. We believe the lack of early season waterhemp control from the PRE herbicides contributed to the lack of POST control from glyphosate, ethofumesate and soil residual herbicides.

Table 5. Hourly rainfall measurements, May 30, 2022, near Blomkest, MN.[a]

Hour	Rainfall (inch)
Midnight to 5:00AM	0.00
5:00AM to 7:00AM	0.04
8:00AM to 9:00AM	0.27
9:00AM to 10:00AM	0.17
10:00AM to noon	0.10
1:00PM to 5:00PM	0.01
6:00PM to 7:00PM	0.18
7:00PM to 8:00PM	0.02
8:00PM to midnight	0.00

[a] Blomkest precipitation data collected using weather station instrumentation by Campbell Scientific.

Sabin was also very dry in early June. However, in contrast to Blomkest, we do not believe there was waterhemp seed germination and emergence throughout May and the first half of June at Sabin, MN. We did have sufficient moisture for sugarbeet emergence and observed uniform stands. Soil residual herbicides were activated by late June and July rainfall, resulting in excellent weed control. We are unsure if the PRE herbicide treatment was activated at Sabin; however, the POST herbicide treatments delivered effective control as compared with the control strips imbedded in the experiment.

Ultra Blazer mixed with Roundup PowerMax3 alone or following ethofumesate at 6 pt/A PRE reduced sugarbeet root yield and recoverable sucrose as compared with soil residual herbicides mixed with Roundup PowerMax3 (Table 6). Herbicide treatments did not affect % sucrose.

Ultra Blazer was mixed with Roundup PowerMax3 in 2022. Roundup PowerMax3 was a new glyphosate formulation, containing 5.88 pounds of glyphosate per gallon as compared with 4.6 pounds of glyphosate per gallon in Roundup PowerMax. The experiments did not contain either the Roundup PowerMax3 alone treatment or Roundup PowerMax plus Ultra Blazer treatment.

Table 6. Root yield, % sucrose and recoverable sucrose in response to herbicide treatment, Moorhead MN, 2022.[a]

Etho PRE[b]	Soil Residual Treatment POST[c]	Rate	Root Yield	Sucrose	Recoverable sucrose/A
		--fl oz/A--	---TPA[d]---	---%---	----lb/A----
No	PowerMax3 + etho / PowerMax3 + Ultra Blazer[e]	25 + 6 / 25 + 16	21.2 c	14.9	5,658 c
No	Outlook / Outlook	12 / 12	26.5 ab	15.1	7,147 ab
No	Warrant / Warrant	48 / 48	27.5 a	14.7	6,900 ab
No	Outlook / Warrant	12 / 48	29.1 a	15	7,838 a
No	Outlook / Warrant	12 / 64	28.4 a	15.2	7,237 ab
Yes	PowerMax3 + etho / PowerMax3 + Ultra Blazer	25 + 6 / 25 + 16	24.0 b	14.9	6,280 bc
Yes	Outlook / Outlook	12 / 12	26.8 a	15.1	7,236 ab
Yes	Warrant / Warrant	48 / 48	28.5 a	15.3	7,895 a
Yes	Outlook / Warrant	12 / 48	27.2 a	14.8	7,124 ab
Yes	Outlook / Warrant	12 / 64	28.1 a	15.1	7,683 a
LSD (0.10)			**2.7**	**NS**	**1,031**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[b]Ethofumesate at 6 pt/A PRE applied at Moorhead.
[c]Roundup PowerMax3 at 25 fl oz/A + ethofumesate at 6 fl oz/A + Destiny HC High Surfactant Methylated Oil Concentrate (HSMOC) at 1.5 pt/A and Amsol Liquid AMS at 2.5% v/v applied with every POST application that did not contain Ultra Blazer.
[d]TPA=Tons per acre.
[e]Ultra Blazer applied with Roundup PowerMax3 at 25 fl oz/A + Prefer 90 NIS at 0.25% v/v + Amsol Liquid AMS at 2.5% v/v.

Our best research practices are not to harvest weed control experiments. In this situation, however, we felt that quantifying yield from sugarbeet treated with Ultra Blazer in a waterhemp rich environment would enable us to demonstrate that weed control from Ultra Blazer might off-set sugarbeet injury.

Conclusion

Rainfall is critical for achieving satisfactory waterhemp control from soil residual herbicides. Evaluating the impact of moisture on herbicide activity was not the primary objective for the experiment, but the observations around the relationship of moisture and herbicide activity became an important benefit from the experiment, especially considering the lack of waterhemp control experienced by many growers in Southern Minnesota Beet Sugar Coop and Minn-Dak Farmers Coop in 2022. This research reinforces that a strategy to layer soil residual herbicides, starting at planting, is our best program for controlling waterhemp in sugarbeet. Finally, this research demonstrated excellent sugarbeet safety from the chloroacetamide herbicides, that the three chloroacetamide herbicides available in sugarbeet are equally effective at providing waterhemp control, and that the differences in waterhemp control among chloroacetamide products are minor.

SUGARBEET TOLERANCE FROM ULTRA BLAZER

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Summary
1. Environmental conditions at application and adjuvants influence sugarbeet tolerance and waterhemp control.
2. Yield parameters support either repeat Ultra Blazer applications at 12 fl oz/A followed by (fb) 12 fl oz/A with non-ionic surfactant or Ultra Blazer at 16 fl oz/A with Crop Oil Concentrate (COC).
3. Greater sugarbeet injury was observed from Ultra Blazer mixtures with Roundup PowerMax3 in 2022 than with Roundup PowerMax in previous years.
4. Acifluorfen use in sugarbeet requires a compromise between sugarbeet injury and waterhemp control.

Introduction
Ultra Blazer (acifluorfen) was repurposed into sugarbeet in 2019 and 2020 to replace Betamix (desmedipham & phenmedipham) and provide control of glyphosate-resistant (GR) waterhemp in sugarbeet. The Environmental Protection Agency (EPA) approved a request for a Section 18 emergency exemption for Ultra Blazer for control of escaped waterhemp in sugarbeet in Minnesota and eastern North Dakota in 2021 and 2022. The exemption allowed a single Ultra Blazer application at 16 fluid ounces per acre per year, either alone or mixed with Roundup PowerMax(3). A Section 18 exemption under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) authorizes EPA to allow an unregistered use of a pesticide for a limited time, if EPA determines that an emergency condition exists.

Our 2022 Ultra Blazer Section 18 emergency exemption label provided flexibility and recommended Ultra Blazer at 16 fl oz/A either alone, with non-ionic surfactant at 0.125% v/v, or mixed with Roundup PowerMax3 and ammonium sulfate at 2.5% v/v, but without NIS, depending on situation (Table 1). However, our challenge has been to optimize waterhemp control without increasing sugarbeet injury. Sugarbeet must be greater than the 6-lf stage and waterhemp less than 4-inches (preferred) for selective control while reducing injury potential.

Table 1. Herbicide treatment, rate, and application timing, Ultra Blazer Section 18 emergency exemption, 2022.

Treatment	Rate (fl oz/A)	Sugarbeet Stage (lvs)
Ultra Blazer	16	>6
Ultra Blazer + Prefer 90 NIS	16 + 0.125% v/v	>6
Ultra Blazer + Roundup PowerMax + Amsol Liquid AMS	16 + 28 + 2.5 % v/v	>6

We have learned that sugarbeet injury increases when oil-based adjuvants or herbicides are mixed with Ultra Blazer. We have also learned that Ultra Blazer is more active on sugarbeet and waterhemp when the maximum day-time temperature is 85°F as compared with 75°F. The objective of this experiment was to determine sugarbeet visible injury, root yield, % sucrose, and recoverable sucrose from Ultra Blazer with adjuvants or mixtures with glyphosate.

Materials and Methods
Experiments conducted near Crookston, Hendrum, Nashua, Lake Lillian, and Murdock, MN in 2022 evaluated sugarbeet tolerance from Ultra Blazer alone or mixed with glyphosate (Roundup PowerMax3). The experimental area was prepared for planting by applying the appropriate fertilizer and tillage. Sugarbeet was seeded in 22-inch rows at about 62,000 seeds per acre with 4.6 inch spacing between seeds. Treatments shown in Table 2 were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 40 feet in length. Environmental conditions at application are in Table 3.

Table 2. Herbicide treatment, herbicide rate, and application timing across locations in 2022.

Herbicide Treatment	Rate (fl oz/A)	Application timing (SGBT leaf stage)
Ultra Blazer + Prefer 90 NIS	16 + 0.25%	6-8 lf
Ultra Blazer + Prefer 90 NIS / Ultra Blazer + Prefer 90 NIS	12 + 0.125% / 12 + 0.125 %	6-8 lf / A + 7-day
Ultra Blazer + Crop Oil Concentrate	16 + 0.25%	6-8 lf
Roundup PowerMax3 + Ultra Blazer + Amsol Liquid AMS	25 + 16 + 2.5% v/v	6-8 lf
Roundup PowerMax3 + Ultra Blazer + Prefer 90 NIS + Amsol Liquid AMS	25 + 16 + 0.25% + 2.5% v/v	6-8 lf
Roundup PowerMax3 + Prefer 90 NIS + Amsol Liquid AMS / Roundup PowerMax3 + Prefer 90 NIS + Amsol Liquid AMS	25 + 0.25% + 2.5% v/v / 25 + 0.25% + 2.5% v/v	2 lf / 6 lf

Table 3. Application information.

	Crookston	Hendrum	Murdock	Lake Lillian
Date	June 24	July 5	June 22	June 22
Time of Day	10:00 AM	1:00 PM	6:00 AM	4:00 PM
Air Temperature (F)	80	73	-	84
Relative Humidity (%)	57	67	29	29
Wind Velocity (mph)	15	4	6	9
Wind Direction	NNW	NNE	NW	W
Soil Temp. (F at 6”)	70	-	74	-
Soil Moisture	Fair	Dry	Dry	Dry
Cloud Cover (%)	100	100	10	10

Visible sugarbeet necrosis, malformation, and growth reduction were evaluated approximately 7 and 14 days after treatment (DAT) as sugarbeet injury using a 0 to 100% injury scale with 0% denoting no sugarbeet injury and 100% denoting complete loss of sugarbeet stature. All evaluations were a visual estimate of injury in the four treated rows compared to the adjacent, two-row, untreated strip.

At harvest, sugarbeet was defoliated, harvested mechanically from the center two rows of each plot, and weighed. A root sample (about 20 lbs) was collected from each plot and analyzed for sucrose content and sugar loss to molasses by American Crystal Sugar Company (East Grand Forks, MN). Experimental design was randomized complete block with six replications. Data were analyzed in this report as a RCBD with the ANOVA procedure of ARM, version 2022.5 software package.

Results

Sugarbeet injury was evaluated multiple times throughout the growing season; however, only the evaluation of injury approximately 14 DAT is presented in Table 4. A very heavy rain event at Nashua, 6 days after planting, impacted sugarbeet stand and compromised the experimental area. We, therefore, elected to not present sugarbeet injury or yield data from Nashua, MN, due to variability.

Necrosis injury was evaluated as the percent of sugarbeet leaf area that was bronzed from Ultra Blazer application (Figure 1). Necrosis injury was greatest from repeat Ultra Blazer applications of 12 fl oz/A fb 12 fl oz/A as compared with a single application of 16 fl oz/A and was consistent across locations (Table 4). Application of Roundup PowerMax3 mixed with Ultra Blazer increased necrosis injury as compared with Ultra Blazer alone. Roundup PowerMax3 alone did not cause necrosis injury to sugarbeet. Visual necrosis was most severe at Hendrum and Lake Lillian, MN.

Sugarbeet growth reduction from Ultra Blazer at 16 fl oz/A plus NIS ranged from 5% to 21% across locations (Table 4). Comparatively, sugarbeet growth reduction either increased, decreased, or remained the same, depending on location, from Ultra Blazer plus crop oil concentrate or from repeat applications of Ultra Blazer plus non-ionic surfactant, with no definitive pattern of growth reduction injury observed. However, sugarbeet growth was consistently reduced from Ultra Blazer plus Roundup PowerMax3 across all locations, regardless of adjuvant use.

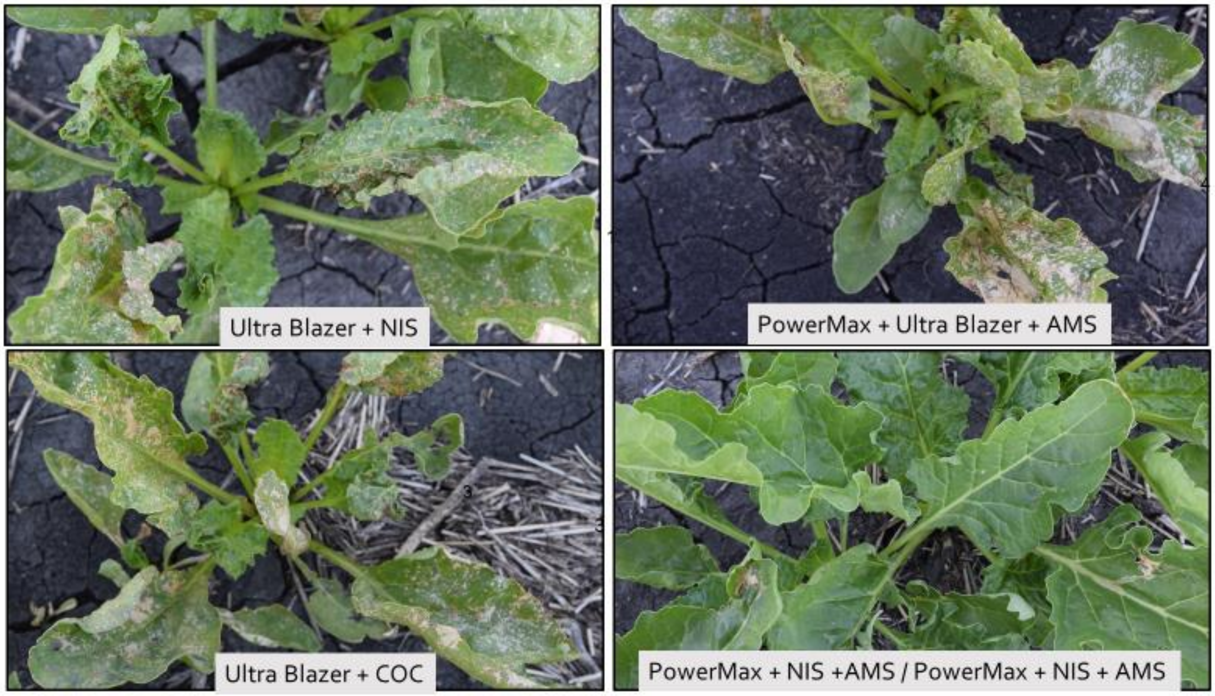

Figure 1. Sugarbeet necrosis injury symptoms in response to Ultra Blazer at 16 fl oz/A plus NIS or COC or mixed with Roundup PowerMax3 at 25 fl oz/A plus AMS as compared with repeat Roundup PowerMax3 at 25 fl oz/A plus NIS plus AMS, Hendrum, MN, 2022.

Table 4. Sugarbeet visible injury from herbicide treatments, across locations, 2022.[a]

		Sugarbeet Injury							
		Crookston		Hendrum		Murdock		Lake Lillian	
Herbicide Treatment	**Rate**	**Nec.[b]**	**GR**	**Nec.**	**GR**	**Nec.**	**GR**	**Nec.**	**GR**
	----fl oz/A----	---------------------------------%-------------------------------------							
Ultra Blazer + Prefer 90 NIS	16 + 0.25%	2 a	21 b	33 b	19 b	0 a	5 a	8 b	12 ab
Ultra Blazer + Prefer 90 NIS / Ultra Blazer + Prefer 90 NIS	12 + 0.125% / 12 + 0.125 %	24 b	17 ab	90 e	26 c	37 b	14 b	38 d	16 bc
Ultra Blazer + Crop oil concentrate	16 + 0.25%	2 a	14 a	46 c	29 c	2 a	13 b	8 b	12 ab
Roundup PowerMax3 + Ultra Blazer + Amsol Liquid AMS	25 + 16 + 2.5% v/v	5 a	32 c	58 d	42 d	2 a	21 c	18 c	23 c
Roundup PowerMax3 + Ultra Blazer + Prefer 90 NIS + Amsol Liquid AMS	25 + 16 + 0.25% + 2.5% v/v	5 a	29 c	50 c	38 d	2 a	25 c	23 c	13 abc
Roundup PowerMax3 Prefer 90 NIS + Amsol Liquid AMS / Roundup PowerMax3 + Prefer 90 NIS + Amsol Liquid AMS	25 + 0.25% + 2.5% v/v / 25 + 0.25% + 2.5% v/v	0 a	12 a	0 a	5 a	0 a	0 a	0 a	4 a
LSD (0.10)		**5**	**6**	**8**	**7**	**3**	**6**	**6**	**10**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 10% level of significance.
[b] Nec. = Visual necrosis and GR = growth reduction collected approximately 14 days after treatment (±3 days).

Sugarbeet injury from Ultra Blazer reduced sugarbeet stature (Figure 2). Stature reduction is greatest when Ultra Blazer is mixed with either oil-based adjuvants or herbicides and the air temperature is 85°F at or later in the day of application. However, sugarbeet rapidly recover from Ultra Blazer injury by producing new leaves (Figure 3).

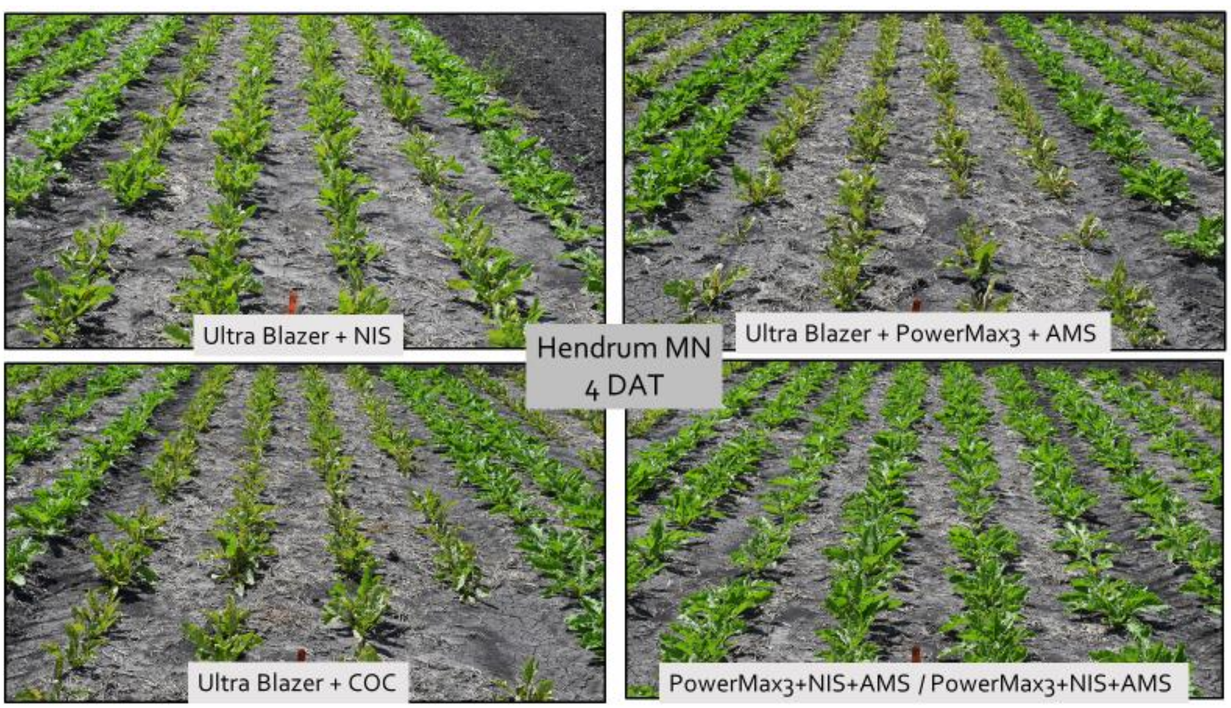

Figure 2. Sugarbeet injury in response to Ultra Blazer alone or mixed with Roundup PowerMax3 as compared with repeat Roundup PowerMax3 application, 4 DAT, Hendrum MN, 2022.

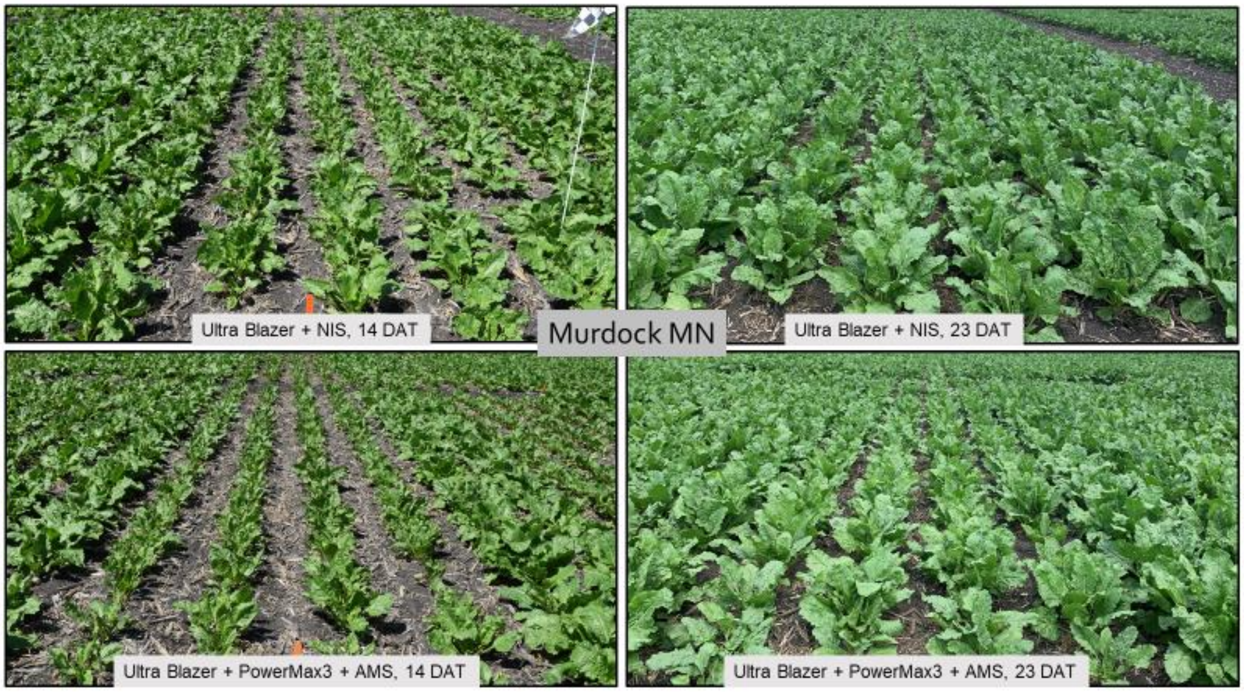

Figure 3. Sugarbeet regrowth following Ultra Blazer or Ultra Blazer mixtures with Roundup PowerMax3, Murdock, MN, 2022.

Not all yield parameters were significantly different at each individual location; however, we have elected to combine yield data and present differences across all locations in Table 5. Root yield and recoverable sucrose from a single application of Ultra Blazer plus NIS, Ultra Blazer plus COC, or repeat applications of Ultra Blazer plus NIS, generally were the same as the glyphosate control. Root yield and recoverable sucrose were less when Ultra Blazer was mixed with Roundup Powermax3 and Amsol or Amsol plus NIS. Ultra Blazer plus Roundup PowerMax3 consistently reduced root yield across locations compared with either product applied alone.

Table 5. Sugarbeet root yield, % sucrose, and recoverable sucrose in response to herbicide treatment across four locations, 2022.[a]

Herbicide Treatment	Rate	Root Yield	Sucrose	Recoverable Sucrose
	----------fl oz/A----------	-Ton/A-	--%--	---lb/A---
Ultra Blazer + Prefer 90 NIS	16 + 0.25%	31.0 b	16.0	8,504 abc
Ultra Blazer + Prefer 90 NIS / Ultra Blazer + Prefer 90 NIS	12 + 0.125% / 12 + 0.125 %	31.7 ab	16.1	8,770 a
Ultra Blazer + Crop oil concentrate	16 + 0.25%	31.4 ab	16.0	8,606 ab
Roundup PowerMax3 + Ultra Blazer + Amsol Liquid AMS	25 + 16 + 2.5% v/v	30.0 c	16.0	8,167 bc
Roundup PowerMax3 + Ultra Blazer + Prefer 90 NIS + Amsol Liquid AMS	25 + 16 + 0.25% + 2.5% v/v	29.4 c	16.0	7,974 c
Roundup PowerMax3 + Prefer 90 NIS + Amsol Liquid AMS / Roundup PowerMax3 + Prefer 90 NIS + Amsol Liquid AMS	25 + 0.25% + 2.5% v/v/ 25 + 0.25% + 2.5% v/v	32.8 a	16.1	8,963 a
P-Value (0.05)		**0.0040**	**NS**	**0.0123**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 5% level of significance.

Roundup PowerMax3 contains the active ingredient glyphosate in the form of potassium salt at 5.88 pound per gallon as compared with potassium salt at 4.5 pounds per gallon in Roundup PowerMax. An increase in sugarbeet injury from Ultra Blazer mixtures with Roundup PowerMax was previously observed. However, we did not observe the magnitude of injury, nor did we observe loss in root yield and recoverable sucrose, from Ultra Blazer mixtures with Roundup Powermax (PowerMax vs. PowerMax3). Observations of increased phytotoxicity from Roundup PowerMax3 as compared with Roundup PowerMax tank mixed with other actives has been observed by other researchers (personal communication with Brett Miller, Syngenta).

Conclusion

The 2022 Ultra Blazer experiment was designed to determine if sugarbeet injury in response to Ultra Blazer could be reduced. Sugarbeet rapidly recovers from necrosis and growth reduction injury from Ultra Blazer plus NIS. The addition of COC with Ultra Blazer increases sugarbeet injury as compared with Ultra Blazer plus NIS; however, injury was less than Ultra Blazer mixtures with Roundup PowerMax3. A remedy to sugarbeet injury that may increase waterhemp control is applying split applications of Ultra Blazer at 12 fl oz/A plus NIS; however, we cannot avoid growth reduction or necrosis injury with split applications. Matter of fact, necrosis injury persists longer from repeat Ultra Blazer applications as compared with single applications; however, reduction in yield parameters did not occur. Ultra Blazer tank-mixtures with Roundup PowerMax3 and AMS or with AMS plus NIS caused significant sugarbeet injury that persisted and negatively impacted yield. We suggest utilizing single Ultra Blazer applications at 16 fl oz/A plus adjuvants or repeat applications of Ultra Blazer at 12 fl oz/A with NIS instead of Ultra Blazer mixtures with Roundup PowerMax3, unless there are significant waterhemp control challenges. Further research is needed to improve the tolerance of sugarbeet to these treatments in order to maintain yield parameters while optimizing waterhemp control.

REINVENTING COMMON RAGWEED CONTROL WITH STINGER HL IN SUGARBEET

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Summary

1. Apply Stinger HL at 1.8 to 2.4 fl oz/A for control of common ragweed less than 2-inches.
2. Repeat Stinger HL applications at 1.8 followed by (fb) 1.8 fl oz/A on common ragweed less than 2-inches.
3. Apply Stinger HL at 2.4 fl oz/A for control of common ragweed greater than 2-inches but less than 4-inches.
4. Repeat Stinger HL applications at 1.8 fb 1.8 fl oz/A or 2.1 fb 2.1 fl oz/A on common ragweed greater than 2-inches but less than 4-inches.
5. Stinger HL maybe applied in mixtures with glyphosate, ethofumesate, and a chloroacetamide herbicide.

Introduction

Common ragweed is a troublesome summer annual broadleaf weed in sugarbeet in Minnesota and North Dakota. Growers attending the 2022 sugarbeet growers' seminars reported common ragweed as their second most troublesome weed following waterhemp. Past experiments investigating chemical control options reported targeting common ragweed less than 2-inches with repeat glyphosate plus clopyralid applications at 28 fl oz/A plus 4 fl oz/A, respectively, provided 92% control. Repeat applications of clopyralid plus glyphosate were more effective on both small (≤2 inches) and larger (≤4 inches) common ragweed; however, common ragweed 6-inches or greater were too large for POST control in sugarbeet. Recent greenhouse evaluation of common ragweed sourced from fields with weed control failures confirmed that the application of glyphosate alone is no longer an effective mode of action for common ragweed control. In addition, certain common ragweed populations from 2021 also demonstrated alarming tolerance to clopyralid; however, clopyralid eventually provided common ragweed suppression at 6 fl oz/A.

The objectives of this experiment were to 1) continue research focused on applications timed to common ragweed stage of growth and 2) identify appropriate Stinger HL use rates to improve common ragweed control.

Materials and Methods

Experiments were conducted on natural populations of common ragweed near Ada, MN in 2022. Plot area was located in a commercial sugarbeet field under conventional tillage. Sugarbeet was seeded 1.25 inches deep in 22-inch spaced rows at 62,000 seeds per acre on May 26. Herbicide treatments were applied June 9, 17, 22, and 27 (Table 1). All treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 40 feet in length in a field with moderate levels of glyphosate-resistant common ragweed.

Table 1. Application Information.

Application Code	A	B	C	D
Date	June 9	June 17	June 22	June 27
Time of Day	11:00 AM	2:00 PM	12:30 PM	9:45 AM
Air Temperature (F)	73	82	77	72
Relative Humidity (%)	32	36	50	53
Wind Velocity (mph)	2	3	6	4
Wind Direction	NNE	NNW	SW	SW
Soil Temp. (F at 6")	60	70	66	60
Soil Moisture	Dry	Dry	Fair	Fair
Cloud Cover (%)	0	100	80	0
Sugarbeet stage (avg)	2 lf	2-4 lf	6-8 lf	8 lf
Common Ragweed (avg)	1"	2"	3"	4"

Sugarbeet injury and weed control were evaluated on June 22 and 28 and July 8 and 16 with one additional weed control evaluation on July 26. All evaluations were a visual estimate of percent fresh weight reduction (0 to 100% control, 0% indicating no control, and 100% indicating complete control) in the four treated rows compared with the adjacent untreated strip. Experimental design was randomized complete block with 4 replications. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Results

Sugarbeet injury was negligible across the experiment; however, injury tended to be greater when herbicide treatments were applied to 6-8 or 8 leaf sugarbeet compared with applications made to 2- or 2-4 leaf sugarbeet (Table 2). Of the treatments applied to 2-leaf sugarbeet, repeat applications of Roundup PowerMax3 plus Stinger HL at 1.8 fl oz/A had the greatest injury at 11%. Likewise, sugarbeet injury was 15% and 13% from repeat applications of Roundup PowerMax3 plus Stinger HL at 1.5 and 1.8 fl oz/A at the 2-4 and 8-leaf sugarbeet stage, respectively.

Table 2. Sugarbeet injury across herbicide treatments, Ada, MN, 2022.[a]

				Sugarbeet Injury	
Herbicide Treatment[b]	**Rate**	**Common Ragweed**	**Sugarbeet**	**June 30**	**July 16**
		----inches---	---lvs---	------------%-----------	
Stinger HL + Roundup PowerMax3	1.2 + 25	<2	2	0 a	0
Stinger HL + Roundup PowerMax3	1.8 + 25	<2	2	0 a	0
Stinger HL + Roundup PowerMax3	2.4 + 25	<2	2	0 a	0
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.5 + 25 / 1.5 + 25	<2 / 10 days	2 / 6-8	4 ab	0
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.8 + 25 / 1.8 + 25	<2 / 10 days	2 / 6-8	11 cd	0
Stinger HL + Roundup PowerMax3	1.2 + 25	2-4	2-4	6 abc	0
Stinger HL + Roundup PowerMax3	1.8 + 25	2-4	2-4	8 bc	0
Stinger HL + Roundup PowerMax3	2.4 + 25	2-4	2-4	11 cd	3
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.5 + 25 / 1.5 + 25	2-4 / 10 days	2-4 / 8	15 d	0
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.8 + 25 / 1.8 + 25	2-4 / 10 days	2-4 / 8	13 cd	0
LSD (0.05)				**7**	**NS**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 5% level of significance.
[b]Roundup PowerMax3 plus Stinger HL treatments were applied with Amsol AMS at 2.5% v/v and Prefer 90 NIS at 0.25% v/v.

Trials conducted in 2014 (Peters and Carlson 2014) and 2018 (Peters and Lystad 2018) had greater sugarbeet injury from Stinger at 2 to 4 fl oz/A plus glyphosate when applied to 4-8 leaf sugarbeet compared with 2-4 leaf sugarbeet (data not presented). Additional trials conducted in 2009 and 2010 had greater sugarbeet injury from two sequential applications of Stinger at 4 fl oz/A compared with a single application of Stinger at 8 fl oz/A (data not presented).

The 2022 trial was similar in both regards with sugarbeet injury tending to be greater from two applications of Stinger HL compared with a single application and greater injury when applications were made to larger sugarbeet compared with smaller sugarbeet. However, there were no differences in sugarbeet injury across treatments at 19 days after the last application.

Common ragweed size impacted control from Stinger HL plus Roundup Powermax3. Herbicide treatments applied to less than 2-inch common ragweed provided greater control than the same treatments applied to 2-4-inch common ragweed (Table 3). On less than 2-inch common ragweed, sequential applications of Stinger HL at 1.8 fl oz/A + Roundup PowerMax3 provided up to 94% common ragweed control compared with a single application at up to 80%, 28 DAT (days after treatment). Similarly, a single application of Stinger HL at 1.8 fl oz/A + Roundup PowerMax3 to 2-4-inch common ragweed gave 63% control while two applications of Stinger HL at 1.8 fl oz/A + Roundup PowerMax3 gave 79% control, 28 DAT.

Table 3. Common ragweed control across herbicide treatments, Ada, MN, 2022.[a]

Herbicide Treatment[b]	Rate	Common Ragweed	Common Ragweed Control July 8 8 DAT[c]	July 16 18 DAT	July 26 28 DAT
		----inches---	------------------%----------------		
Stinger HL + Roundup PowerMax3	1.2 + 25	<2	75 b	61 cd	60 cd
Stinger HL + Roundup PowerMax3	1.8 + 25	<2	91 a	83 b	80 b
Stinger HL + Roundup PowerMax3	2.4 + 25	<2	91 a	87 ab	88 a
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.5 + 25 / 1.5 + 25	<2 / 10 days	91 a	91 ab	89 a
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.8 + 25 / 1.8 + 25	<2 / 10 days	95 a	92 a	94 a
Stinger HL + Roundup PowerMax3	1.2 + 25	2-4	65 c	59 cd	54 c
Stinger HL + Roundup PowerMax3	1.8 + 25	2-4	68 bc	61 cd	63 c
Stinger HL + Roundup PowerMax3	2.4 + 25	2-4	71 c	67 c	65 c
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.5 + 25 / 1.5 + 25	2-4 / 10 days	69 c	69 c	77 b
Stinger HL + Roundup PowerMax3 / Stinger HL + Roundup PowerMax3	1.8 + 25 / 1.8 + 25	2-4 / 10 days	70 bc	69 c	79 b
LSD (0.05)			**6**	**8**	**6**

[a]Means within a rating timing that do not share any letter are significantly different by the LSD at the 5% level of significance.
[b]Roundup PowerMax3 plus Stinger HL treatments were applied with Amsol AMS at 2.5% v/v and Prefer 90 NIS at 0.25% v/v.
[c]DAT=Days after treatment.

Common ragweed control tended to increase as Stinger HL rate increased in both single and sequential applications across all common ragweed sizes. Single applications of Stinger HL at 1.8 fl oz/A or 2.4 fl oz/A plus Roundup PowerMax3 provided 80% and 88% control, respectively, on less than 2-inch common ragweed as compared with Stinger HL at 1.8 fl oz/A or 2.4 fl oz/A plus Roundup PowerMax3 at 63% or 65% control, respectively, on 2-4-inch common ragweed. Stinger HL at 1.2 fl oz/A plus Roundup PowerMax3 did not provide acceptable control, or greater than 90%, across all common ragweed sizes.

Acceptable control was achieved when herbicide applications were made on small common ragweed. Stinger HL rates should be 1.8 to 2.4 fl oz/A plus Roundup PowerMax3, applied to less than 2-inch common ragweed, to provide the best opportunity for greater than 90% control. Sequential applications increase the length of control across small and large common ragweed; however, two sequential applications of Stinger HL at 1.8 fl oz/A plus Roundup PowerMax3 on less than 2-inch common ragweed provided the greatest control. Common ragweed that is 2-4-inches or greater is too big for a POST herbicide program in sugarbeet to provide acceptable control.

Conclusion

Throughout the common ragweed experiments over the years, one message has stayed consistent, which is: Greatest common ragweed control is achieved when sprayed small. We must time our Stinger HL applications to ragweed size rather than sugarbeet stage for optimal common ragweed control. We recommend Stinger HL at 1.8 fl oz/A as the lowest rate applied for common ragweed control. For a single application, we recommend Stinger HL at 2.4 fl oz/A plus Roundup PowerMax3. For sequential applications, we recommend Stinger HL at 1.8 fl oz/A plus Roundup PowerMax3. It is difficult to achieve acceptable control when common ragweed is 2-4-inches. There are no herbicide options that will provide acceptable control for common ragweed that is 6-inches or greater.

If nurse crops are a concern, glyphosate and Stinger HL applications may need to be separated in order to control early emerged common ragweed while maintaining the nurse crop. Stinger HL may be tank-mixed with glyphosate, ethofumesate, and a chloroacetamide, while preserving sugarbeet tolerance.

Literature Cited

1. Peters, TJ and Carlson, AL (2014) Featured weed-common ragweed controlling common ragweed in fields planted to sugarbeet. Sugarbeet Research and Extension Reports.

2. Peters, TJ and Lystad, AL (2018) Controlling common ragweed in fields planted to sugarbeet. Sugarbeet Research and Extension Reports.

KOCHIA CONTROL IN SUGARBEET AND CROPS IN SEQUENCE WITH SUGARBEET

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Summary

1. Kochia, 1-inch to 2-inches tall, is easier to control with glyphosate than kochia 3- to 4-inches tall.
2. Ethofumesate preemergence (PRE) provides good to excellent kochia control when it is activated into the soil, before kochia germination and emergence.
3. Kochia control in the crop sequence is the most effective kochia control in fields to be planted to sugarbeet. However, the landscape is changing with the advent of Group 14 kochia resistant biotypes.
4. Glyphosate applied in relevant mixtures with adjuvants has resulted in the most consistent kochia control in sugarbeet.

Introduction

Glyphosate-resistant (GR) kochia is resurfacing as a weed control challenge in both sugarbeet fields and fields in sequence with sugarbeet in Minnesota, and eastern North Dakota. While waterhemp gets a lot of attention, 57% of respondents attending the Grafton sugarbeet growers' seminar identified kochia as their most important weed control challenge. Growers attending the Grand Forks and Wahpeton seminars called kochia their second most important weed control threat. The challenge with kochia is effective herbicides. There are very few effective kochia control herbicide options in sugarbeet. Conversely, herbicides are a major component of kochia control programs, especially with advent of strip tillage sugarbeet in the northern Red River Valley. Kochia typically emerges in April and May, but some kochia biotypes emerge as late as June (Beckie et al. 2018). Kochia is most severe when drought conditions reduce both sugarbeet stands and early season sugarbeet growth and development. Finally, kochia interferes with sugarbeet root yield by virtue of its rapid growth, resulting in sugarbeet interference due to its enormous growth potential.

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 and eastern North Dakota. 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.

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 herbicide 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 herbicides for kochia control in fallow, wheat, or 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 across the sequence including corn, soybean, spring wheat, and spring barley. However, Brian Jenks at the North Central Research and Extension Center recently reported PPO (Group 14) resistant kochia (Figure 2). Furthermore, 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.

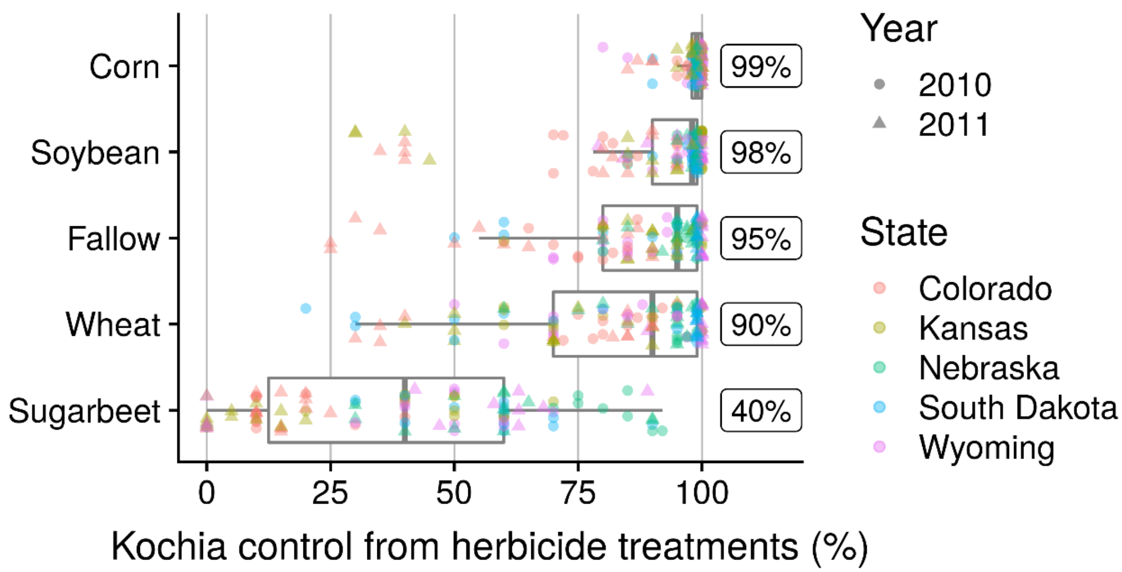

Figure 1. Kochia control, 30 days after final application of herbicide treatment, labeled for corn, soybean, fallow, wheat, and sugarbeet. Each point represents a plot in a field. Percentages are the median kochia control from herbicide treatments within each crop.

Figure 2. Control of 2- to 2.5-inch kochia with Sharpen at 1 and 2 fl oz/A with AMS and MSO, 13 DAT (image courtesy of Dr. Brian Jenks). Kochia biotypes were putative group 14 resistant biotypes collected from multiple western ND locations.

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)

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.

Objectives

The objectives of this research were to 1) evaluate non-glyphosate herbicide options for kochia control in sugarbeet and; 2) provide kochia control options in Minnesota and North Dakota fields when corn, soybean, or wheat are seeded in sequence with sugarbeet.

Material and Methods

Three kochia experiments were planned for 2022. Two field experiments were conducted on natural kochia populations that were a mixture of glyphosate susceptible and glyphosate resistant biotypes, one near Fairview, MT and a second near Manvel, ND in 2022. The third experiment was kochia planted in strips across sugarbeet near Horace, ND. The Manvel, ND experiment was terminated due to the late plant from an overland spring flood, causing a less than expected kochia infestation. Kochia at the Horace, ND location generally was glyphosate sensitive and was easily control with glyphosate.

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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.

Soil residual herbicides were applied after sugarbeet planting in a furrow irrigated field in 24-inch rows at Farview, MT. Treatments were applied through 8002 XR flat fan nozzles with a backpack sprayer with CO_2 at 40 psi to deliver 17 GPA. Experiments were conducted to evaluate ethofumesate PRE and POST applications of Betamix, Spin-Aid, Ultra Blazer, and ethofumesate at rates and timings to maximize kochia control and minimize sugarbeet injury.

Table 1. Herbicide treatment, rate, and application timing, Fairview, ND, 2022.

Treatment	Rate (fl oz/A)	SGBT (leaf stage)
Etho[1] / RU PowerMax3[2] / RU PowerMax3	64 / 25 / 25	PRE / 2 / 6
Etho / RU PowerMax3 / RU PowerMax3	96 / 25 / 25	PRE / 2 / 6
RU PowerMax3 + Etho[3] / RU PowerMax3 + Etho / RU PowerMax3 + Etho	25 + 4 / 25 + 4 / 20 + 4	2 / 6 / 10
RU PowerMax3 + Etho + Betamix / RU PowerMax3 + Etho + Betamix / RU PowerMax3 + Etho + Betamix	25 + 4 + 12 / 25 + 4 + 24 / 20 + 4 + 24	2 / 6 / 10
RU PowerMax3 + Etho + Spin-Aid / RU PowerMax3 + Etho + Spin-Aid / RU PowerMax3 + Etho + Spin-Aid	25 + 4 + 12 / 25 + 4 + 24 / 20 + 4 + 24	2 / 6 / 10
Etho / RU PowerMax3 / Ultra Blazer[4]	96 / 25 / 16	PRE / 2 / 6
Etho / Ultra Blazer[4] / Ultra Blazer[4]	96 / 12 / 12	PRE / 6 / 10
Etho / RU PowerMax3 / Ultra Blazer[5]	96 / 25 / 16	PRE / 2 / 6
Etho / RU PowerMax3 + Loyant / RU PowerMax3 + Loyant	96 / 25 + 0.28 / 25 + 0.28	PRE / 2 / 6
Etho / RU PowerMax3 + Loyant / RU PowerMax3 + Ultra Blazer[5]	96 / 25 + 0.28 / 25 + 16	PRE / 2 / 6

[1] etho = ethofumesate.

[2]Roundup PowerMax3 applied with Prefer 90 NIS at 0.25%v/v and Amsol Liquid AMS at 2.5% v/v.

[3]Roundup PowerMax3 + ethofumesate, Betamix, or Spin-Aid 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.

[5]Ultra Blazer applications applied with Prefer 90 non-ionic surfactant at 0.25% 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 2022.7 software package.

Results and Discussion

Sugarbeet injury ranged from 0-29% in this experiment (Table 2). Increased injury was observed in treatments containing Ultra Blazer, either alone or in tank mixtures. Sugarbeet injury was negligible across all other herbicide treatments. Sugarbeet injury was greatest from Ultra Blazer followed by Ultra Blazer. We anticipated more growth reduction injury with treatments containing Loyant; however, injury was negligible. Environmental conditions may have influenced sugarbeet injury as air temperature at applications (71°F and 62°F) and relative humidity were less as compared with applications in eastern North Dakota and Minnesota.

Kochia control was exceptional across most treatments. The trial was conducted in a flood-irrigated production field. The utilization of irrigation likely ensured herbicide activation, which was observed in weed control evaluations.

Table 2. Visible kochia control in response to herbicide treatment, Fairview, ND, 2022.[1]

		Sugarbeet Injury		Kochia Control	
Treatment	Rate	14 DAAC[2]	21 DAAC	14 DAAC	21 DAAC
	---fl oz/A---	---------------------------%-------------------------			
Etho3 / RU PowerMax3[4] / RU PowerMax3	64 / 25 / 25	0 a	0 a	98 ab	98 a
Etho / RU PowerMax3 / RU PowerMax3	96 / 25 / 25	0 a	0 a	99 a	99 a
RU PowerMax3 + Etho[5] / RU PowerMax3 + Etho / RU PowerMax3 + Etho	25 + 4 / 25 + 4 / 20 + 4	8 b	0 a	99 a	98 a
RU PowerMax3 + Etho + Betamix / RU PowerMax3 + Etho + Betamix / RU PowerMax3 + Etho + Betamix	25 + 4 + 12 / 25 + 4 + 24 / 20 + 4 + 24	0 a	1 a	95 ab	98 a
RU PowerMax3 + Etho + Spin-Aid / RU PowerMax3 + Etho + Spin-Aid / RU PowerMax3 + Etho + Spin-Aid	25 + 4 + 12 / 25 + 4 + 24 / 20 + 4 + 24	5 ab	3 a	93 b	95 ab
Etho / RU PowerMax3 / Ultra Blazer[6]	96 / 25 / 16	20 c	0 a	93 b	93 ab
Etho / Ultra Blazer[4] / Ultra Blazer[6]	96 / 12 / 12	29 d	23 b	14 c	23 c
Etho / RU PowerMax3 / Ultra Blazer[7]	96 / 25 / 16	24 cd	1 a	96 ab	90 b
Etho / RU PowerMax3 + Loyant / RU PowerMax3 + Loyant	96 / 25 + 0.28 / 25 + 0.28	5 ab	1 a	96 ab	95 ab
Etho / RU PowerMax3 + Loyant / RU PowerMax3 + Ultra Blazer[7]	96 / 25 + 0.28 / 25 + 16	24 cd	1 a	98 ab	94 ab
LSD (0.10)		**6**	**4**	**5**	**7**

[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]DAC= days after application C treatment.
[3]etho = ethofumesate.
[4]Roundup PowerMax3 applied with Prefer 90 NIS at 0.25%v/v and Amsol Liquid AMS at 2.5% v/v.
[5]Roundup PowerMax3 + ethofumesate, Betamix, or Spin-Aid applied with Destiny HC HSMOC at 1.5 pt/A and Amsol Liquid AMS at 2.5 % v/v.
[6]Ultra Blazer applications applied with Prefer 90 non-ionic surfactant at 0.125% v/v.
[7]Ultra Blazer applications applied with Prefer 90 non-ionic surfactant at 0.25% v/v.

A greenhouse experiment was conducted in the winter of 2022 evaluating kochia control from Ultra Blazer alone or mixed with Roundup PowerMax at various sizes (Peters and Lystad 2023). In summary, Ultra Blazer plus NIS applied to 2-inches or less kochia provided the greatest control (data not shown). Ultra Blazer plus Roundup PowerMax provided greater kochia control as compared with Ultra Blazer alone. Similarly, Ultra Blazer alone provided the least kochia control at 14 and 23% at 14 and 21 days after application C (DAAC), respectively, in the field experiment (Table 2). The use of Roundup PowerMax3, prior to Ultra Blazer application, increased kochia control from 23 to 90%; however, provided less kochia control as compared with the other treatments.

We observed Ultra Blazer does not have a technical fit for kochia control in sugarbeet since kochia germinates and emerges early in the season and sugarbeet must be greater than the 6-lf stage for application. This combination of weed size and sugarbeet growth stage explains the inconsistent kochia control we have observed from Ultra Blazer in previous experiments. The majority of kochia size in a production field, like at Fairview, ND, was greater than 2-inches at the 6-lf sugarbeet stage, resulting in unacceptable kochia control from Ultra Blazer applications.

Common lambsquarters was also evaluated in this experiment (data not shown). Treatments with ethofumesate PRE significantly improved common lambsquarters control compared with no PRE. Roundup PowerMax3 plus either Betamix or Spin-aid improved common lambsquarters control as compared with Roundup PowerMax3 alone. Ultra Blazer alone did not provide acceptable control on common lambsquarters.

Recommendations in sugarbeet

Ethofumesate at 6 pt/A or greater PRE 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.

References

Beckie HJ Blackshaw RE Leeson JY Stahlman PW Gaines TA Johnson EN (2018) Seedbank persistence, germination and early growth of glyphosate-resistant Kochia scoparia. Weed Research. 58:177-187

Peters TJ and Luecke AB (2016) Kochia control in sugarbeet – a progress report. Sugarbeet Res Ext Rep. 46:41-44

Peters TJ and Lystad AL (2021) Kochia control in sugarbeet. Sugarbeet Res Ext Rep. 51:18-23

Sbatella GM, Adjesiwor AT, Kniss AR, Stahlman PW, Westra P, Moechnig M, Wilson RG (2019) Herbicide options for glyphosate-resistant kochia (*Bassia scoparia*) management in the Great Plains. Weed Technol. 33: 658–663

SPIN-AID PROVIDES SELECTIVE WEED CONTROL IN SUGARBEET

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Summary

1. Kochia approximately 1-inch tall (dime-size), or 6- to 8-lvs, is controlled best with Spin-Aid.
2. Kochia control was greater when ethofumesate was mixed with Spin-Aid. In the field, we recommend Spin-Aid plus ethofumesate and Roundup PowerMAX3 at 4+25 fl oz/A, respectively, plus adjuvant.
3. Kochia control was greater from repeat Spin-Aid applications as compared with Spin-Aid singly.
4. Recommendations for kochia control with Spin-Aid are in the conclusions section of this document.

Introduction

Some might remember the herbicide, Betanal, or more affectionally, 'Blue Can.' Phenmedipham was registered in 1970 and sold under the trade name Betanal from 1970 through 1981. A pre-mix of phenmedipham and desmedipham (1:1 ratio) was registered in 1982 and was sold as Betamix. U.S. registration for Betamix was cancelled in 2014 (EPA 2014). Currently, there is no active phenmedipham registration in sugarbeet in the United States; however, Belchim Crop Protection has been marketing phenmedipham with the trade name 'Spin-Aid' on spinach and red beet for six years and has recently completed the acquisition of the registration from Bayer. Phenmedipham is marketed for use in sugarbeet in other world areas. I have evaluated phenmedipham alone and in mixtures in sugarbeet since 2016, including experiments for control of glyphosate resistant (GR) kochia and GR common ragweed and common lambsquarters in 2022. The objective of this greenhouse experiment was to evaluate sugarbeet tolerance and kochia control from single or repeat applications of Spin-Aid alone, Spin-Aid plus ethofumesate, or Spin-Aid plus ethofumesate and Roundup PowerMAX3.

Materials and Methods

Greenhouse experiments were conducted using a glyphosate sensitive kochia seed source collect at North Dakota State University (NDSU) field research facilities. Kochia was grown in a flat filled with PROMIX general purpose greenhouse media (Premier Horticulture, Inc., Quakertown, PA) to 1-inch and transplanted in 4 × 4-inch pots. Betaseed 8927 sugarbeet were grown in 4 × 4 pots with a 1:1 mixture of Wheatville silt loam from the Northwest Research and Outreach Center, Crookston and PROMIX greenhouse media to the 2-lf stage. Both kochia and sugarbeet were grown at 75°F to 81°F under natural light supplemented with a 16 h photoperiod of artificial light.

Herbicide treatments were applied using a spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a TeeJet® 8002 even banding nozzle (TeeJet Technologies, Glendale Heights, IL) calibrated to deliver 15 gpa spray solution at 25 psi and 3 mph when kochia was 6- to 8-lf or 'dime' size in diameter (Figure 1) and when sugarbeet was at the 2- lf stage. Visible sugarbeet injury (0% to 100%, 100% indicating complete loss of stand) and kochia control (0% to 100%, 100% indicating complete control) were evaluated approximately 5, 14, and 21 days after treatment (DAT).

Spin-Aid rate screen

Herbicide treatment for control of 1-inch (dime size) kochia and tolerance of 2- lf sugarbeet were a single Spin-Aid application at 48, 72, 96 and 144 fl oz/A and Spin-Aid at 32, 48, and 64 fl oz/A followed by a repeat Spin-Aid application after six days at 32, 48, and 64 fl oz/A, respectfully. All Spin-Aid applications were with Noble methylated seed oil (MSO) (Winfield United, Arden Hills, MN) at 1.5 pt/A (Table 1). Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Spin-Aid plus ethofumeste for kochia control; Sugarbeet tolerance from Spin-Aid plus ethofumesate and Roundup PowerMAX3

Herbicide treatments were a single Spin-Aid application at 64, 80, and 96 fl oz/A or Spin-Aid application at 24, 32, 40, and 48 fl oz/A followed by a repeat Spin-Aid application at 24, 32, 40 and 48 fl oz/A, respectively. Spin-Aid

Figure 1. One-inch (dime-size) kochia.

was mixed with ethofumesate and Noble MSO at 1.5 pt/A for kochia control or Spin-Aid with ethofumesate and Roundup PowerMAX3 plus Destiny HC high surfactant methylated seed oil (HSMOC) for sugarbeet tolerance evaluation (Table 2). We elected not to use PowerMAX3 in the kochia experiment since our kochia seed source was segregating for glyphosate resistance. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Table 1. Spin-Aid rate and sugarbeet and kochia stage at application, greenhouse, 2023.

Herbicide treatment[a]	Rate	Sugarbeet stage	Kochia size
	(fl oz/A)	(Num of lvs)	(Num of lvs)
Spin-Aid	48	2-4 lvs	6-8 (dime size)
Spin-Aid	72	2-4 lvs	6-8 (dime size)
Spin-Aid	96	2-4 lvs	6-8 (dime size)
Spin-Aid	144	2-4 lvs	6-8 (dime size)
Spin-Aid / Spin-Aid	32/32	2-4 lvs / 6 days	6-8 (dime size) / 6 days
Spin-Aid / Spin-Aid	48/48	2-4 lvs / 6 days	6-8 (dime size) / 6 days
Spin-Aid / Spin-Aid	64/64	2-4 lvs / 6 days	6-8 (dime size) / 6 days
Non Treated Control	-	2-4 lvs	6-8 (dime size)

[a]Spin-Aid with Noble methylated seed oil (MSO) at 1.5 pt/A.

Table 2. Herbicide treatment and sugarbeet and kochia stage at application, greenhouse, 2023.

Herbicide treatment[a]	Rate	Sugarbeet stage	Kochia size
	(fl oz/A)	(Num of lvs)	(Num of leaves)
Spin-Aid + ethofumesate	64 +11	2-4 lvs	6-8 (dime size)
Spin-Aid + ethofumesate	80 + 13.8	2-4 lvs	6-8 (dime size)
Spin-Aid + ethofumesate	96 + 16.5	2-4 lvs	6-8 (dime size)
Spin-Aid + etho / Spin-Aid + etho	24 + 4.1 /24 + 4.1	2-4 lvs	6-8 (dime size)
Spin-Aid + etho / Spin-Aid + etho	32 + 5.5 /32 + 5.5	2-4 lvs / 7 days	6-8 (dime size) / 7 days
Spin-Aid + etho / Spin-Aid + etho	40 + 6.9 /40 + 6.9	2-4 lvs / 7 days	6-8 (dime size) / 7 days
Spin-Aid + etho / Spin-Aid + etho	48 + 8.3 /48 + 8.3	2-4 lvs / 7 days	6-8 (dime size) / 7 days
Non Treated Control	-	2-4 lvs	6-8 (dime size)

[a]Spin-Aid with Noble methylated seed oil (MSO) at 1.5 pt/A mixed with Spin-Aid for kochia control. Roundup PowerMAX at 25 fl oz/A and High Surfactant Methylated Oil Concentrate (HSMOC) at 1.5 pt/A was mixed with Spin-Aid and ethofumesate for sugarbeet tolerance evaluation.

Results and Discussion

Spin-Aid rate screen

Sugarbeet injury ranged from 18% to 49% from a single Spin-Aid application, 5 days after application A (DAAA). Injury was greatest from Spin-Aid alone at 144 fl oz/A (Table 3). Repeat Spin-Aid applications at 32 or 48 fl oz/A

Table 3. Sugarbeet injury and kochia control in response to herbicide treatment, greenhouse, 2023.

Herbicide treatment[a]	Rate	Sugarbeet injury			Kochia control		
		5 DAAA	10 DAAA	16 DAAA	10 DAAA	12 DAAA	20 DAAA
	--fl oz/A--	------------------%----------------			--------------------%------------------		
Spin-Aid	48	20 cd	24 c	3 de	43 e	53 d	23 d
Spin-Aid	72	33 b	20 c	5 de	55 d	65 c	28 d
Spin-Aid	96	33 b	20 c	15 bc	68 bc	68 c	43 c
Spin-Aid	144	49 a	40 b	28 a	78 ab	79 ab	60 ab
Spin-Aid / Spin-Aid	32/32	18 d	23 c	11 cd	58 cd	74 bc	50 bc
Spin-Aid / Spin-Aid	48/48	26 bcd	23 c	15 bc	80 a	81 ab	73 a
Spin-Aid / Spin-Aid	64/64	28 bc	48 a	23 ab	85 a	84 a	71 a
Non-Treated Control	-	0 e	5 d	0 e	0 f	8 e	5 e
LSD (0.10)		10	7	9	11	9	13

[a]Spin-Aid with methylated seed oil (MSO) at 1.5 pt/A for kochia control

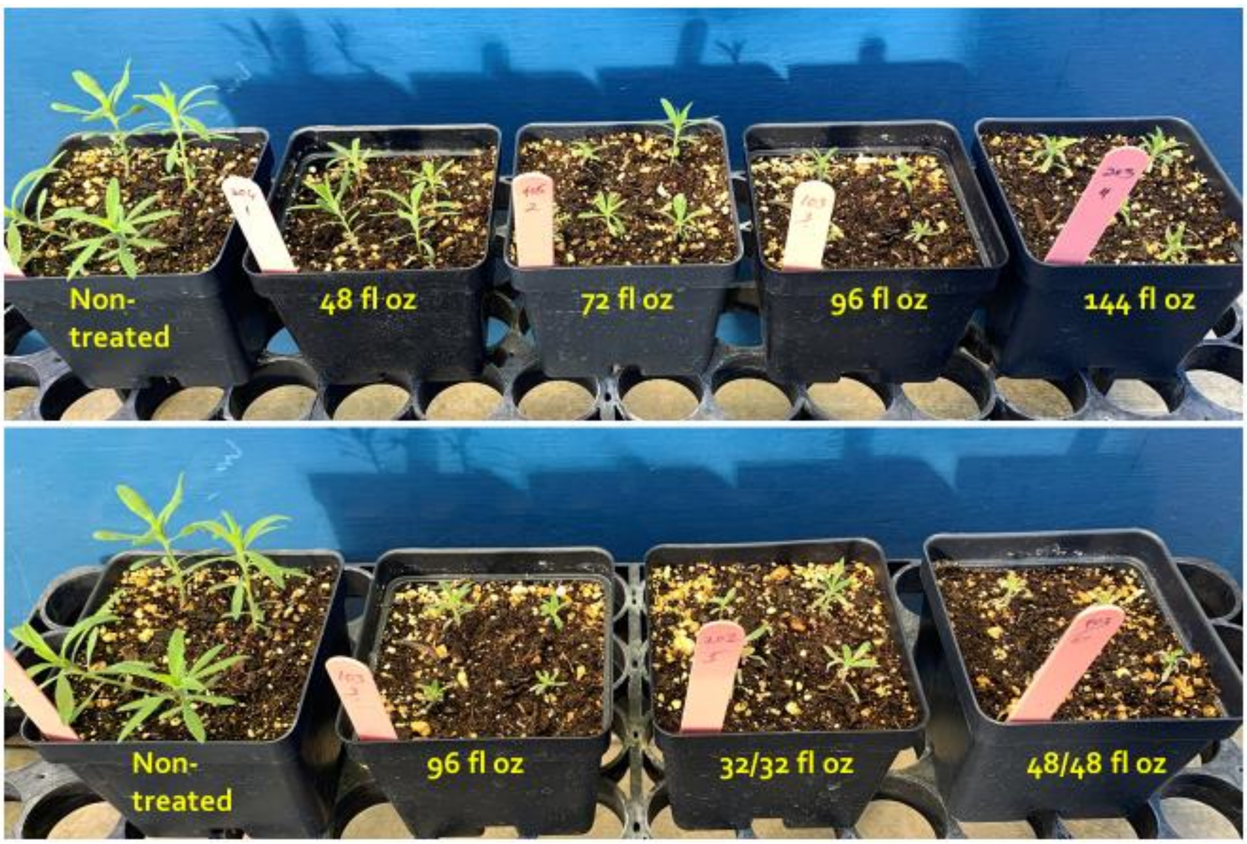

Figure 2. Kochia control in response to Spin-Aid singly or repeat Spin-Aid applications 6 days after Spin-Aid application, greenhouse, 2023.

did not increase sugarbeet injury as compared with Spin-Aid at 72 or 96 fl oz/A applied singly, 10 DAAA. However, repeat Spin-Aid 64 fb 64 fl oz/A applications caused more sugarbeet injury than a single 144 fl oz/A Spin-Aid application. Repeat 32 and 48 fl oz/A applications and a single application at 48, 72 and 96 fl oz/A caused less than 20% injury or negligible injury, 16 DAAA.

Kochia control was dependent on Spin-Aid rate and single or repeat Spin-Aid applications (Table 3, Figure 2). Kochia control was greatest from either Spin-Aid at 144 fl oz/A singly or from Spin-Aid at 48 or 64 fl oz/A followed by a repeat Spin-Aid application after six days. Spin-Aid at 48 fl oz/A fb Spin-Aid at 48 fl oz/A provided kochia control superior to a single 96 fl oz/A Spin-Aid application.

Spin-Aid plus ethofumeste for kochia control; Sugarbeet tolerance from Spin-Aid plus ethofumesate and Roundup PowerMAX3

Sugarbeet visible necrosis injury 4 days after application A (DAAA) was greatest with Spin-Aid at 80 and 96 fl oz/A mixed with ethofumesate and Roundup PowerMAX3 (Figure 3 and Table 4). Necrosis injury tended to correlate with Spin-Aid rate; injury was least with Spin-Aid at 24 fl oz/A and most with Spin-Aid at 96 fl oz/A. Necrosis injury was less with repeat Spin-Aid applications at 32 or 48 fl oz/A as compared to Spin-Aid singly at 64 or 96 fl oz/A, respectively. Sugarbeet visible growth reduction injury 15 DAAA was greatest with Spin-Aid singly at 96 fl

Table 4. Sugarbeet injury and kochia control from single or repeat Spin-Aid applications with ethofumesate (and PowerMAX3), greenhouse, 2023.

		Sugarbeet injury		Kochia control	
Herbicide treatment[a]	Rate	4 DAAA	15 DAAA	4 DAAA	12 DAAA
	--fl oz/A--	----------%----------		-----------%-----------	
Spin-Aid + ethofumesate	64 +11	33 b	18 b	70 b	66 d
Spin-Aid + ethofumesate	80 +14	35 ab	14 b	73 b	74 c
Spin-Aid + ethofumesate	96 + 17	40 a	21 ab	86 a	91 a
Spin-Aid+etho / Spin-Aid+etho	24+4 / 24+4	13 e	18 b	33 e	74 c
Spin-Aid+etho / Spin-Aid+etho	32+6 / 32+6	18 de	21 ab	48 d	76 bc
Spin-Aid+etho / Spin-Aid+etho	40+7 / 40+7	20 cd	15 b	58 c	81 b
Spin-Aid+etho / Spin-Aid+etho	48+8 / 48+8	25 c	28 a	60 c	81 b
Non-Treated	-	0 f	4 c	0 f	0 e
LSD (0.10)		6	10	8	7

[a]Spin-Aid + ethofumesate (kochia) or Spin-Aid + ethofumesate + Roundup PowerMAX3 (sugarbeet); treatment contained methylated seed oil (MSO) at 1.5 pt/A for kochia control; treatment contained high surfactant methylated oil concentrate (HSMOC) at 1.5 pt/A for sugarbeet control.

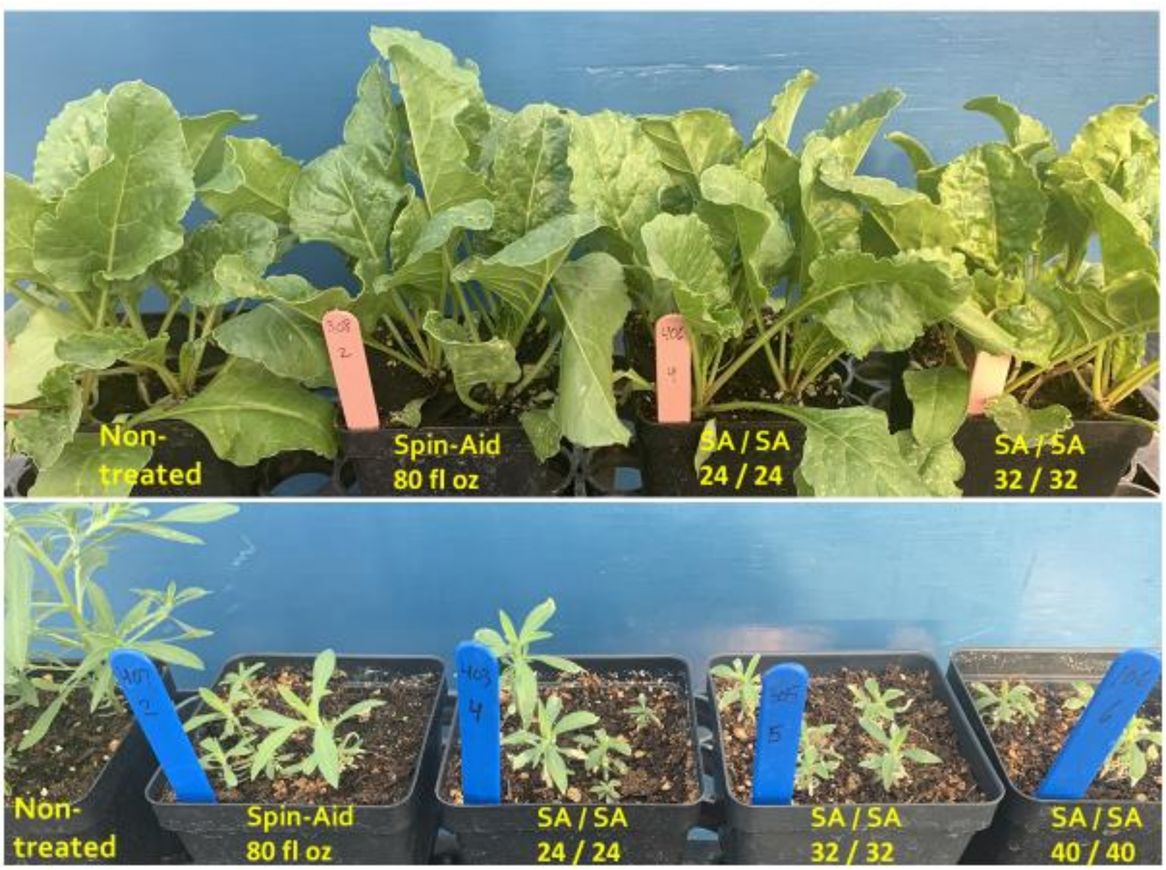

Figure 3. Sugarbeet tolerance or kochia control in response to Spin-Aid singly or repeat Spin-Aid applications after 7 days (sugarbeet) or after 6 days (kochia), greenhouse, 2023.

oz/A, or repeat Spin-Aid applications at 32 or 48 fl oz/A with ethofumesate and Roundup PowerMAX3. Sugarbeet injury from other treatments was or tended to be the same.

Kochia control was greatest with Spin-Aid singly at 96 fl oz/A with ethofumesate 8 and 12 DAAA (Table 4, Figure 3). However, in general, repeat Spin-Aid applications with ethofumesate provided kochia control greater than Spin-Aid + ethofumesate singly. For example, Spin-Aid at 32 or 40 fl oz/A with ethofumesate followed by a repeat application 6 days after the first application provided kochia control greater than Spin-Aid singly at 64 or 80 fl oz/A with ethofumesate.

Conclusions

Target herbicide applications to kochia less than 1-inch tall (dime size) if sugarbeet growth stage will allow. Kochia is a difficult weed to control. These greenhouse experiment and observations from field experiments indicate kochia dime-sized in diameter is easier to control than kochia quarter-sized in diameter or kochia 2 or 3 inches tall. We observed a compromise with kochia control and sugarbeet tolerance from repeat Spin-Aid applications as compared with Spin-Aid singly. Further, mixing Spin-Aid with ethofumesate seemed to improved kochia control as compared to Spin-Aid alone, although Spin-Aid alone or Spin-Aid mixed with ethofumesate were not herbicide treatments in the same experiments. Finally, most producer applications will be a mixture of Spin-Aid with ethofumesate and RoundupPowerMAX3.

Spin-Aid rate will be triggered by sugarbeet growth stage (Table 5) although we prefer dime sized kochia as compared to larger kochia. We favor Spin-Aid at 24 to 32 fl oz/A and sugarbeet at the 2-lf stage and Spin-Aid at 32 or 40 fl oz/A for repeat application.

Field research will be conducted in 2023 to evaluate common lambsquarters and common ragweed control with Spin-Aid or Spin-Aid + ethofumesate.

Table 5. Dime-sized kochia control with Spin-Aid alone or in mixtures with ethofumesate or Spin-Aid following a soil residual herbicide, based on field and greenhouse research, 2022 and 2023.

	No Soil Residual Herbicides		Following soil residual herbicides
Sugarbeet stage (lf stage)	Spin-Aid	Spin-Aid + etho	Spin-Aid + etho
	--------------fl oz/A--------------		---fl oz/A---
Cotyledon	24	16 + 4	12 + 4
2	32	24 + 4	16 + 4
4	48	32 + 4	24 + 4
6	72	40 + 4	32 + 4

SUGARBEET TOLERANCE TO COMPLEX MIXTURES, REVISITED IN 2023

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Summary

1. Sugarbeet injury from formulation changes including Roundup PowerMAX3 and Stinger HL previously have not been evaluated in complex mixtures.
2. We observed more sugarbeet injury from PowerMAX3 and ethofumesate mixed with Outlook than in previous experiments.
3. Stinger HL mixed with PowerMAX3, ethofumesate, and Outlook increased sugarbeet injury with or without high surfactant methylated oil concentrate (HSMOC).
4. Mustang Maxx can be mixed with PowerMAX3, ethofumesate, and Outlook, but should not be mixed with PowerMAX3, ethofumesate, Outlook, and Stinger HL.
5. We continue to recommend reducing the HSMOC rate or eliminating HSMOC from the mixture when Stinger HL and/or Mustang Maxx is mixed with PowerMAX3, ethofumesate, and Outlook.

Introduction

Dr. Dexter wrote: “Sugarbeet herbicides may be tank mixed legally if all herbicides in the mixture are registered for use on sugarbeet, and if no prohibitions against tank mixes appear on a label.”

Questions about tank-mixing herbicides are one of the most common telephone calls I receive from agriculturists and producers, and rightfully so. Combinations of postemergence herbicides can improve overall weed control and spectrum of control as compared with individual treatments. Mixtures also improve time efficiency as compared with making individual applications. However, the risk of sugarbeet injury also increases with combinations, especially under adverse environmental conditions. There are few herbicides truly safe to sugarbeet, meaning sugarbeet must detoxify sugarbeet sprays after application and before normal sugarbeet growth and development can resume. Detoxification is much more challenging with combinations or as “complex mixtures” as I like to call them, especially in cold and wet environments.

Key messages about complex mixtures are as follows. However, most of these messages were developed when Lorsban was available for control of insect pests and Stinger and Roundup PowerMAX formulations were used for weed control.

- Stinger can be mixed with Roundup PowerMAX, ethofumesate, and a chloroacetamide herbicide.
- Malformation injury resembling damage from Stinger when Betamix or Lorsban is mixed with Roundup PowerMAX, ethofumesate, a chloroacetamide herbicide, and Stinger is borderline not acceptable.
- HSMOC rate should be reduced when Lorsban is mixed with PowerMAX, ethofumesate and a chloroacetamide. HSMOC should be eliminated from the mixture when/if Stinger and Lorsban are mixed with PowerMAX3, ethofumesate and, a chloroacetamide herbicide.

The objective of this greenhouse research was a) to investigate sugarbeet injury from Stinger HL and Mustang Maxx mixed with Roundup PowerMAX3, ethofumesate and a chloroacetamide herbicide and b) to investigate if HSMOC contributes to injury when applied in complex mixtures.

Materials and Methods

Greenhouse experiments were conducted in 2023 to evaluate sugarbeet injury from complex mixtures POST with or without HSMOC. Greenhouse experiments were a randomized complete block design with a factorial treatment arrangement and four replications. Treatment factors were a) with or without HSMOC adjuvant and b) herbicide treatment. Herbicide treatment lists are found in Tables 1 and 2.

Soil was a 1:1 mixture of Wheatville silt loam from the Northwest Research and Outreach Center, Crookston and PROMIX general purpose greenhouse media (Premier Horticulture, Inc., Quakertown, PA). Herbicides were applied all sugarbeet were at a strong 2-lf stage. Plants were grown at approximately 73 to 81°C for a 16 h photoperiod under natural light supplemented with artificial lighting. Plants were watered and fertilized as necessary. Herbicide

Table 1. Herbicide treatment with or without HSMOC adjuvant, greenhouse Run 1, 2023.

Num	Factor A Adjuvant[a]	Factor B Postemergence Herbicide	Rate (fl oz / A)	Sugarbeet stage (lvs)
1	No	PowerMAX3 + ethofumesate	30 + 12	2-4 lvs
2	No	PowerMAX3 + etho + Outlook	30 + 12 + 21	2-4 lvs
3	No	PowerMAX3 + etho + Outlook + Stinger HL	30 + 12 + 21 + 3.6	2-4 lvs
4	No	PowerMAX3 + etho + Outlook + Stinger HL + Mustang Maxx	30 + 12 + 21 + 3.6 + 4.0	2-4 lvs
5	HSMOC	PowerMAX3 + ethofumesate	30 + 12	2-4 lvs
6	HSMOC	PowerMAX3 + etho + Outlook	30 + 12 + 21	2-4 lvs
7	HSMOC	PowerMAX3 + etho + Outlook + Stinger HL	30 + 12 + 21 + 3.6	2-4 lvs
8	HSMOC	PowerMAX3 + etho + Outlook + Stinger HL + Mustang Maxx	30 + 12 + 21 + 3.6 + 4.0	2-4 lvs
9		Non-treated Control	-	2-4 lvs

[a]HSMOC=Destiny HC at 1.5 pt/A.

Table 2. Herbicide treatment with or without HSMOC adjuvant, greenhouse Run 2, 2023.

Num	Factor A Adjuvant[a]	Factor B Postemergence Herbicide	Rate (fl oz / A)	Sugarbeet stage (lvs)
1	No	PowerMAX3 + ethofumesate	30 + 12	2-4 lvs
2	No	PowerMAX3 + etho + Outlook	30 + 12 + 21	2-4 lvs
3	No	PowerMAX3 + etho + Outlook + Mustang Maxx	30 + 12 + 21 + 4.0	2-4 lvs
4	No	PowerMAX3 + etho + Outlook + Mustang Maxx + Stinger HL +	30 + 12 + 21 + 4.0 + 3.6	2-4 lvs
5	HSMOC	PowerMAX3 + ethofumesate	30 + 12	2-4 lvs
6	HSMOC	PowerMAX3 + etho + Outlook	30 + 12 + 21	2-4 lvs
7	HSMOC	PowerMAX3 + etho + Outlook + Mustang Maxx	30 + 12 + 21 + 4.0	2-4 lvs
8	HSMOC	PowerMAX3 + etho + Outlook + Mustang Maxx + Stinger HL +	30 + 12 + 21 + 4.0 + 3.6	2-4 lvs
9		Non-treated Control	-	2-4 lvs

[a]HSMOC=Destiny HC at 1.5 pt/A.

treatments were applied using a spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a TeeJet® 8002 Even banding nozzle (TeeJet Technologies, Glendale Heights, IL) calibrated to deliver 15 gpa spray solution at 25 psi and 3 mph. Visible sugarbeet injury (0% to 100%, 100% indicating complete loss of stand) was evaluated approximately 5, 10, 14, and 21 days after treatment (DAT). Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package. This report summarizes results from Run 1 and Run 2. In run 1 Stinger HL was incorporated into the mixture before Mustang Max. The order was flipped in Run 2 (see treatment list, Tables 1 and 2).

Results

Run 1

Herbicide treatment interacted with HSMOC, 10 and 14 DAT but not 5 (data not presented) and 21 DAT (Table 3). Likewise, images captured sugarbeet injury differences between herbicide treatments with or without HSMOC (Figure 1).

Table 3. Sugarbeet injury in response to herbicide treatment with and without HSMOC, Run 1, 2023.[a]

		Growth Reduction 10 DAT[b]		Growth Reduction 14 DAT		Growth Reduction 21 DAT	
Herbicide treatment	Rate	No HSMOC	HSMOC	No HSMOC	HSMOC	No HSMOC	HSMOC
	----fl oz/A----	--------------------------------%---------------------------------					
Base[c]		0 e	10 d	5 d	13 d	5	10
Base + Outlook	21	35 c	31 c	33 bc	30 c	20	13
Base + Outlook and Stinger HL	21 + 3.6	50 ab	48 b	48 b	43 bc	40	33
Base + Outlook, Stinger HL and Mustang Maxx	21 + 16 + 3.6 + 4	46 b	58 a	40 bc	68 a	33	50
LSD (0.10)		9		16		NS	

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance.
[b]DAT=Days after POST treatment.
[c]Base= Roundup PowerMAX3 at 25 fl oz/A + Ethofumesate 4SC at 12 fl oz/A.

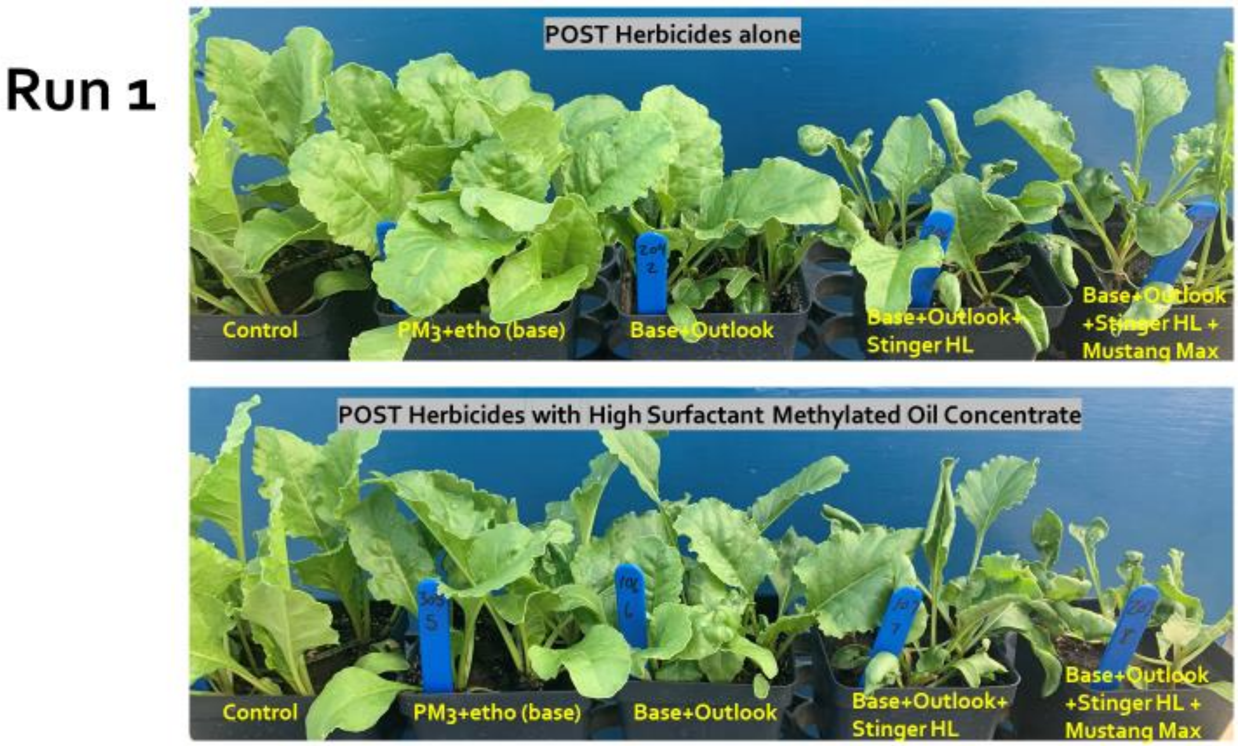

Figure 1. Sugarbeet injury from herbicide treatments with and without HSMOC 14 days after treatment (DAT), greenhouse, 2023.

Roundup PowerMAX3 mixed with ethofumesate caused negligible sugarbeet injury 10, 14 and 21 DAT. However, we observed increased injury from Outlook mixed with Roundup PowerMAX3 than in previous experiments with or without HSMOC. Sugarbeet injury from Stinger HL mixed with Roundup PowerMAX3, ethofumesate, and Outlook was greater or tended to be greater than sugarbeet injury from Roundup PowerMAX3, ethofumesate, and Outlook alone, across evaluation timings. The addition of HSMOC did not increase sugarbeet injury. Sugarbeet injury was or tended to be the greatest when Stinger HL and Mustang Maxx were mixed with Roundup PowerMAX3, ethofumesate, and Outlook. The addition of HSMOC increased or tended to increase injury as compared with no HSMOC.

We wondered if Mustang Maxx would similarly increase sugarbeet injury when mixed with Roundup PowerMAX3, ethofumesate, and Outlook as compared with Roundup PowerMAX3, ethofumesate, Outlook, and Stinger HL. Thus, in our second run, we switched the order; we mixed Mustang Maxx with Outlook, ethofumesate, and Roundup PowerMAX3 before evaluating the 5-way mixture.

Run 2
Herbicide treatment did not interact with oil adjuvant in Run 2 (P-Value > 0.10). Thus, herbicide treatments were averaged across HSMOC adjuvant. We observed less injury from Outlook mixed with Roundup PowerMAX3 and ethofumesate as compared with Run 1; however, we continued to observe more injury than in previous experiments (Table 4, Figure 2).

Table 4. Sugarbeet injury in response to herbicide treatment, averaged across HSMOC, Run 2, 2023.[a]

Herbicide treatment	Rate	10 DAT[b]	14 DAT	17 DAT
	----fl oz/A----	-------------------%-------------------		
Base[c]		10 c	4 c	3 c
Base + Outlook	21	27 b	12 b	9 c
Base + Outlook and Mustang Maxx	21 + 4	16 c	15 b	18 b
Base + Outlook, Mustang Maxx and Stinger HL	21 + 16 + 4 + 3.6	37 a	37 a	43 a
LSD (0.10)		10	9	10

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance
[b]DAT=Days after POST treatment.
[c]Base= Roundup PowerMAX3 at 25 fl oz/A + Ethofumesate 4SC at 12 fl oz/A.

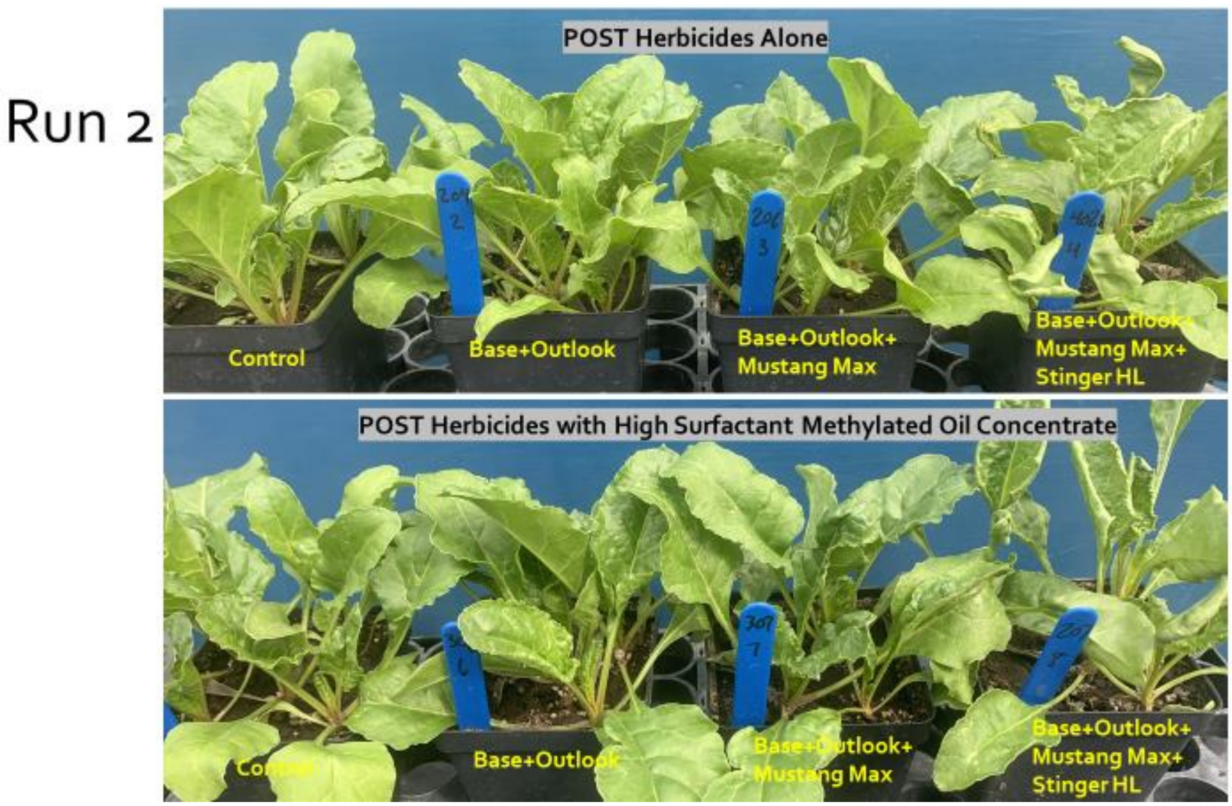

Figure 2. Sugarbeet injury from herbicide treatments with and without HSMOC 17 days after treatment (DAT), greenhouse, 2023.

Outlook in the field is usually split applied at 10 to 14 fl oz/A so perhaps the concern with increased sugarbeet injury with Roundup PowerMAX3 and ethofumesate mixtures with Outlook is unwarranted. Mustang Maxx mixed with Roundup PowerMAX3, ethofumesate, and Outlook was inconsistent; we observed less injury than PowerMAX3, ethofumesate and Outlook, 10 DAT but we observed more injury 17 DAT. Nonetheless, our results indicate it is safe to mix Mustang Maxx with Roundup PowerMAX3, ethofumesate, and a chloroacetamide herbicide.

Once again, sugarbeet injury was greatest with the 5-way mixture or Stinger HL mixed with Roundup PowerMax3, ethofumesate, Outlook, and Mustang Maxx. Observed injury consisted of a combination of growth reduction and malformation. Note, Stinger HL was applied at 3.6 fl oz/A in these experiments.

Conclusion
Pesticides (herbicides, fungicides, and insecticides) approved for use in sugarbeet usually are safe to sugarbeet when applied individually. These same pesticides applied in mixtures, however, occasionally injure sugarbeet since each pesticide must be detoxified by the plant. Environmental stressors such as low air and soil temperatures or saturated soil-water content are conditions that often reduce photosynthesis and may reduce energy needed for the developing sugarbeet to metabolize pesticides (Smith and Schweizer 1983), thus increasing the risk of sugarbeet injury. Sugarbeet is better able to manage biotic or abiotic stressors as it develops; sugarbeet with more leaf area have greater metabolic activity, dissipating the effect of herbicides, and other stressors.

We are using different Roundup PowerMAX3 and clopyralid formulations with potentially different adjuvant systems than formulations previously evaluated. A confusing image from the field (Figure 3) and results from two greenhouse experiments suggest sugarbeet injury from Stinger HL mixed with Roundup PowerMAX3, ethofumesate, and a chloroacetamide herbicide might be different from previous experiments. Likewise, sugarbeet injury is more likely from complex mixtures or combinations of four or five pesticides with or without adjuvants as compared with past observations, both in the field and in the greenhouse, with previous formulations.

These experiments were conducted with individual treatments applied at full rates. I use full rates as an indicator for what might happen in the field under adverse environmental conditions. I will be the first to say that the possibility of Stinger HL injury at 3.6 fl oz/A is much greater than Stinger HL at 1.8 fl oz/A.

Figure 3. Ethofumesate + Dual Magnum (PRE) at 2 + 0.5 pt/A followed by Roundup PowerMAX3 + ethofumesate + *S*-metolachlor + Stinger HL (2-lf) at 25 + 6 + 16 +1.5 fl oz/A followed by Roundup PowerMAX3 + ethofumesate + *S*-metolachlor + Stinger HL (6-lf) at 25 + 6 + 16 + 1.5 fl oz/A, Rothsay, MN, 2022.

Literature Cited
Smith GA, Schweizer EE (1983) Cultivar x herbicide interaction in sugarbeet. Crop Sci 23:325-328

COMPLEX MIXTURES WITH EXCALIA

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Summary

1. Quadris or Excalia can be mixed and applied with Mustang Maxx.
2. Sugarbeet injury from Excalia mixed with Roundup PowerMAX3, ethofumesate, Outlook, and Stinger HL was similar to injury with Roundup PowerMAX3, ethofumesate, and Outlook alone.
3. Quadris mixed with oil-based formulations or oil-based adjuvants causes necrosis injury.
4. Growers need to follow recommendations for complex mixtures or Roundup PowerMAX3 mixed with ethofumesate, the chloroacetamides, Stinger HL, and/or Mustang Maxx.

Introduction

Quadris is frequently used for control of Rhizoctonia in Minnesota and North Dakota. Questions about tank mixing Quadris with herbicides are common. Our research indicates Quadris can safely be tank mixed with glyphosate and Stinger HL, but mixing Quadris with oil-based herbicides like ethofumesate, the chloroacetamide herbicides for waterhemp control, or even oil-based adjuvants, such as methylated seed oil (MSO), causes unacceptable necrosis damage or leaf bronzing to sugarbeet. We recommend Quadris be applied three days prior to, or three days after, oil-based herbicides to avoid sugarbeet injury.

Drs. Chanda and Khan have been evaluating Excalia fungicide for Rhizoctonia control in sugarbeets. Valent has alluded that Excalia can be tank mixed with oil-based herbicides for both Rhizoctonia control and management of weeds. The objective of this greenhouse experiment was to compare sugarbeet tolerance with complex mixtures including Quadris or Excalia.

Materials and Methods

Betaseed 8927 sugarbeet was grown in 4 × 4 pots with a 1:1 mixture of Wheatville silt loam from the Northwest Research and Outreach Center, Crookston, MN and PROMIX greenhouse media to the 2-lf stage in the greenhouse. Sugarbeet were grown at 75°F to 81°F under natural light supplemented with a 16 h photoperiod of artificial light.

Herbicide treatments are in Table 1. All treatments were applied with Destiny HC high surfactant methylated oil concentrate (HSMOC) and ammonium sulfate (AMS) using a spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a TeeJet® 8002 even banding nozzle (TeeJet Technologies, Glendale Heights, IL) calibrated to deliver 15 gpa spray solution at 25 psi and 3 mph when sugarbeet was at the 2- lf stage. Visible sugarbeet necrosis injury (0% to 100%, 100% indicating complete necrosis) and sugarbeet growth reduction injury (0% to 100%, 100% indicating complete loss of stand) were evaluated approximately 5, 7, and 14 (+/- 3 days) days after treatment (DAT). Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2022.5 software package.

Table 1. Herbicide treatment, rate, and sugarbeet stage at application, greenhouse, 2023.

Herbicide treatment[a]	Rate (fl oz/A)	Sugarbeet stage (Num of lvs)
Glyphosate + etho + Outlook	30 + 12 + 18	2-4
Excalia + glyphosate + etho + Outlook	2+ 30 + 12 + 18	2-4
Excalia + glyphosate + etho + Outlook + Mustang Maxx	2+ 30 + 12 + 18 + 4	2-4
Excalia + glyphosate + etho + Outlook + Stinger HL	2+ 30 + 12 + 18 + 2.4	2-4
Excalia + Mustang Maxx	2 + 4	2-4
Quadris + glyphosate + etho + Outlook	14.3 + 30 + 12 + 18	2-4
Quadris + glyphosate + etho + Outlook + Mustang Maxx	14.3 + 30 + 12 + 18 + 4	2-4
Quadris + glyphosate + etho + Outlook + Stinger HL	14.3 + 30 + 12 + 18 + 2.4	2-4
Quadris + Mustang Maxx	14.3 + 4	2-4
Non-treated control	-	2-4

[a]Treatment with Destiny HC HSMOC at 1.5 pt/A and Amsol Liquid AMS at 2.5% v/v.

Results and Discussion

Tank mixing Quadris with Roundup PowerMAX3, ethofumesate, and Outlook, or tank mixing Quadris with Mustang Maxx or Stinger HL and Roundup PowerMAX3, ethofumesate, and Outlook caused necrosis injury (Table 2, Figure 1). Sugarbeet injury was similar for all treatments and necrosis injury tended to be along the edges of sugarbeet leaves. There was no injury, or injury was negligible, with Excalia mixed with Roundup PowerMax3, ethofumesate, Outlook, Mustang Maxx, or Stinger HL.

Figure 1. Sugarbeet injury in response to Excalia or Quadris mixed with various sugarbeet pesticides greenhouse, 2023. Images collected on May 1, 2023, 11 DAT. *Base is Roundup PowerMAX3 + ethofumesate + Outlook.

Table 2. Sugarbeet injury in response to herbicide treatment, greenhouse, 2023.

		Necrosis	Growth Reduction		
Herbicide treatment[a]	Rate	4 DAT	4 DAT	8 DAT	14 DAT
	--fl oz/A--	---------------------------%---------------------------			
Base + Outlook	16	8 c	16 cd	5 d	13 bcd
+ Excalia + Outlook	2 + 16	0 d	16 cd	18 c	20 b
+ Excalia + Outlook + Mustang Maxx	2 + 16 + 4	0 d	8 de	10 cd	14 bc
+ Excalia + Outlook + Mustang Maxx + Stinger	2 + 16 + 4 + 2.4	0 d	19 c	28 b	21 b
Excalia and Mustang Maxx	2 + 4	0 d	10 cde	3 d	0 e
+ Quadris + Outlook	14.3 + 16	30 a	50 b	48 a	33a
+ Quadris + Outlook + Mustang Maxx	14.3 + 16 + 4	20 b	65 a	53 a	43 a
+ Quadris + Outlook + Mustang Maxx + Stinger	14.3 + 16 + 4 + 2.4	30 a	60 ab	55 a	43 a
Quadris and Mustang Maxx	14.3 + 4	0 d	11 cde	5 d	5 cde
Non-treated Control	-	0 d	3 e	3 d	3 de
LSD (0.10)		5	11	10	11

[a]Base = Roundup PowerMAX3 plus ethofumesate at 25 + 6 fl oz/A plus HSMOC at 1.5 pt/a and Amsol AMS at 2.5 % v/v.

Quadris mixed with Roundup PowerMAX3, ethofumesate, and Outlook, or mixing Quadris with Mustang Maxx or Stinger HL and Roundup PowerMAX3, ethofumesate, and Outlook caused growth reduction injury ranging from 65% to 33%, 4, 8 or 14 DAT (Table 2). Necrosis, or growth reduction injury, from Quadris with Roundup PowerMAX3, ethofumesate, and Outlook alone, or Quadris, Roundup PowerMAX3, ethofumesate, and Outlook mixed with Stinger HL or Mustang Maxx was the same or tended to be the same.

Roundup PowerMAX3 mixed with ethofumesate and Outlook tended to be negligible but growth reduction injury was statistically greater than the non-treated control. Tank mixing Mustang Maxx or Stinger HL with Excalia and Roundup PowerMAX3, ethofumesate, and Outlook did not increase sugarbeet injury.

Mustang Maxx mixed with either Quadris or Excalia did not cause necrosis damage or growth reduction damage (Figure 2).

Figure 2. Sugarbeet injury from Excalia or Quadris mixed with Mustang Maxx, greenhouse, 2023. Images collected on May 1, 2023, 11 DAT.

Conclusions

Questions about tank mixing herbicides are one of the most common telephone calls I receive from agriculturists and producers, and rightfully so. Combinations of postemergence herbicides can improve weed control and spectrum of control as compared with individual treatments. Mixtures also improve time efficiency as compared with making individual applications. However, the risk of sugarbeet injury also increases with combinations, especially under adverse environmental conditions. There are few herbicides truly safe to sugarbeet, meaning sugarbeet must detoxify herbicide sprays after application and before normal sugarbeet growth and development can resume. Detoxification is much more challenging with combinations, or as “complex mixtures” as I like to call them, especially in cold and wet environments.

Sometimes herbicides interact with components of other herbicides and/or adjuvants. Quadris should not be tank mixed with oil-based herbicide formulations or oil containing (petroleum or crop) adjuvants since sugarbeet injury may occur under certain weather conditions, particularly high temperature conditions.

This experiment concludes that Excalia mixed with oil-based adjuvants or herbicide formulations does not increase sugarbeet injury as compared with these same herbicides or adjuvants alone.