Gold Section: Sugarbeet Weed Control **Page**

HOODED SPRAYER FOR APPLICATION OF NONSELECTIVE HERBICIDES IN SUGARBEET

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Summary

1. Liberty and Gramoxone are not approved for POST directed application in sugarbeet.

2. Gramoxone at 21 fl oz/A plus non-ionic surfactant (NIS) and Liberty at 32 fl oz/A plus ammonium sulfate (AMS) improved 4- and 6-inch waterhemp control as compared with repeat glyphosate applications at 28 fl oz/A / 28 fl oz/A plus NIS and AMS.

3. PowerMax was more effective than Liberty or Gramoxone for common lambsquarters control.

4. Growth reduction injury was negligible from Gramoxone or Liberty applied at the 6-lf sugarbeet stage or greater and Gramoxone or Liberty did not reduce root yield, sucrose content or recoverable sucrose as compared to repeat glyphosate application.

Introduction

Sugarbeet producers recognized waterhemp as their most troublesome weed control challenge on 373,064 acres or 59% of the production acreage in Minnesota and eastern North Dakota in 2020 (survey conducted at 2020 Sugarbeet Growers Seminars, Turning Technologies, Youngstown, OH). Waterhemp control is maximized by using soil residual herbicides applied preemergence, early postemergence, and postemergence in sugarbeet. Optimal control is dependent on timely rainfall following application to move herbicides into the weed seed zone, or from soil surface to 2-cm into soil. Postemergence (POST) applications of Betamix and UpBeet and inter-row cultivation have been used to control escaping weeds. However, remnant inventories of Betamix have been exhausted, UpBeet-resistant waterhemp populations are increasingly common in the production area, and (re)adoption of inter-row cultivation by sugarbeet growers has been slow.

Selective and nonselective herbicides applied through hooded sprayers are used in cotton production to control weeds between rows. The hood protects cotton plants from herbicides that may cause growth reduction injury. The practicality and value of a hooded sprayer is being evaluated in sugarbeet as herbicide-resistance continues to increase in species such as waterhemp and Palmer amaranth. Experiments conducted in 2020 evaluated sugarbeet tolerance and waterhemp and common lambsquarters control from Roundup PowerMax (glyphosate), Liberty (glufosinate) and Gramoxone (paraquat) applied through a hooded sprayer at multiple locations in North Dakota and Minnesota.

Objectives

Liberty and Gramoxone are not labeled in sugarbeet and will require action by Minnesota and North Dakota Department of Agriculture before use, even between rows through a hooded sprayer. Thus, sugarbeet tolerance and weed control must be measured before support can be solicited from industry and a petition submitted to the Department of Agriculture. The objectives of these research were to determine sugarbeet tolerance and weed control when Liberty or Gramoxone were applied at different rates and timings through a hooded sprayer.

Materials and Methods

Sugarbeet Tolerance. Experiments were conducted near Crookston, MN, Lake Lillian, MN, Hickson, ND, and Prosper, ND in 2020. The Hickson, ND location was not included in the analysis due to erratic sugarbeet stands. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage to each location. Sugarbeet was planted between April 27 and May 27, 2020.

Herbicide treatments were applied between each row within a 30-foot long by six row plot when sugarbeet was at the 2-, 6-, and 10-lf stage using a hooded sprayer traveling 3 mph delivering 22 gpa spray solution through 8002 EVS Teejet nozzles pressurized with CO_2 at 35 psi. The treatment list can be found in Table 1.

Table 1. Herbicide treatments, rates, and application timing in trials near Prosper, ND and Lake Lillian and Crookston, MN in 2020.

Herbicide treatment	Rate (fl oz/A)	Sugarbeet stage (lvs)
RU PowerMax / RU PowerMax[1]	28 /28	4 / 6-8
Liberty[2]	86	2-4
Liberty	86	6-8
Liberty	86	10-12
Gramoxone SL 3.0[3]	32	2-4
Gramoxone SL 3.0	32	6-8
Gramoxone SL 3.0	32	10-12

[1]Treatments with Roundup PowerMax applied with Prefer 90 NIS at 0.25% v/v + N-Pak AMS Liquid at 2.5% v/v.
[2]Treatments with Liberty applied with dry AMS at 3 lb/A.
[3]Treatments with Gramoxone SL 3.0 applied with Prefer 90 NIS at 1 qt/A.

Sugarbeet injury was evaluated as a visual estimate of percent growth reduction (0 to 100% scale, 0 is no visible injury and 100 is complete loss of plant / stand) in the middle four rows of the six-row plot compared to the glyphosate check. Leaf damage ratings were also evaluated by counting the number of sugarbeet plants within treated rows with visual damage. Damage factors included herbicide drift, operator or equipment error, environment, etc. Sugarbeet was harvested from the center two rows within a plot in the fall and assessed for yield and quality. Data were analyzed using either SAS Data Management software PROC MIXED procedure to test for significant differences at p=0.05 or the ANOVA procedure of ARM, version 2020.2 software package depending on variable. Experimental design was randomized complete block with six replications.

Hooded Sprayer Efficacy. Experiments were conducted on native populations of common lambsquarters and waterhemp in sugarbeet fields near Moorhead and Lake Lillian, MN and Galchutt and Hickson, ND in 2020. The Galchutt location was dropped due to insufficient waterhemp populations; the Hickson site was dropped due to sprayer mechanical challenges. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage to each location. Sugarbeet was planted April 28th and May 19th at Lake Lillian and Moorhead, respectively.

Herbicide treatments were applied between each row within a 30-foot long by six row plot when waterhemp was 3- or 6-inches tall using a hooded sprayer delivering 22 gpa spray solution through 8002 EVS Teejet nozzles pressurized with CO_2 at 35 psi. The treatment list can be found in Table 2.

Table 2. Herbicide treatments, rates, and application timing in trials near Moorhead and Lake Lillian, MN in 2020.

Herbicide treatment	**Rate (fl oz /A)**	**Waterhemp (inch)**
RU PowerMax / RU PowerMax[1]	28 / 28	2 to 4 fb 10 d
Liberty[2]	32	3-4
Liberty	32	6-8
Liberty	43	3-4
Liberty	43	6-8
Gramoxone SL 3.0[3]	21	3-4
Gramoxone SL 3.0	21	6-8
Gramoxone SL 3.0	32	3-4
Gramoxone SL 3.0	32	6-8

[1]Treatments with Roundup PowerMax applied with Prefer 90 NIS at 0.25% v/v + N-Pak Liquid AMS at 2.5% v/v.
[2]Treatments with Liberty applied with dry AMS at 3 lb/A.
[3]Treatments with Gramoxone SL 3.0 applied with Prefer 90 NIS at 1 qt/A.

Weed control was evaluated as a visual estimate of percent fresh weight reduction (0 is no injury and 100 is complete control) in the four treated rows compared to the glyphosate check at 7, 14, and 21 days (+/- 3 days) after application. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2020.4 software package.

Tolerance Results

Tolerance Probe. Experiments conducted by BASF Corp at two locations in 2020 evaluated RR sugarbeet tolerance to glufosinate in an over-the-top application using a rate titration of 1x, 1/10x, 1/100x, and 1/1000x the recommended rate applied to 4- and 8-lf sugarbeet (Table 3). The research simulated sugarbeet injury from spray solution escaping from hoods at two growth stages. Sugarbeet were sensitive to Liberty, especially at 43 fl oz/A at the 4-lf stage. However, injury was less at the 10-lf stage or with the 1/10, 1/100 or 1/1000x Liberty rate. No injury to either the 4- or 10-lf stage sugarbeet was observed at the 1/100x or 1/1000x rate. The experiment demonstrated sugarbeet sensitivity to glufosinate when sprayed over the top of sugarbeet; however, sugarbeet may not be as susceptible to injury when applications are made through a hooded sprayer.

Table 3. RR sugarbeet tolerance to Liberty herbicide following broadcast application.[1]

			Injury 4 DAT[2]	
Treatment	Rate	Rate	4-lf Sugarbeet	10-lf Sugarbeet
	fl oz/A		----------------%----------------	
Liberty[3]	43	1x	100	70
Liberty	4.3	1/10x	30	15
Liberty	0.43	1/100x	0	0
Liberty	0.043	1/1000x	0	0

[1]Bird Island, MN plot ratings by Dr. Duane Rathmann, BASF Corp.
[2]DAT=Days after treatment.
[3]All Liberty treatments applied with dry AMS at 3 lb/A.

Sugarbeet growth reduction injury from herbicides applied through a hooded sprayer was negligible across application timings (Table 4). Injury was divergence from a uniform stand and tended to represent damage to specific sugarbeet plants and not uniform damage across the plot. Numerically, growth reduction injury was greatest following either Liberty or Gramoxone application at the 2 to 4 leaf sugarbeet. We did not observe any difference in injury between Liberty and Gramoxone. Injury became less as sugarbeet grew and was not observed or was negligible at 14 or 21 DAT (data not presented). Leaf damage counts represent single locations since the cause of damage was experiment specific (Table 4). Leaf damage injury from Gramoxone was generally greater than from Liberty. Leaf damage at the 2- to 4-lf stage at Lake Lillian may have been extenuated by breeze conditions at application. Damage ratings at the 10- to 12-leaf stage is likely from wheel traffic, especially since it was not supported by the growth reduction observations. Damage was less as sugarbeet developed and was negligible 14 or 21 DAT (data not presented). Root yield, % sucrose, and recoverable sucrose from Liberty or Gramoxone through the hooded sprayer was the same as yield parameters treated with repeat glyphosate application (Table 5). However, Liberty and Gramoxone at the 2- to 4-leaf stage applications tended to give root yield less than the glyphosate check.

Table 4. Growth reduction, averaged across three environments and number of damaged plants in plots, by environment, in response to POST herbicides through the hooded sprayer in 2020.[1]

		Growth Reduction	Damaged Plants		
		Across Locations	Crookston, MN	Prosper, ND	Lake Lillian, MN
Herbicide treatment	**Sugarbeet stage**	7 DAT[2]	7 DAT	7 DAT	7 DAT
	--lvs--	--%--	-------------# plants/plot------------------		
RU PowerMax / RU PowerMax	4 / 6-8	1	6 a	2 a	4 a
Liberty	2-4	15	11 ab	2 a	81 b
Liberty	6-8	7	5 a	2 a	19 ab
Liberty	10-12	9	80 e	45 c	13 a
Gramoxone SL 3.0	2-4	16	23 bc	2 a	134 c
Gramoxone SL 3.0	6-8	10	46 d	9 a	31 ab
Gramoxone SL 3.0	10-12	7	27 c	30 b	30 ab
		---------------------------------*P*-value----------------------------			
		0.0925	<0.0001	<0.0001	<0.0001

[1]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.
[2]DAT=Days after treatment.

Table 5. Root yield, sucrose content, and recoverable sucrose in response to POST herbicides through the hooded sprayer, across three environments, in 2020.[1]

Herbicide treatment	**Sugarbeet stage**	**Root Yield[2]**	**Sucrose Content**	**Rec. Suc[3]**
	--lvs--	--Tons/A--	--%--	--lb/A--
RU PowerMax / RU PowerMax	4 / 6-8	30.1	16.2	8,628
Liberty	2-4	27.9	16.4	8,055
Liberty	6-8	29.3	16.2	8,789
Liberty	10-12	29.2	16.0	8,468
Gramoxone SL 3.0	2-4	27.9	16.4	8,392
Gramoxone SL 3.0	6-8	29.2	16.1	8,680
Gramoxone SL 3.0	10-12	28.6	16.0	8,362
		----------------------------*P*-value--------------------		
		0.3146	0.8799	0.6049

[1]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.
[2]Root yield reported in ton per acre.
[3]Recoverable sucrose reported in pound per acre.

Efficacy Results

The first observation of symptomology was herbicide specific in efficacy experiments. A necrosis phenotype was observed from Gramoxone 1 DAT on waterhemp and common lambsquarters. Symptomology from Liberty was observed first on waterhemp and second on lambsquarters 5- to 7-DAT. Symptomology from glyphosate was slowest to be observed, especially on waterhemp. Gramoxone applied through the hooded sprayer improved waterhemp control compared to repeat glyphosate applications (Table 6). Waterhemp control from Gramoxone was not influenced by weed size or application rate. Waterhemp control from Liberty was dependent on rate and weed size. Liberty at 32 fl oz/A provided or tended to provide control of 3- to 4-inch waterhemp greater than 6- to 8-inch waterhemp. Waterhemp size did not influence control when Liberty was applied at 43 fl oz/A. However, Liberty applied at 43 fl oz/A tended to provide greater control of 3- to 4-inch waterhemp compared to 6-to 8-inch waterhemp.

Table 6. Waterhemp and common lambsquarters control in response to POST herbicides applied through the hooded sprayer, 2020.[1]

Herbicide treatment	Rate	Weed Height	Waterhemp	Common Lambsquarters: Lake Lillian	Common Lambsquarters: Moorhead
	-fl oz/A-	----inch----	------%	------%	------%
RU PowerMax / RU PowerMax	28 / 28	2 to 4 fb 10 d	55 c	94 a	99 a
Liberty	32	3-4	81 ab	65 c	77 de
Liberty	32	6-8	56 c	29 e	81 cd
Liberty	43	3-4	86 ab	79 b	85 bcd
Liberty	43	6-8	70 bc	41 d	86 bcd
Gramoxone SL 3.0	21	3-4	90 a	89 a	77 de
Gramoxone SL 3.0	21	6-8	90 a	65 c	73 e
Gramoxone SL 3.0	32	3-4	96 a	94 a	93 ab
Gramoxone SL 3.0	32	6-8	96 a	85 ab	89 bc
			------*P*-value------		
			0.0020	<0.0001	<0.0001

[1]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.

Common lambsquarters ranged from 6- to 12-inches at Lake Lillian due to high wind conditions in June which delayed application timings. Lambsquarters was sprayed according to protocol at Moorhead, MN. Thus, lambsquarters control was not combined and are reported separately for each experiment. Glyphosate was equally effective at controlling small and large common lambsquarters in this experiment. At Lake Lillian, control from Liberty was dependent on rate and lambsquarters size at application. However, common lambsquarters control from Liberty was the same across rates and height at Moorhead where applications were successfully timed to protocol. Lambsquarters control from Liberty was less than control from glyphosate and tended to be less than control from Gramoxone at both locations. Common lambsquarters control differences from Liberty and Gramoxone were much less at Moorhead than at Lake Lillian where Gramoxone gave greater lambsquarters control at a given weed size compared with control from Liberty. At Moorhead, common lambsquarters height did not affect control from Gramoxone at 21 fl oz/A. However, at Lake Lillian, applying Gramoxone to smaller lambsquarters resulted in greater control at both 21 and 32 fl oz/A.

Conclusions

Liberty and Gramoxone are effective herbicides for controlling waterhemp and can be safely applied inter-row through a hooded sprayer when sugarbeet are at the 6-8 leaf stage or greater. Liberty might be slightly safer than Gramoxone. Weed control from Liberty generally decreases as weed height increases and numerically was better on waterhemp than common lambsquarters. Waterhemp control from Gramoxone was not influenced by rate or height but control of taller lambsquarters was less at Lake Lillian as compared to Moorhead. Waterhemp should be the primary weed control focus when using a hooded sprayer since glyphosate remains highly effective for common lambsquarters control. Liberty at 32 fl oz/A applied to small weeds or Gramoxone at 21 fl oz/A applied to small or large weeds provided improved waterhemp control than glyphosate.

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WATERHEMP CONTROL IN SUGARBEET IN 2020

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Summary
1. Ethofumesate provided partial waterhemp control at 1.5 pt/A, even when activating rainfall was 21 day after treatment (DAT). However, ethofumesate at rates less than 6 pt/A provided less than 85% waterhemp control. Ethofumesate at greater than 6 to 7.5 pt/A provided 36 or 54 days, respectively, of greater than 85% waterhemp control.
2. Preemergence herbicides are effective for controlling early germinating waterhemp. Waterhemp control was similar with ethofumesate at 2 pt/A and Dual Magnum at 0.75 pt/A but was less than waterhemp control from ethofumesate at 4 pt/A.
3. Herbicide, herbicide rate, or timing of herbicide application did not influence waterhemp control from treatments applied layby.
4. Inter-row cultivation or Liberty applied through a hooded sprayer controlled escaped waterhemp.

Introduction
A survey conducted at the 2020 winter Sugarbeet Growers Seminars indicated waterhemp is the primary weed control challenge in sugarbeet fields in Southern Minnesota Beet Sugar Cooperative, Minn-Dak Farmers' Cooperative, and American Crystal Sugar Cooperative. Early-season weed escapes turn into late-season weed control failures which can lead to weed issues at harvest. There are minimal effective POST herbicide options for rescue control of glyphosate-resistant biotypes, especially when waterhemp is greater than 4-inches tall. Three experiments were conducted in 2020 to evaluate herbicide treatments, timing of herbicide application, and methods of herbicide application to create an effective weed management program.

Objective
The objective of these studies was to understand the weed control methods available and how to best to combine them into a weed control program to control waterhemp in sugarbeet.

Materials and Methods
Experiment 1
Experiments were conducted on natural weed populations near Moorhead, MN and Blomkest, MN in 2020 to evaluate waterhemp control and wheat nurse-crop tolerance to ethofumesate preemergence (PRE) at multiple rates. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage. Spring wheat at 0.75 bu/A was evenly spread throughout the plot area and incorporated with shallow tillage before ethofumesate application. Sugarbeet was seeded in rows spaced 22 inches apart at approximately 62,000 seeds/A or approximately 4.6 inch spacing between seeds along the row in the experiment at Blomkest, MN but sugarbeet was not planted in the experiment at Moorhead, MN.

Herbicide treatments were applied PRE after planting with a bicycle wheel sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center of the 11 by 40 feet long plots. Treatments consisted of one application of ethofumesate at 0, 1.5, 3.0, 4.5, 6.0 and 7.5 pt/A
Wheat injury and waterhemp control were evaluated visually, beginning approximately twenty-three days after ethofumesate application. Additional waterhemp control was evaluated 43, 56, and 62 DAP (days after planting) at Moorhead and 36, 44, 58, and 77 DAP at Blomkest. All evaluations were a visual estimate of control in the treated area compared to the adjacent untreated strip. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2020.2 software package.

Experiment 2
Experiments were conducted on natural weed populations near Hickson, ND and Blomkest, MN in 2020 to consider sugarbeet tolerance and waterhemp control from preemergence and postemergence herbicides. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage. Sugarbeet was seeded in rows spaced 22 inches apart at approximately 62,000 seeds/A or approximately 4.6 inch spacing between seeds along the row.

Herbicide treatments were applied on April 27, May 27, and June 12 at Hickson and Blomkest with a bicycle wheel sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2. Treatment list for Hickson and Blomkest can be found in Table 1 and 2, respectively.

Table 1. Herbicide treatment, rate, and application timing at Hickson, ND in 2020.

Preemergence Herbicide	PRE Rate	Lay-by Herbicide	Lay-by Rate	Stage
	(pt/A)		(fl oz/A)	(lvs)
–	–	–[1]	–[1]	4 / 8
–	–	Dual Magnum[2]	18	4
–	–	Dual Magnum	18	8
–	–	Dual Magnum / Dual Magnum	18 / 18	4 / 8
Dual Magnum	0.75	–	–	4 / 8
Dual Magnum	0.75	Dual Magnum	18	4
Dual Magnum	0.75	Dual Magnum	18	8
Dual Magnum	0.75	Dual Magnum / Dual Magnum	18 / 18	4 / 8
Ethofumesate 4SC	2	–	–	4 / 8
Ethofumesate 4SC	2	Dual Magnum	18	4
Ethofumesate 4SC	2	Dual Magnum	18	8
Ethofumesate 4SC	2	Dual Magnum / Dual Magnum	18 / 18	4 / 8
Ethofumesate 4SC	4	–	–	4 / 8
Ethofumesate 4SC	4	Dual Magnum	18	4
Ethofumesate 4SC	4	Dual Magnum	18	8
Ethofumesate 4SC	4	Dual Magnum / Dual Magnum	18 / 18	4 / 8

[1] – indicates that no lay-by herbicide was applied but that applications of Roundup PowerMax at 28 fl oz/A + Prefer 90 NIS at 0.25% v/v + N-Pak Liquid AMS at 2.5% v/v were applied at the leaf stage shown.
[2]All POST treatments of Dual Magnum also included Roundup PowerMax at 28 fl oz/A + HSMOC at 1.5 pt/A + AMS 2.5% v/v.

Table 2. Herbicide treatment, rate, and application timing at Blomkest, MN in 2020.

Preemergence Herbicide	PRE Rate	Lay-by Herbicide	Lay-by Rate	POST Stage
	(pt/A)		(fl oz/A)	(lvs)
–	–	–[1]	–[1]	4 / 8
–	–	Warrant[2]	48	4
–	–	Warrant	48	8
–	–	Outlook / Outlook	12 / 12	4 / 8
–	–	Warrant / Warrant	48 / 48	4 / 8
–	–	Outlook / Warrant	12 / 48	4 / 8
Ethofumesate 4SC	2	–	–	4 / 8
Ethofumesate 4SC	2	Warrant	48	4
Ethofumesate 4SC	2	Warrant	48	8
Ethofumesate 4SC	2	Outlook / Outlook	12 / 12	4 / 8
Ethofumesate 4SC	2	Warrant / Warrant	48 / 48	4 / 8
Ethofumesate 4SC	2	Outlook / Warrant	12 / 48	4 / 8
Ethofumesate 4SC	4	–	–	4 / 8
Ethofumesate 4SC	4	Warrant	48	4
Ethofumesate 4SC	4	Warrant	48	8
Ethofumesate 4SC	4	Outlook / Outlook	12 / 12	4 / 8
Ethofumesate 4SC	4	Warrant / Warrant	48 / 48	4 / 8
Ethofumesate 4SC	4	Outlook / Warrant	12 / 48	4 / 8

[1] – indicates that no lay-by herbicide was applied but that applications of Roundup PowerMax at 28 fl oz/A + Prefer 90 NIS at 0.25 % v/v + N-Pak Liquid AMS at 2.5% v/v were applied at the leaf stage shown.
[2]All POST treatments of Warrant and Outlook also included Roundup PowerMax at 28 fl oz/A + HSMOC at 1.5 pt/A + AMS at 2.5% v/v.

Sugarbeet tolerance and waterhemp control were evaluated. All evaluations were a visual estimate of control in the four treated rows compared to the adjacent untreated strip. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2020.2 software package.

Experiment 3
Experiments were conducted on natural weed populations near Moorhead, MN and Blomkest, MN in 2020 investigating waterhemp control and sugarbeet tolerance from a program approach. The program utilized PRE ethofumesate (either broadcast or in a band) followed by POST herbicides (with or without lay-by herbicides or lay-by timed to different sugarbeet growth stage) and followed by inter-row weed control from either Liberty (glufosinate) (applied through a hooded sprayer) or from inter-cultivation. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage. Sugarbeet was seeded in rows spaced 22 inches apart at approximately 62,000 seeds/A or approximately 4.6 inch spacing between seeds along the row.

Preemergence ethofumesate was applied at 6 pt/A. Banded treatments of ethofumesate were applied at 6 pt/A broadcast equivalent in an 11-inch band. Herbicide treatments were applied on May 2, June 1, June 11, and June 17 at Moorhead and April 27, May 27, June 9 and June 16 at Blomkest with a CO_2-pressurized bicycle-wheel sprayer in 17 gpa spray solution. Preemergence treatments were made using TeeJet TP4002E flat fan nozzles and EPOST, POST, and LPOST treatments were broadcast using 8002 XR flat fan nozzles. Liberty treatments were banded between rows using a hooded sprayer at 22 gpa spray solution through TP4002E nozzles pressurized with CO_2 at 35 psi. The treatment list can be found in Table 3.

Table 3. Treatment, application method, and herbicide rate at Moorhead and Blomkest, MN in 2020.

Preemergence Herbicide[1]	Application Method	EPOST[2] / POST Herbicide	Rate	Stage	LPOST[4] Treatment	Rate
	(broadcast or band)		(fl oz/A)	(lvs)		(fl oz/A)
Ethofumesate 4SC	broadcast	RUPM[4] / RUPM[4]	28 / 28	4 / 8	RUPM[4]	22
Ethofumesate 4SC	band	RUPM[4] / RUPM[4]	28 / 28	4 / 8	RUPM[4]	22
Ethofumesate 4SC	band	RUPM[5] + Dual Magnum	32 + 16	4	Liberty	32
Ethofumesate 4SC	band	RUPM[3] + Dual Magnum	32 + 16	8	Liberty	32
Ethofumesate 4SC	band	RUPM[3] + Dual Magnum	32 + 16	4	cultivation	–
Ethofumesate 4SC	band	RUPM[3] + Dual Magnum	32 + 16	8	cultivation	–

[1]Preemerge ethofumesate was applied at 6 pt/A broadcast or equivalent (3 pt/A in 11 inch band)
[2]EPOST = early postemergence at 4 lf-stage; POST = postemergence at 8-lf state; LPOST = late postemergence at 12-lf stage
[3]LPOST treatments were applied as follows: RUPM + N-Pak Liquid AMS at 2.5% v/v was broadcast, Liberty + dry AMS at 3 lb/A was applied to inter-row areas with a hooded sprayer, cultivation was directed to inter-row areas.
[4]RUPM = Roundup PowerMax applied with Ethofumesate at 4 fl oz/A + HSMOC at 1.5 pt/A + N-Pak Liquid AMS at 2.5% v/v.
[5]RUPM = Roundup PowerMax applied with Ethofumesate at 12 fl oz/A + HSMOC at 1.5 pt/A + N-Pak Liquid AMS at 2.5% v/v.

Sugarbeet tolerance and waterhemp control were evaluated. All evaluations were a visual estimate of control in the four treated rows compared to the adjacent untreated strip. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2020.2 software package.

Results

Experiment 1. Ethofumesate requires rainfall for activation. The experimental area near Moorhead, MN received 0.4- and 0.5-inch rains 48 and 72 hours, respectively, after ethofumesate application on May 2. Rain fell on the experiment near Blomkest, MN 1 and 9 days after ethofumesate application. However, these rain events did not provide sufficient moisture (0.7-inch rainfall or greater) to activate ethofumesate and activating rainfall did not occur until 21 days after application. Ethofumesate at 4.5 pt/A or greater reduced wheat stand by more than 50% at 23 and 43 DAT. Wheat ground cover loss was negligible at Blomkest, even at the 7.5 pt/A rate.

Growers frequently ask if ethofumesate can be used in concert with a nurse crop to reduce effect of blowing soil on sugarbeet. Our research indicates that oat tolerates soil residual herbicides better than wheat or barley and S-metolachlor is safer on nurse crops than ethofumesate. However, our data from 2020 clearly demonstrated nurse crop survival if offered the opportunity to achieve a head-start before activation of soil applied herbicides.

Waterhemp control was dependent on ethofumesate rate and evaluation timing (Figure 1). Waterhemp control of 85% or greater was seen from ethofumesate at 7.5 pt/A, only as far as 54 days after application, indicating ethofumesate at the full rate does not provide season long waterhemp control. Ethofumesate at 6 pt/A provided greater than 90% control but only for 36 days after planting. Eighty percent or greater waterhemp control was accomplished with ethofumesate at 7.5 pt/A, 6 pt/A, and 4.5 pt/A at 79, 56, and 36 DAP, respectively.

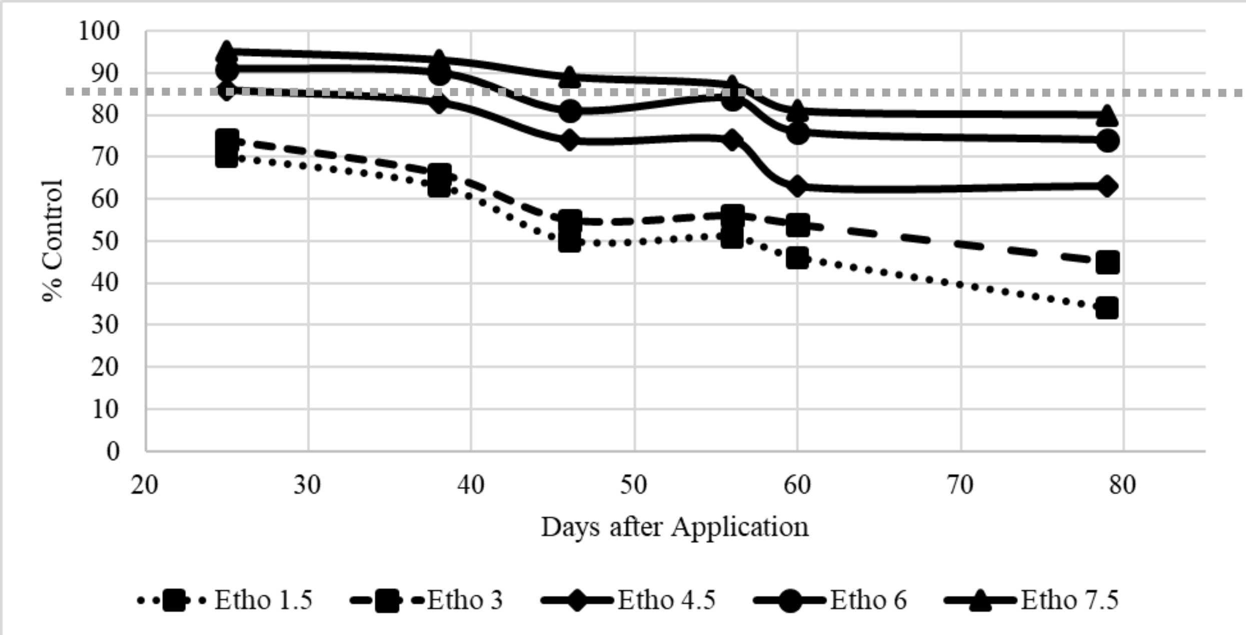

Figure 1. Waterhemp control from increasing ethofumesate rates at Blomkest in 2020.
These spring wheat and waterhemp data suggest we did not properly activate ethofumesate in either experiment in 2020. In addition, waterhemp emergence was much earlier than normal in 2020 than in previous years. An early germinating seed bank means there is less time for herbicide activation before waterhemp emergence.

Experiment 2. This experiment considered a weed management program including preemergence, early postemergence and postemergence herbicides for season-long waterhemp control. Waterhemp control 25 to 28 DAP was dependent on location (Table 4). At Hickson, ND, waterhemp control from ethofumesate at 4 pt/A provided greater waterhemp control than ethofumesate at 2 pt/A or Dual Magnum at 0.75 pt/A. However, at Blomkest, MN, preemergence herbicides did not influence waterhemp control. Preemergence control was influenced by waterhemp emergence date. Waterhemp emergence was documented near Fargo, ND on May 1 and near Mapleton, ND on May 2 (communication with Dr. Joe Ikley, NDSU and Mr. Greg Krause, Minn-Dak Farmers Cooperative) and waterhemp was a uniform and heavy infestation from cotyledon to 2-lf stage on May 28 at Hickson. The waterhemp infestation at Blomkest was sporadic across the experimental area, probably related to dry surface moisture conditions in April and May. Thus, waterhemp PRE control at Blomkest was an estimate of ground cover since the running checks were unreliable due to a light and uneven waterhemp infestation.

Waterhemp control was evaluated 14, 28 and 42 days (+/- 3 days) after POST application at Hickson and 14 days (+/- 3 days) after POST application at Blomkest. Waterhemp control at Hickson will not be presented since there was a tremendous amount of plot to plot variation in POST waterhemp control in the experiment. At Blomkest, waterhemp control from POST herbicide treatments tended to be greatest following ethofumesate at 4 pt/A PRE (Table 5). POST herbicide treatments generally provided similar waterhemp control within PRE treatment.

Table 4. Waterhemp control from the main effect of preemergence herbicide treatment when averaged across postemergence herbicide treatment, 28 DAP at Hickson, ND and 25 DAP at Blomkest, MN in 2020.[1]

Treatment	Rate	Hickson	Blomkest
	--pt/A--	---%---	---%---
No PRE		27 c	81
Dual Magnum	0.75	86 b	–[2]
Ethofumesate	2	85 b	87
Ethofumesate	4	91 a	87
P-value		0.0001	0.1917

[1]Means not sharing any letter are significantly different by t-test at the 5% level of significance.
[2]- treatment was not part of the trial at Blomkest.

Table 5. Waterhemp control 14 days after POST application from PRE, EPOST and POST herbicides at Blomkest in 2020.[1]

Lay-by Treatment[2]	Rate	Timing[3]	No Preemergence Herbicide	Ethofumesate 2 pt/A	Ethofumesate 4 pt/A
	---pt/A---	--lf stage--	------------------------%------------------------		
Warrant	3	4	73 bc	83 ab	90 ab
Warrant	3	8	76 abc	86 ab	89 ab
Outlook/Outlook	0.75 / 0.75	4/8	64 c	79 abc	89 ab
Warrant/Warrant	3 / 3	4/8	76 abc	83 abc	92 a
Outlook/Warrant	0.75 / 3	4/8	72 bc	88 ab	90 ab

[1]Means not sharing any letter are significantly different by t-test at the 20% level of significance.
[2]All POST treatments of Warrant and Outlook also included Roundup PowerMax at 28 fl oz/A + HSMOC at 1.5 pt/A + AMS at 2.5% v/v.
[3]Timing=Sugarbeet leaf stage.

Experiment 3. Grower survey results indicated escaped waterhemp occurred following PRE, EPOST, and POST herbicide treatments. Band applying ethofumesate was a common grower practice before the development of Roundup Ready (RR) sugarbeet. Ethofumesate at 6-pt/A broadcast PRE followed by repeat applications of Roundup PowerMax + ethofumesate controlled waterhemp better than ethofumesate at 6-pt per treated acre (band applied) followed by repeat applications of Roundup PowerMax + ethofumesate (Table 6). Improved control from broadcast applied ethofumesate was most likely due to complete soil coverage as compared with only 11-inches of soil coverage from ethofumesate banded over the sugarbeet row. Waterhemp that emerged between the ethofumesate bands were only partially controlled due to the presence of glyphosate-resistant biotypes. Waterhemp control was improved in treatments where ethofumesate was banded by including Dual Magnum (S-metolachlor) and ethofumesate with Roundup PowerMax applied POST and followed with either inter-row cultivation or an inter-row application of Liberty through a hooded sprayer at the 12 leaf, LPOST, stage.

Table 6. Waterhemp control and recoverable sucrose in response to preemergence and postemergence herbicide treatment, Blomkest and Moorhead, 2020.[1]

Herbicide Treatment	Rate	Blomkest, MN		Moorhead, MN	
		58 DAP[2]	67 DAP	62 DAP	Rec. Suc.[3]
	----fl oz/A----	------------------%------------------			--lb/A--
Ethofumesate / RUPM[4] / RUPM[4] / RUPM[4]	96 / 28 / 28 / 22	99 a	99 a	84 b	6,555
Etho (band) / RUPM[4] / RUPM[4] / RUPM[4]	48 / 28 / 28 / 22	69 b	79 c	76 bc	6,796
Etho (band) / Dual Mag + RUPM[5] + Etho / Liberty (hood)	48 / 16 + 32 + 12 / 32 (hood)	93 a	91 abc	68 c	6,777
Etho (band) / Dual Mag + RUPM[5] + Etho / Inter-row cultivation	48 / 16 + 32 + 12 / (cold hard steel)	100 a	99 ab	99 a	6,952
P value		0.0001	0.0201	0.0001	0.6013

[1]Means not sharing any letter are significantly different by t-test at the 5% level of significance.
[2]DAP=Days after planting.
[3]Rec. Suc. = Recoverable Sucrose.
[4]RUPM = Roundup PowerMax applied with Ethofumesate at 4 fl oz/A + HSMOC at 1.5 pt/A + NPak Liquid AMS at 2.5% v/v.
[5]RUPM = Roundup PowerMax applied with Ethofumesate at 12 fl oz/A + HSMOC at 1.5 pt/A + NPak Liquid AMS at 2.5% v/v.

Summary

Waterhemp control in sugarbeet has been our most important weed management challenge since the beginning of my tenure in 2014. Our research in creating a waterhemp control strategy is based on results from 86 sugarbeet tolerance and waterhemp control experiments since 2014 and has been successfully implemented on over 373,064 acres, where producers identify waterhemp as their most important weed management challenge (according to the 2020 Turning Point survey). The foundation for the program is use of chloroacetamide herbicides (SOA15) early postemergence (EPOST) and postemergence (POST) and in combination with glyphosate and ethofumesate in sugarbeet.

We observed integrating a PRE herbicide into the management plan improved waterhemp control, especially when sugarbeet emergence or timely rainfall to activate chloroacetamide herbicides is delayed (Figure 2). Growers planting after April 20 were encouraged to use a PRE since waterhemp emergence may occur before chloroacetamide herbicide activation. However, 2020 research and commercial experience indicates a PRE should be used regardless of plant date.

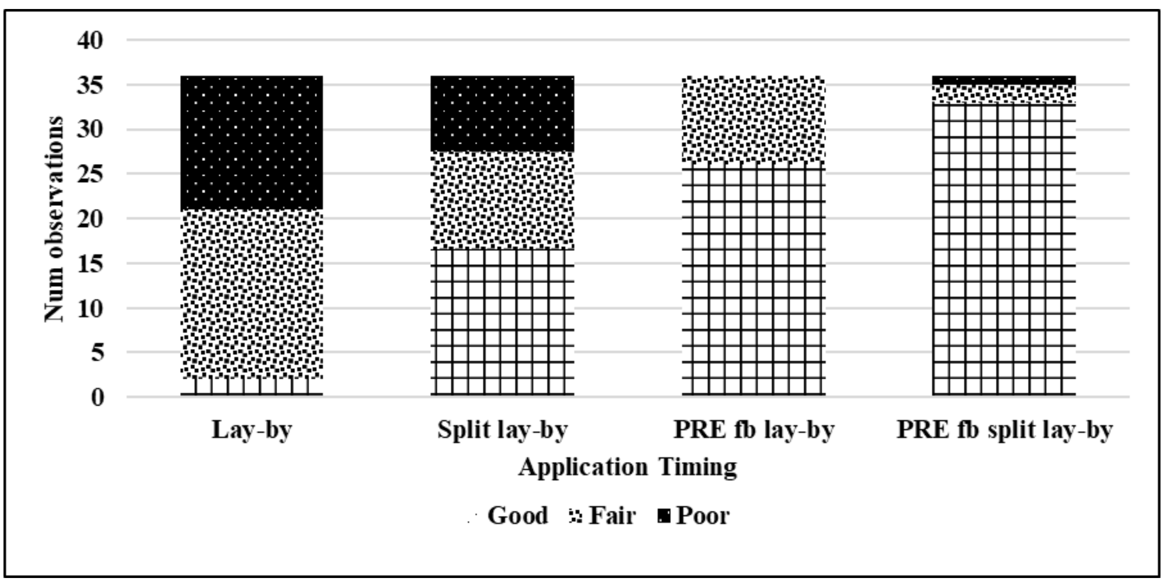

Figure 2. Number of good, fair, and poor estimates of waterhemp control across herbicides and application timing, summed across evaluations, locations, and years.

Surveyed growers attending the 2020 SMBSC seminar in Willmar indicated waterhemp control following PRE and layby application in 2019 did not meet their expectations (31% and 24% of respondents, respectively). POST control of escapes is difficult due to widespread ALS inhibitor (SOA 2) resistance biotypes and depleting Betamix inventories. In 2020, we observed escaped waterhemp can be controlled using inter-row cultivation or by the use of inter-row application of Liberty through a hooded sprayer. BASF Corp is drafting a 24c local needs label for Minnesota and North Dakota for 2021 to allow for this type of application.

Acknowledgements
We wish to thank the Sugarbeet Research and Education Board for funding this research in 2020. Thank you to our cooperators, Vince Ulstad, Hickson, ND and Youngkrantz Family Farms, Blomkest, MN. We also want to thank the Sugarbeet Cooperatives, American Crystal Sugar, Minn-Dak Farmers Cooperative, and Southern Minnesota Beet Sugar Cooperative for collaborating with field research. We also thank our summer student employees Ryan Borgen and Brad Stewart along with other NDSU colleagues for their contributions.

KOCHIA CONTROL IN SUGARBEET

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Summary

1. Apply ethofumesate preplant incorporated (PPI) or preemergence (PRE) at 6 to 7.5 pt/A in sugarbeet fields where kochia is identified as the most important weed control challenge in sugarbeet.
2. Consult with your Agriculturalist, ag-retailer or crop consultant to determine if your field is a glyphosate-resistant kochia biotype.
3. Time herbicide applications to kochia growth stage to optimize control.
4. Betamix improved control from PowerMax + ethofumesate postemergence (POST) in these experiments. However, we highly recommend you carefully manage Betamix rate based on sugarbeet growth stage to ensure sugarbeet safety, especially when Betamix follows ethofumesate soil applied.
5. Kochia control from crops in sequence with sugarbeet are often more effective than sugarbeet herbicides for kochia control.

Introduction
Kochia is an invasive annual broadleaf native to Asia. Kochia was introduced into the United States at the end of the 1800s as an ornamental from Europe (Friesen et al. 2009). Kochia is found in grasslands and pastures, along roadsides and ditch banks, and in cultivated fields in North Dakota and northwestern Minnesota. Kochia has been ranked among the most serious weed species in the United States due to its high rate of spread (Forcella 1985). In North Dakota and Minnesota, kochia is a major concern because it is competitive with many crop species. Traits including early-season emergence, rapid growth, and drought tolerance confer upon kochia a unique competitive ability, especially in slow growing crops like sugarbeet. Kochia was ranked in a Weed Science Society of America member's survey as one of the top six most troublesome weeds in row crops production (Van Wychen 2016) and has been documented to cause yield loss in sugarbeet (Mesbah et al. 1994).

Herbicides are a major component of kochia control programs. The outcome of relying on herbicides combined with kochia's competitive characteristics and high genetic diversity, has created weed population shifts and led to the evolution of herbicide-resistant populations. These resistant populations are often found in sugarbeet. Kochia has evolved resistance to at least four herbicide sites of action, including (ALS) inhibitors, synthetic auxins, photosystem II (PSII) inhibitors, and EPSP synthase inhibitors or glyphosate. Glyphosate-resistant kochia is widespread and concerning to farmers since glyphosate is relied upon in many cropping systems.

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

Material and Methods
Experiments were conducted on natural kochia populations near Hickson, ND and Manvel, ND in 2020. 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 4.7 inch spacing between seeds.

Treatment list can be found in Table 1. All treatments were applied with a bicycle sprayer through appropriate nozzles and CO_2 pressure to deliver 17 gpa spray solution to the center four rows of six row plots 35 feet in length. Herbicides were immediately incorporated using a field cultivator set 3 to 4 inches deep. The entire experimental area received field cultivation after PPI treatments were applied to remove the variability that could otherwise be caused by the incorporating tillage.

Table 1. Herbicide treatment, rate, and application timing.

Herbicide Treatment	Rate (fl oz/A)	Sugarbeet or kochia growth stage (lvs/ size)
Ethofumesate	32	PPI
Ethofumesate	64	PPI
Ethofumesate	96	PPI
Ethofumesate	32	PRE
Ethofumesate	64	PRE
Ethofumesate	96	PRE
Ethofumesate	16	2 lf
Ethofumesate	32	2 lf
Ethofumesate + Roundup PowerMax	16 + 28	2 lf
Ethofumesate + Roundup PowerMax	32 + 28	2 lf
Ethofumesate + Roundup PowerMax	4 +28 / 4 + 28 / 4 + 22	Dime size / 10 day / 10 day
Ethofumesate + Roundup PowerMax + Betamix	4+28+10 / 4+28+12 / 4 + 22+16	Dime size / 10 day /10 day
+ Ultra Blazer	16	10 lf
Ethofumesate + Roundup PowerMax + Ultra Blazer	4 + 28 + 16	10 lf

[1]Treatments with ethofumesate POST applied with HSMOC (High Surfactant Methylated Oil Concentrate) at 1.5 pt/A.
[2]Treatments with Roundup PowerMax plus ethofumesate applied with HSMOC at 1.5 pt/A plus N-Pak AMS at 2.5% v/v.
[3]Treatments with Ultra Blazer applied with Prefer 90 NIS at 0.25% v/v plus N-Pak AMS at 2.5% v/v.

Sugarbeet injury was evaluated as a visual estimate of percent growth reduction (0 to 100% scale, 0 is no visible injury and 100 is complete loss of plant / stand) of the middle 4 rows per plot compared with the adjacent untreated rows. Weed control was evaluated as a visual estimate of percent fresh weight reduction (0 is no injury and 100 is complete control) in the four treated rows compared to the adjacent untreated rows 7, 14, and 21 days (+/- 3 days) after application. Experimental design was randomized complete block with 6 replications. All data were analyzed with the ANOVA procedure of ARM, version 2020.2 software package.

Results

Sugarbeet injury ranged from 0 to 80% and 0 to 25% in Manvel, ND and Hickson, ND, respectively (Table 2). Sugarbeet stands were variable in both experiments. Increased rates of ethofumesate plus PowerMax or ethofumesate plus PowerMax plus Betamix caused unacceptable sugarbeet injury across locations. The first POST application was applied to 2-lf sugarbeet with 10 fl oz of Betamix in mixtures with PowerMax plus ethofumesate. The rate of Betamix was too great in this combination which was made evident by 45% sugarbeet injury compared with 29% from repeat applications of PowerMax and ethofumesate at Manvel, ND.

Table 2. Sugarbeet growth reduction at Manvel, ND and Hickson, ND in 2020.[1]

Treatment	Rate	Sugarbeet or kochia growth stage	Sugarbeet Growth Reduction Manvel, ND	Sugarbeet Growth Reduction Hickson, ND
	--fl oz/A--	--lvs/size--	---------------%--------------	
Ethofumesate	32	PPI	0 a	0 a
Ethofumesate	64	PPI	3 ab	15 bc
Ethofumesate	96	PPI	7 ab	15 bc
Ethofumesate	32	PRE	0 a	0 a
Ethofumesate	64	PRE	3 ab	0 a
Ethofumesate	96	PRE	-[2]	0 a
Ethofumesate	16	2 lf	23 abc	0 a
Ethofumesate	32	2 lf	3 ab	0 a
Ethofumesate + Roundup PowerMax	16 + 28	2 lf	15 ab	13 abc
Ethofumesate + Roundup PowerMax	32 + 28	2 lf	55 cd	20 bc
Ethofumesate + Roundup PowerMax	4 +28 / 4 + 28 / 4 + 22	Dime size / 10 day / 10 day	29 abc	8 ab
Ethofumesate + Roundup PowerMax + Betamix	4+28+10 / 4+28+12 / 4 + 22+16	Dime size / 10 day /10 day	45 bc	25 c
Ultra Blazer	16	10 lf	60 cd	0 a[3]
Ethofumesate + Roundup PowerMax + Ultra Blazer	4 + 28 + 16	10 lf	80 d	0 a[3]
			------------*P*-value-----------	
			0.0001	0.0015

[1]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.
[2]Treatments contained too much variability across experiments.
[3]Evaluation made before treatment effects could be observed.

Kochia control with herbicide treatments was unacceptable at Hickson and Manvel in 2020. Kochia control from ethofumesate applied PPI or PRE ranged from 13% to 40% control (Table 3) across locations. A rate response was observed with kochia control from ethofumesate applications. Ethofumesate at 96 fl oz/A, applied as either a PPI or PRE, provided greater kochia control than ethofumesate at 32 or 64 fl oz/A across locations. There was no difference between ethofumesate applied before or after planting, although there was a slight numeric advantage to ethofumesate applied PPI.

Table 3. Kochia control 14 days after the last application, across environments, 2020.[1]

Treatment	Rate	Sugarbeet or kochia growth stage	Kochia Control
	--fl oz/A--	--lvs/size--	---------%----------
Ethofumesate	32	PPI	18 c
Ethofumesate	64	PPI	21 bc
Ethofumesate	96	PPI	40 bc
Ethofumesate	32	PRE	13 c
Ethofumesate	64	PRE	23 bc
Ethofumesate	96	PRE	33 bc
Ethofumesate	16	2 lf	41 bc
Ethofumesate	32	2 lf	47 bc
Ethofumesate + Roundup PowerMax	16 + 28	2 lf	95 a
Ethofumesate + Roundup PowerMax	32 + 28	2 lf	93 a
Ethofumesate + Roundup PowerMax	4 +28 / 4 + 28 / 4 + 22	Dime size / 10 day / 10 day	97 a
Ethofumesate + Roundup PowerMax + Betamix	4+28+10 / 4+28+12 / 4 + 22+16	Dime size / 10 day /10 day	98 a
Ultra Blazer	16	10 lf	54 b
Ethofumesate + Roundup PowerMax + Ultra Blazer	4 + 28 + 16	10 lf	91 a
			---*P*-value---
			0.0003

[1]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.

The most efficacious treatment with the least amount of sugarbeet injury in the experiment across locations were POST applications of PowerMax (Manvel and Hickson contained glyphosate sensitive kochia populations) plus ethofumesate in a single or repeat applications (Table 3). PowerMax plus ethofumesate plus Betamix provided excellent kochia control. However, was too injurious to the sugarbeet crop.

Ethofumesate POST at 32 fl oz/A gave a disappointing lack of early kochia control. Kochia was at least 1-inch tall at application which apparently was too large for POST control from ethofumesate. Ultra Blazer, an herbicide not yet approved for in season sugarbeet production, provided greater than 83% control but resulted in unacceptable sugarbeet injury at Manvel, ND (data not presented). Ultra Blazer provided less kochia control at the Hickson, ND site. Ultra Blazer was applied to smaller sugarbeet than intended due to the robust kochia density. The result was good kochia control but an unacceptable level of sugarbeet injury. Sugarbeet must be at least the 8-lf stage before Ultra Blazer applications are made. These results suggest Ultra Blazer in sugarbeet will only be useful for POST control of kochia following ethofumesate soil applied or PowerMax and ethofumesate POST. These data reinforce the necessity for focusing on kochia control in preceding crops to minimize kochia infestations during a sugarbeet cropping season.

Kochia control in crops in sequence with sugarbeet. Researchers selected their preferred programs for kochia control in corn, soybean, sugarbeet, wheat and fallow in 2010 and 2011. Preferred programs were a combination of soil residual and POST programs applied singly or used in sequence in a kochia control program. Kochia control was arranged by crop and location across years (Figure 1). Herbicide programs labeled for kochia control in corn or soybean demonstrated less variability in kochia control compared with fallow, wheat, and sugarbeet (Sbettala et al. 2019). The potential for kochia control failure was relatively low in corn, regardless of the herbicide program evaluated, whereas there was no herbicide program evaluated in sugarbeet that provided greater than 86% kochia control at any field location with the median control of 40% across all sites (Figure 1).

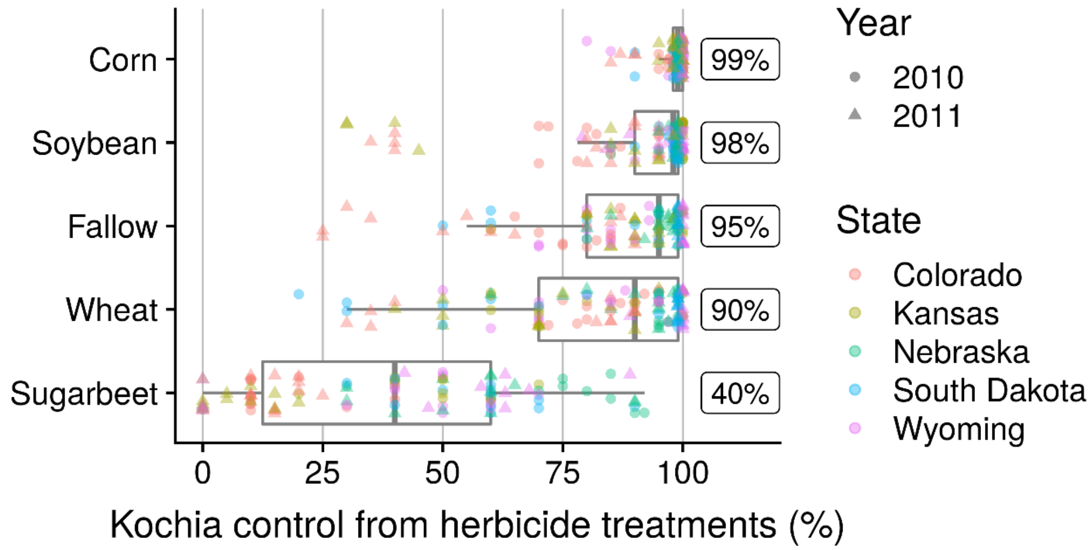

Figure 1. Kochia control 30 days after final application of herbicide treatment labeled for corn, soybean, fallow, wheat and sugarbeet. Each point represents a plot in a field. Number are the median kochia control from herbicide treatments.

Effective long-term kochia management in sugarbeet will likely depend on rotation with crops such as corn and soybean for which effective herbicides are available. However, rotations with these crops create challenges as kochia control programs in corn and soybean will often not permit the planting of sugarbeet the following year. Corn and soybean herbicide treatments included combinations of PRE plus POST herbicide applications. Corn, wheat, and to an extent, soybean, have dense canopies forming early in the growing season, allowing them to compete with kochia. In contrast, sugarbeet is a poor competitor with kochia because it has a slow developing and short canopy structure.

Dr. Joseph Ikley, North Dakota Extension Weed Control Specialist, has provided 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.

Corn

1) 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)
2) 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)
3) 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)

Soybean

1) Authority Edge[3] (full rate for soil type) fb PowerMax + dicamba or Liberty (dicamba use requires Xtend soybeans, Liberty use requires Enlist, LibertyLink, LLGT27, or XtendFlex soybeans)
2) Fierce MTZ[4] (full rate for soil type) fb PowerMax + dicamba or Liberty (dicamba use requires Xtend soybeans, Liberty use requires Enlist, LibertyLink, LLGT27, or XtendFlex soybeans)
3) 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

Wheat

1) Huskie FX[6] (full rate)

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[1]Atrazine requires a second cropping season after herbicide application crop rotation restriction to sugarbeet.
[2]Acuron/Flexi requires an 18 month after application crop rotation restriction to sugarbeet.
[3] Authority Edge requires up to 36 months after application crop rotation restriction to sugarbeet.
[4] Fierce MTZ requires up to 18 months after application crop rotation restriction to sugarbeet.
[5] Authority MTZ requires up to 24 months after application crop rotation restriction to sugarbeet.

2) Starane NXT[7] (full rate)
3) Talinor[8] (full rate)

Recommendations

Ethofumesate should be applied preplant or preemergence at 6 to 7.5 pt/A in sugarbeet fields where kochia is identified as the most important weed control challenge in sugarbeet. Herbicide applications should be timed to kochia growth stage rather than sugarbeet. The addition of Betamix improved control from PowerMax + ethfofumesate POST in these experiments. However, we highly recommend you carefully manage Betamix rate based on sugarbeet growth stage to ensure sugarbeet safety, especially when Betamix follows soil applied (PPI or PRE) ethofumesate. Experiments will be conducted in 2021 to evaluated soil applied applications of ethofumesate. Betamix, Ultra Blazer, and ethofumesate rates and timings must be further evaluated to reduce sugarbeet injury.

Acknowledgements

We wish to thank Mr. Scott Johnson, Manvel, ND and Mr. Neil Rockstad, Hendrum, MN along with KayJay Ag Services for agreeing to collaborate on this research. However, we needed to drop the Hendrum, MN location do to travel restrictions associated with COVID-19 in 2020. We also thank our summer student employees Ryan Borgen and Brad Stewart.

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[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.

WEED CONTROL USING HIGH VOLTAGE ELECTRICITY

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Summary

1. The Weed Zapper™ provided greater than 80% waterhemp (primary stem) control, 14 days after treatment (DAT). Kochia (highly branched stem) control 14 DAT was less.
2. Operating speed did not influence waterhemp control (Univ of Missouri research).
3. One pass across the field controlled waterhemp in a dense canopy but multiple passes provided better control in an open canopy.
4. Seed viability experiments on harvested seed will be conducted in January to March 2021.
5. The Weed Zapper is not a replacement for soil residual herbicides but appears to be an effective approach for rescue control of glyphosate resistant weeds.

Introduction

Herbicide resistance is on the rise in many weed species, including waterhemp (Heap 2020). Herbicide resistance has redefined weed thresholds since weed escapes produce large quantities of resistant seed, adding to weed seedbanks and potentially affecting crops the following season (Oerke and Dehne 2004; Schweizer and Dexter 1987). One tool that is being utilized by growers to control weed escapes is the electric discharge system (EDS). This machine is comprised of a front-end tractor mounted boom/bar with a rear-mounted PTO-driven generator that creates high-voltage electricity. The front-end tractor mounted boom can unfold to provide up to a 44-foot swath and the generator can produce 200,000 watts or up to 15,000 volts. Voltage is adjusted with three settings based on target species and density; broadleaf (low), broadleaf (medium), and grass (high). The EDS is operated from and powered by a 275+ horsepower tractor. The boom height is set just above the sugarbeet canopy and operating speeds range from 2 to 6 mph. The boom contacts the stem and leaves of weed escapes that have grown above the canopy as the tractor moves through the field. Once contacted, the electricity heats cellular fluids and bursts vascular bundles. The EDS system is commercially marketed as the "Weed Zapper™" and manufactured in Sedalia, Missouri. The Weed Zapper is a modern-day prototype of the original EDS the "Lasco Lightening Weeder" developed in Grand Forks County in 1979. The Weed Zapper features more wattage and major safety improvements for the operator compared to the original EDS. Growers have been utilizing this equipment to manage weed escapes late in the growing seasons of 2019 and 2020.

Objectives

The objectives of this study were to: 1) determine waterhemp control using the Weed Zapper; 2) determine if increasing passes over the same area will improve waterhemp control; and 3) determine the viability of waterhemp seed at sugarbeet harvest.

Material and Methods

On-farm experiments were conducted in 2020 in collaboration with three local sugarbeet producers on eight production fields. In the first experiment, waterhemp control was estimated after operating the Weed Zapper at a consistent speed across the field beginning mid-July through late August or when waterhemp grew above the sugarbeet canopy. Waterhemp density was scored in each field (0 to 10, 0 indicating no waterhemp and 10 indicating a uniform and complete waterhemp infestation) and ranged from '1' to '9'. Sugarbeet fields were considered replications and waterhemp control was evaluated in two 5 x 5 square foot quadrats within each field. Quadrats were placed in areas of each field that represented the weed density of that location. A second experiment was established to evaluate waterhemp control following one, two, or four passes of the Weed Zapper through each quadrat, with multiple passes immediately following one another. This experiment was conducted in two fields; the first field had a waterhemp density score of '4' and the second field was scored a '9.' A third experiment considered kochia control from the Weed Zapper and was conducted at a single location where quadrats corresponded to replications. The standard speed used was 4 mph and the controller voltage was adjusted to broadleaf (low).

Visible percent necrosis (0 to 100% with 100% being complete darkening of vegetation), visible percent wilting (0 to 100% with 100% being complete wilting phenotype), and visible percent weed control (0 to 100% with 100% being complete waterhemp control) were collected 1, 3, 7, and 14 DAT (days after treatment). Data were analyzed using SAS Data Management software PROC MIXED procedure to test for significant differences at p=0.05.

To evaluate the effect of the Weed Zapper on weed seed viability, seed samples were collected from representative kochia or waterhemp plants in each quadrat before sugarbeet harvest. Samples were dried in the greenhouse, were threshed, and seed was stored in the cold storage room at Waldron Hall, NDSU, at 52 degrees F and 37% humidity for 30 days to vernalize seed and break dormancy in preparation for growth room and greenhouse experiments to determine seed viability (germination and emergence).

Results and Discussion

Waterhemp control. Waterhemp wilting phenotype was observed immediately following Weed Zapper application and changed very little 1 to 14 DAT (Table 1). However, necrosis injury or blackening of the stem and leaves increased from 26% to 79%, 1 to 14 DAT, respectively. Waterhemp overall control corresponded more closely to necrosis injury than wilting and increased significantly from 3 to 14 DAT.

Table 1. Waterhemp wilting, necrosis, and overall control with the Weed Zapper from 1 to 14 days after treatments, averaged across eight locations, 2020.

	Waterhemp		
Days after treatment	Wilting Phenotype	Necrosis	Control
	------------------------------------	%	------------------------------------
1	72 a	0 d	15 c
3	73 a	26 c	39 b
7	74 a	71 b	76 a
14	70 a	79 a	85 a

Waterhemp control as influenced by number of passes. Waterhemp control was evaluated following 1, 2, or 4 passes of the Weed Zapper in two fields. The first field had a waterhemp density that scored ‘9’ (Figure 1) and the second field had a waterhemp density that scored ‘4’ (Figure 2). We were interested in determining if multiple passes affected waterhemp control, especially in the Kragnes field where waterhemp density scored ‘9’. We observed improved waterhemp control over time in both fields. Waterhemp control following four passes increased at 3 and 7 DAT compared to a single pass and tended to increase control 14 DAT at Kragnes. Waterhemp control was significantly improved from making two passes through the field compared to a single pass at Felton (Figure 2).

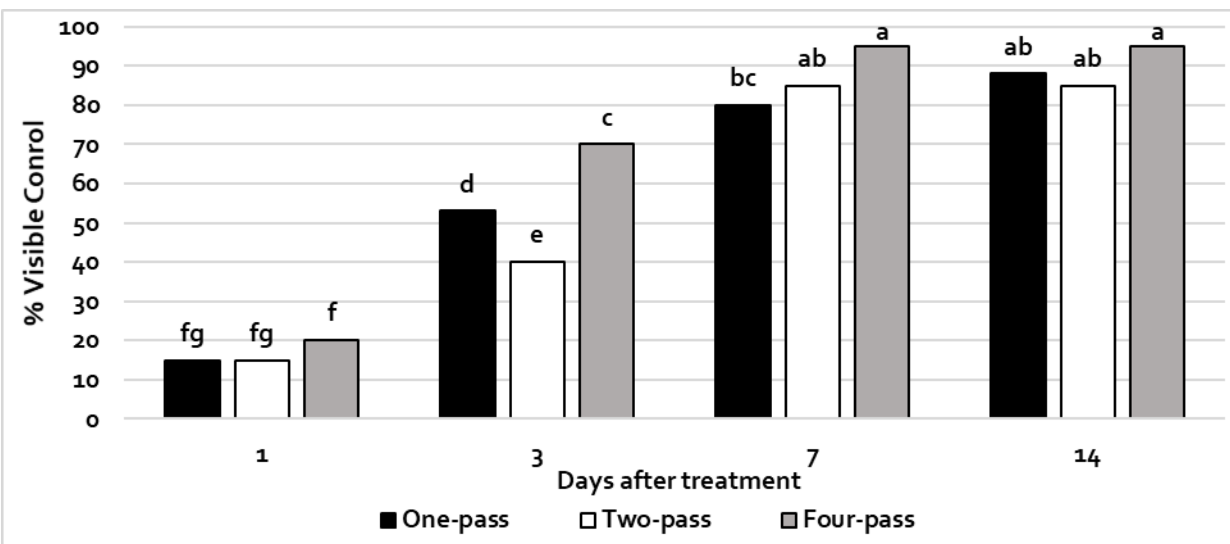

Figure 1. Waterhemp control by treatment, Kragnes, MN, 2020.

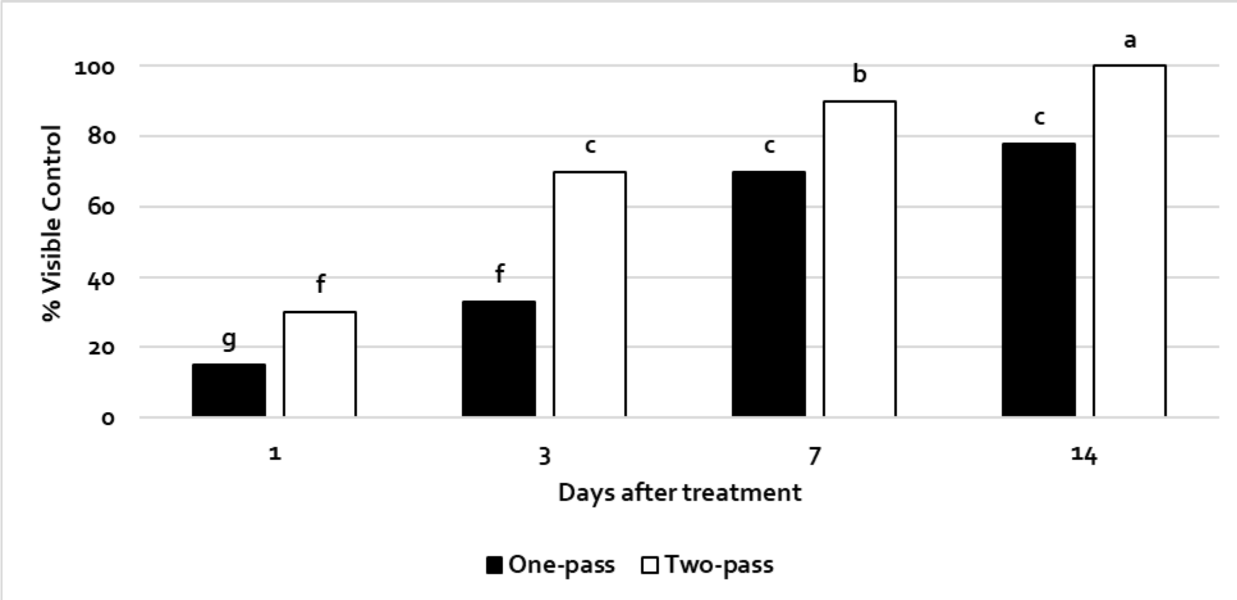

Figure 2. Waterhemp control by treatment, Felton, MN, 2020

Kochia control. Kochia control with the Weed Zapper was evaluated at one location in 2020. We observed the immediate wilting phenotype with kochia, similar to waterhemp, but observed less necrosis and overall kochia control compared with waterhemp (Table 2). Our results were similar to observations with the Lasco Lightening Weeder. Rasmusson et al. (1979) observed better control from the Lasco Lightening Weeder on weeds with a primary stem (i.e. giant ragweed or sunflower) than those with highly branched stems (kochia) or grasses. Our data, though limited to one kochia location, suggested the Weed Zapper gave greater waterhemp control than kochia control.

Table 2. Kochia wilting, necrosis, and overall control with the Weed Zapper from 1 to 14 days after treatment, Glyndon, MN, 2020.

	Kochia		
Days after treatment	Wilting Phenotype	Necrosis	Control
	---------------------------------%-----------------------------------		
1	86 a	0 f	14 d
3	73ab	5 ef	19 d
7	65 ab	18 de	44 c
14	51 b	43 c	76 b

The Weed Zapper is used for weed control when weed height extends above the cultivated crop height. In Minnesota and North Dakota, waterhemp generally extends above the sugarbeet canopy and begins to flower in July. The Weed Zapper was used in July and early August in 2019. However, in 2020, we observed the Weed Zapper in use in fields in late August, well beyond when waterhemp typically begins flowering. Waterhemp seed becomes viable very rapidly following flowering. Researchers at the University of Illinois reported waterhemp seed was viable 9 to 12 days after flowering (Bell and Tranel, 2010), thereby leading to questions about how the Weed Zapper will affect weed seed viability.

Seed was collected in quadrats from waterhemp and kochia plants treated with the Weed Zapper. We hypothesize that waterhemp seed could be killed if the electrical treatment resulted in heating the seed to the extent that proteins were denatured. Growth room and greenhouse experiments are planned to examine seed viability and seed emergence.

Conclusions

Wilting was observed immediately after application and the Weed Zapper effectively controlled 80% of escaped waterhemp and 76% of escaped kochia, 7 to 14 days after treatment. Multiple passes may improve efficacy in moderately dense waterhemp infestation but may not improve efficacy in dense waterhemp infestations. However, weed interference resulting in reduced sugarbeet root yield and quality will presumably occur since the Weed Zapper is operated after weeds extended above the crop canopy. Growers that purchased the Weed Zapper indicate that treatment in July and August kills weeds and reduces weed biomass, thus improving harvest efficiency and storage. We believe the Weed Zapper can be a component of a weed management system in sugarbeet, much like a rescue herbicide treatment, but it is not a substitute for soil residual herbicides for waterhemp or kochia control. Replicated plot research will be needed to investigate the effect on yield, sucrose content, harvestability, seed viability, the relationship with soil applied herbicides, timing of application, voltage settings, speed, etc. to determine more precise evaluation of this equipment.

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SUGARBEET TOLERANCE TO COMPLEX MIXTURES IN 2020

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Summary

1. Ethofumesate preemergence (PRE) followed by postemergence (POST) herbicides alone or in combinations did not increase sugarbeet injury in the field.

2. High surfactant methylated oil concentrate (HSMOC) increased growth reduction injury from Lorsban plus Stinger applied with glyphosate, ethofumesate and Outlook, 7 days after treatment (DAT). HSMOC with herbicide combinations did not increase growth reduction or impact fresh weigh at 14 DAT.

3. Stinger plus Lorsban mixed with glyphosate, ethofumesate and Outlook caused greater growth reduction injury compared with Outlook plus glyphosate and ethofumesate.

4. HSMOC rate should be reduced when Lorsban is mixed with glyphosate, ethofumesate and a chloroacetamide. HSMOC should be eliminated from the mixture when/if Stinger and Lorsban are mixed with glyphosate, ethofumesate and a chloroacetamide herbicide.

Introduction

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. Combinations of postemergence herbicides can improve the spectrum of weeds controlled and provide greater total weed control, 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, so combinations should be used with caution. Glyphosate is frequently combined with other herbicides including ethofumesate, Stinger, or a chloroacetamide herbicide (Dual, Outlook, or Warrant) in sugarbeet. On occasion, growers may mix as many as five active ingredients into a single mixture.

Observations of malformation and necrosis injury from POST Betamix and Stinger applied in combination with glyphosate, ethofumesate, and S-metolachlor were assessed in a field near Amenia, ND in 2019. We later learned the sugarbeet field had also been treated with ethofumesate PRE at 3 pt/A. Researchers have reported ethofumesate PRE may change the texture of surface waxes thus increasing the sensitivity of sugarbeet to POST herbicides (Abulnaja et al. 1992).

We have coined the term 'complex mixtures' to describe combinations of three or more herbicides applied POST to sugarbeet. We anticipate two outcomes for the immediate future. First, ethofumesate PRE will be used on more acres for control of waterhemp and kochia in sugarbeet. Second, complex mixtures will be more commonplace in our pursuit of broad spectrum and effective control of glyphosate-resistant weeds.

Objective

The objective of this research was a) to investigate sugarbeet injury from ethofumesate PRE followed by POST mixtures with glyphosate and b) to investigate the role of HSMOC in relation to sugarbeet injury when applied with complex mixtures.

Materials and Methods

Field. Experiments evaluating sugarbeet injury from ethofumesate PRE followed by POST mixtures with glyphosate were conducted near Christine, ND and Prosper, ND in 2020. 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. Herbicide treatments were applied on May 12 and June 11, and May 30 and June 18 at Christine and Prosper, respectively, with a bicycle wheel sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 43 psi. The treatment list can be found in Table 1. Visible sugarbeet necrosis, malformation, and growth reduction injury was evaluated at both field locations. All evaluations were a visual estimate of injury phenotypes in the four treated rows compared to the adjacent, two-row, untreated strip. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2020.2 software package.

Table 1. Herbicide treatment, rate, and application timing at Christine and Prosper, ND in 2020.

Preemergence (PRE) Treatment	Postemergence (POST) Treatment	Rate (fl oz / A)	Sugarbeet stage (lvs)
-[1]	Glyphosate + Nortron[2]	32 + 12	2-4
-	Glyphosate + Nortron + Stinger	32 + 12 + 6	2-4
-	Glyphosate + Nortron + Stinger + Outlook	32 + 12 + 6 +21	2-4
-	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx	32 + 12 + 6 +21 + 4	2-4
-	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx + Betamix	32 + 12 + 6 +21+ 4 + 32	2-4
Nortron[3]	Glyphosate + Nortron	32 + 12	PRE / 2-4
Nortron	Glyphosate + Nortron + Stinger	32 + 12 + 6	PRE / 2-4
Nortron	Glyphosate + Nortron + Stinger + Outlook	32 + 12 + 6 +21	PRE / 2-4
Nortron	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx	32 + 12 + 6 +21 + 4	PRE / 2-4
Nortron	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx + Betamix	32 + 12 + 6 +21+ 4 + 32	PRE / 2-4

[1] – indicates that no PRE herbicide was applied but that POST applications were applied at the leaf stage shown.
[2]All POST entries included Destiny HC (HSMOC) + N-Pak Liquid AMS at 1.5 pt/A + 2.5% v/v. Glyphosate used was Roundup PowerMax.
[3]Nortron was applied at 3 pt/A PRE.

Greenhouse. Greenhouse experiments were conducted in 2019, 2020, and 2021 to evaluate sugarbeet injury from complex mixtures POST with or without ethofumesate PRE as well as complex mixtures with or without HSMOC. Greenhouse experiments were a randomized complete block design with a factorial treatment arrangement and three or four replications. Treatment factors were herbicide treatment and PRE herbicide treatment or adjuvant depending on the experiment. Herbicides were applied PRE to 2-4 leaf sugarbeet. Plants were grown at 24 to 27C for a 16 h photoperiod under natural light supplemented with artificial lighting. Plants were watered and fertilized as necessary. Herbicide treatments were applied using a spray booth (Generation III, DeVries Manufacturing, Hollandale, MN) equipped with a single 8001 XR nozzle calibrated to deliver 11 gpa spray solution at 40 psi and 3 mph. The herbicide treatment lists are found in Tables 2 and 3.

Table 2. Herbicide treatment, rate, and application timing in the greenhouse in 2019 and 2020.

Preemergence (PRE) Treatment	Postemergence (POST) Treatment	Rate (fl oz / A)	Sugarbeet stage (lvs)
-[1]	Glyphosate + Nortron[2]	32 + 12	2-4
-	Glyphosate + Nortron + Stinger	32 + 12 + 6	2-4
-	Glyphosate + Nortron + Stinger + Dual Magnum	32 + 12 + 6 + 20	2-4
-	Glyphosate + Nortron + Stinger + Dual Magnum + Betamix	32 + 12 + 6 + 20 + 32	2-4
-	Glyphosate + Nortron + Stinger + Dual Magnum + Betamix + Lorsban	32 + 12 + 6 + 20 + 32 + 16	2-4
Ethofumesate 4 SC[3]	Glyphosate + Nortron	32 + 12	PRE / 2-4
Ethofumesate 4 SC	Glyphosate + Nortron + Stinger	32 + 12 + 6	PRE / 2-4
Ethofumesate 4 SC	Glyphosate + Nortron + Stinger + Dual Magnum	32 + 12 + 6 + 20	PRE / 2-4
Ethofumesate 4 SC	Glyphosate + Nortron + Stinger + Dual Magnum + Betamix	32 + 12 + 6 + 20 + 32	PRE / 2-4
Ethofumesate 4 SC	Glyphosate + Nortron + Stinger + Dual Magnum + Betamix + Lorsban	32 + 12 + 6 + 20 + 32 + 16	PRE / 2-4

[1]– indicates that no PRE herbicide was applied but that POST applications were applied at the leaf stage shown.
[2]All POST entries included Destiny HC (HSMOC) + N-Pak AMS at 1.5 pt/A + 2.5% v/v. Glyphosate was Roundup PowerMax.
[3]Ethofumesate 4 SC was applied at 3 pt/A PRE.

Table 3. Herbicide treatment, rate, and application timing in the greenhouse in 2020 and 2021.

Postemergence Treatment[1]	Rate (fl oz / A)	Adjuvant	Sugarbeet stage (lvs)
Glyphosate + ethofumesate	32 + 12	-	2-4 lvs
Glyphosate + ethofumesate + Outlook	32 + 12 + 21	-	2-4 lvs
Glyphosate + ethofumesate + Outlook + Lorsban	32 + 12 + 21 + 16	-	2-4 lvs

Glyphosate + ethofumesate + Outlook + Lorsban + Stinger	32 + 12 + 21 + 16 + 6	-	2-4 lvs
Glyphosate + ethofumesate	32 + 12	HSMOC[2]	2-4 lvs
Glyphosate + ethofumesate + Outlook	32 + 12 + 21	HSMOC	2-4 lvs
Glyphosate + ethofumesate + Outlook + Lorsban	32 + 12 + 21 + 16	HSMOC	2-4 lvs
Glyphosate + ethofumesate + Outlook + Lorsban + Stinger	32 + 12 + 21 + 16 + 6	HSMOC	2-4 lvs

[1]All mixtures contained N-Pak Liquid AMS at 2.5% v/v. Glyphosate used was Roundup PowerMax and ethofumesate was Ethofumesate 4SC.
[2]HSMOC=Destiny HC at 1.5 pt/A.

Visual sugarbeet injury evaluations (0 to 100% with 100% reflecting complete sugarbeet death) were completed 3, 7, and 14 (±3) DAT. Above-ground fresh weight (g pot^{-1}) were collected at the conclusion of the experiment or after the 14 DAT evaluation. Data were analyzed with the ANOVA procedure of ARM, version 2020.4 software package.

Results
Field. The Christine experiment was discontinued due to poor sugarbeet stands. At Prosper, PRE ethofumesate had minimal effect on sugarbeet injury across POST treatments (Factor A) or ethofumesate did not increase sugarbeet injury from postemergence herbicides, even when Betamix was part of the mixture (Factor A × B) (Table 4).

Table 4. Sugarbeet growth reduction in response to preemergence and postemergence herbicide treatments at Prosper, ND in 2020.

			Growth Reduction		
Preemergence Herbicide	Postemergence (POST) Herbicide	Rate	10 DAT[1]	20 DAT	Mean[2]
		------fl oz/A------	------------%------------		
-	Glyphosate + Nortron[4]	32 + 12	5	0	5
-	Glyphosate + Nortron + Stinger	32 + 12 + 6	0	0	0
-	Glyphosate + Nortron + Stinger + Outlook	32 + 12 + 6 +21	26	9	20
-	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx	32 + 12 + 6 +21 + 4	30	25	26
-	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx + Betamix	32 + 12 + 6 +21+ 4 + 32	58	28	47
Nortron[3]	Glyphosate + Nortron	32 + 12	3	0	4
Nortron	Glyphosate + Nortron + Stinger	32 + 12 + 6	10	9	13
Nortron	Glyphosate + Nortron + Stinger + Outlook	32 + 12 + 6 +21	12	10	16
Nortron	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx	32 + 12 + 6 +21 + 4	31	21	33
Nortron	Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx + Betamix	32 + 12 + 6 +21+ 4 + 32	67	20	41
P-Value, Factor A	PRE ethofumesate		0.2847	0.5560	0.6842
P-Value, Factor B	POST Herbicide treatments		0.0001	0.0001	0.0001
P-Value, Factor A×B	PRE herbicide × POST Herbicide treatment		0.1954	0.5112	0.6258

[1]DAT=Days after POST treatment.
[2]Average of growth reduction 5, 10, and 20 DAT.
[3]Nortron was applied at 3 pt/A.
[4]All POST entries included Destiny HC (HSMOC) + N-Pak Liquid AMS at 1.5 pt/A + 2.5% v/v. Glyphosate used was Roundup PowerMax.

Sugarbeet injury 10 DAT, 20 DAT or the average across evaluations was greater when the number of herbicides mixed with glyphosate and ethofumesate increased, averaged across ethofumesate PRE (Table 5). Growth reduction injury was negligible when Stinger was mixed with glyphosate plus ethofumesate but increased when Mustang Maxx was combined with glyphosate, ethofumesate, Stinger and Outlook. Necrosis and malformation damage varied from plant to plant in plots. Sugarbeet injury was greatest or tended to be greatest when Betamix was combined with glyphosate, ethofumesate, Stinger, Outlook and Mustang Maxx. Sugarbeet necrosis injury from mixtures including Betamix was not consistent but generally was negligible (data not presented). Malformation injury was greater when Outlook, Mustang Maxx or Betamix was mixed with glyphosate, ethofumesate and Stinger (data not presented).

Table 5. Sugarbeet growth reduction in response to postemergence herbicide treatments with or without ethofumesate PRE at Prosper, ND in 2020.

Postemergence (POST) Herbicide[1]	Rate	Growth Reduction 10 DAT[2]	20 DAT	Mean[2]
	--------fl oz/A--------	------------------%------------------		
Glyphosate + Nortron	32 + 12	4 c	0 c	5 d
Glyphosate + Nortron + Stinger	32 + 12 + 6	5 c	4 bc	6 d
Glyphosate + Nortron + Stinger + Outlook	32 + 12 + 6 +21	19 b	9 b	18 c
Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx	32 + 12 + 6 +21 + 4	30 b	23 a	29 b
Glyphosate + Nortron + Stinger + Outlook + Mustang Maxx + Betamix	32 + 12 + 6 + 21+ 4 + 32	62 a	24 a	44 a
P-value		0.0001	0.0001	0.0001

[1]All POST entries included Destiny HC (HSMOC) + N-Pak Liquid AMS at 1.5 pt/A + 2.5% v/v. Glyphosate used was Roundup PowerMax.DAT=Days after POST treatment.
[2]Average of growth reduction 5, 10, and 20 DAT.

Greenhouse. Ethofumesate 4SC at 3 pt/A PRE did not affect sugarbeet malformation or growth reduction from POST herbicide treatments and, in general, did not have any effect on sugarbeet necrosis (Table 6).

Table 6. Sugarbeet necrosis, malformation, and growth reduction injury from postemergence herbicide treatments with and without Ethofumesate 4SC PRE at 3 pt/A in the greenhouse in 2020.

	Necrosis[2]		Malformation		Growth Reduction	
Herbicide treatment[1]	No PRE	PRE	No PRE	PRE	No PRE	PRE
	---------------------------------%---------------------------------					
Base[3]	1 c[4]	1 c	3	5	2	3
Base + Stinger	0 c	2 c	17	15	2	4
Base + Stinger + Dual Magnum	7 bc	0 c	12	10	0	4
Base + Stinger + Dual Magnum + Betamix	11b	11 b	30	27	22	11
Base + Stinger + Dual Magnum + Betamix + Lorsban	23 a	13 b	25	27	18	19
P-Value	0.0241		0.9159		0.1594	

[1]All POST entries included Destiny HC (HSMOC) + N-Pak Liquid AMS at 1.5 pt/A + 2.5% v/v.
[2]Necrosis, malformation and growth reduction averaged across evaluations.
[3]Base = Roundup PowerMax at 32 fl oz/A + Ethofumesate 4SC at 12 fl oz/A.
[4]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance.

Due to the lack of effect from Ethofumesate 4SC PRE, data were combined to the POST treatment level (Table 7). The addition of Betamix and Lorsban increased sugarbeet necrosis, malformation, and growth reduction injury compared with glyphosate plus ethofumesate or glyphosate plus ethofumesate plus Stinger.

Table 7. Sugarbeet necrosis, malformation, and growth reduction injury in response to postemergence herbicide treatments averaged across PRE herbicide in the greenhouse in 2020.

Herbicide treatment[1]	Necrosis[2]	Malformation	Growth Reduction
	------------------------------	--%	------------------------------
Base[3]	1 c[4]	4 c	3 b
Base + Stinger	1 c	16 b	3 b
Base + Stinger + Dual Magnum	3 c	11 bc	2 b
Base + Stinger + Dual Magnum + Betamix	11 b	28 a	17 a
Base + Stinger + Dual Magnum + Betamix + Lorsban	18 a	26 a	18 a
P-Value	0.0001	0.0001	0.0001

[1]All POST entries included Destiny HC (HSMOC) + N-Pak Liquid AMS at 1.5 pt/A + 2.5% v/v.
[2]Necrosis, malformation and growth reduction averaged across evaluations.
[3]Base = Roundup PowerMax at 32 fl oz/A + Ethofumesate 4SC at 12 fl oz/A.
[4]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance.

The second greenhouse experiment considered both the visual assessment of sugarbeet growth reduction injury and sugarbeet fresh weight (g/pot) in response to herbicide mixtures both with and without HSMOC. Sugarbeet injury from glyphosate + ethofumesate + Outlook + Stinger + Lorsban was greatest 7 DAT and was greater or tended to be greater when HSMOC was added with the mixture (Table 8). Injury decreased with time and HSMOC, when added to herbicide mixtures, did not influence growth reduction or fresh weight at 14 DAT.

Visible sugarbeet growth reduction injury at 7 and 14 DAT increased when Outlook or Outlook + Lorsban +/- Stinger was mixed with glyphosate plus ethofumesate (Table 9). Growth reduction injury tended to be less 14 DAT than 7 DAT indicating that plants were starting to recover from their injury. Sugarbeet fresh weight per pot tended to be reduced as the complexity of mixtures increased.

Table 8. The effect of herbicide mixtures both with and without high surfactant methylated oil (HSMOC) on visual sugarbeet growth reduction injury and fresh weight averaged across two greenhouse runs in 2020 to 2021.

Herbicide treatment	Rate	Growth Reduction 7 DAT[1]		Growth Reduction 14 DAT		Fresh Weight	
		No HSMOC	HSMOC	No HSMOC	HSMOC	No HSMOC	HSMOC
	--fl oz/A--	---------------------	--%--		---------------------	-------g/pot-------	
Base[2]		6 ab[3]	1 a	6	12	32.6	30.3
Base + Outlook	21	18 c	15 bc	17	23	30.3	27.8
Base + Outlook and Lorsban	21 + 16	22 c	34 d	19	23	29.4	26.3
Base + Outlook, Lorsban and Stinger	21 + 16 + 6	38 d	49 e	32	39	29.8	28.0
P-Value		0.0257		0.9401		0.9869	

[1]DAT=Days after POST treatment.
[2]Base= Roundup PowerMax at 32 fl oz/A + Ethofumesate 4SC at 12 fl oz/A + N-Pak Liquid AMS at 2.5% v/v.
[3]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance.

Table 9. The effect of herbicide mixtures averaged across both with and without high surfactant methylated oil (HSMOC) on visual sugarbeet growth reduction injury and fresh weight averaged across two greenhouse runs in 2020 to 2021.

Herbicide treatment	Rate	Growth Reduction 7 DAT[2]	Growth Reduction 14 DAT	Sugarbeet Fresh Weight
	--fl oz/A--	--------------%--------------		--g/pot--
Base[2]		4 d[3]	9 c	31.4
Base + Outlook	21	16 c	20 b	29.0
Base + Outlook and Lorsban	21 + 16	28 b	21 b	28.9
Base + Outlook, Lorsban and Stinger	21 + 16 + 6	43 a	35 a	28.1
P-Value		0.0001	<0.0001	0.1436

[1]DAT=Days after POST treatment.
[2]Base= Roundup PowerMax at 32 fl oz/A + Ethofumesate 4SC at 12 fl oz/A + N-Pak Liquid AMS at 2.5% v/v.
[3]Means within a main effect not sharing any letter are significantly different by the LSD at the 10% level of significance.

Malformation injury from Stinger was negligible in these greenhouse experiments (data not presented). However, Stinger did cause greater sugarbeet growth reduction injury when added to Outlook + Lorsban compared with Outlook + Lorsban alone. Sugarbeet growth reduction injury was observed as both stature reduction and speckling of the leaves, presumably from the oils in some of the herbicide formulations as well as in the HSMOC adjuvant.

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.

These field and greenhouse experiments suggest sugarbeet injury concerns with complex pesticide mixtures. For example, we observed injured phenotypes suggesting Betamix or Betamix plus Lorsban caused sugarbeet injury. However, we do not believe Betamix or Lorsban alone are the culprits since Betamix with glyphosate and ethofumesate caused necrosis and malformation injury 14 DAT similar to glyphosate and ethofumesate (in full disclosure we never evaluated Lorsban plus glyphosate or ethofumesate compared with glyphosate and ethofumesate alone). But rather injury from Betamix and/or Lorsban are exacerbated by ‘activators’ such as a Stinger combined with glyphosate, ethofumesate and chloroacetamide herbicides in complex mixtures under certain environmental conditions. HSMOC had less effect on sugarbeet injury than the herbicides did and it’s unclear how much of the injury from the herbicide can be attributed to the active ingredient versus the oil content of the formulation.

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WATERHEMP CONTROL IN SMALL GRAIN STUBBLE

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Introduction
Waterhemp is troublesome weed that can begin emerging in May and continue to emerge through early August (Hartzler et al. 1999). Many producers have expressed concern about controlling waterhemp after small grains have been harvested.

Objective
The objective of this experiment was to evaluate waterhemp control in small grain stubble.

Materials and Methods
The experiment was conducted in wheat stubble on natural waterhemp populations near Hickson, ND in 2020. Experimental area consisted of a uniform infestation of waterhemp ranging from newly emerged to 12 inches tall.

Herbicide treatments were applied on August 8 and September 2, 2020 with a bicycle wheel sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 43 psi. Treatment list can be found in Table 1.

Table 1. Herbicide treatments and rates in trial near Hickson, ND in 2020.

Herbicide Treatment	Rate (fl oz/A)
RoundUp PowerMax[1]	32
RoundUp PowerMax + Weedar 64[1]	32 + 64
RoundUp PowerMax + Sharpen[2]	32 + 1
RoundUp PowerMax + Sharpen[2]	32 + 2
RoundUp PowerMax + Sharpen + Valor SX[2]	32 + 1 + 1
RoundUp PowerMax + Sharpen + Valor SX[2]	32 + 1 + 2
RoundUp PowerMax / RoundUp PowerMax[1]	32 / 32
RoundUp PowerMax + Weedar 64 /	32 + 64 /
RoundUp PowerMax + Weedar 64[1]	32 + 64

[1]Treatment applied with Prefer 90 NIS at 0.25 % v/v + NPak AMS at 2.5% v/v.
[2]Sharpen and Valor SX applied with methylated seed oil at 1.5 pt/A + NPak AMS at 2.5% v/v.

Waterhemp control were evaluated visually, beginning approximately six days after the first herbicide application was made and continued on a generally weekly interval for three weeks. All evaluations were a visual estimate of control in the treated area compared to the adjacent untreated strip. Experimental design was randomized complete block with 4 replications. Data were analyzed with the ANOVA procedure of ARM, version 2019.4 software package.

Results
Waterhemp control ranged from 26 to 30% from a single glyphosate (RoundUp PowerMax) application at 32 fl oz/A and from 33 to 50% control from a two-spray glyphosate program (Table 2). One or two glyphosate applications did not provide acceptable control of a glyphosate-resistant waterhemp population. 2, 4-D (Weedar 64) at 64 fluid ounces per acre plus glyphosate improved waterhemp control compared to glyphosate alone. Control ranged from 64 to 88% control from a single application and from 63 to 78% from repeat applications. There was no statistical difference between a single or repeat applications of 2, 4-D plus glyphosate.

Sharpen at 1 or 2 fl oz plus glyphosate provided greater than 89% waterhemp control. There was no observable benefit from increasing the Sharpen rate from one to two fluid ounces/A. Sharpen plus glyphosate were applied with N-Pak and MSO (methylated seed oil) to maximize Sharpen performance. Valor SX plus Sharpen plus RoundUp PowerMax provided the best numerical control of waterhemp and there was no difference in control between Valor SX at 1 versus 2 oz/A. Likewise, there was no significant difference in waterhemp control between Sharpen plus RoundUp PowerMax and Sharpen plus Valor SX plus RoundUp PowerMax.

Table 2. Percent visual waterhemp control by treatment and evaluation date near Hickson, ND in 2020.

		Waterhemp Control		
Treatment	Rate	6 DAT[3]	15 DAT	22 DAT
	--fl oz/A--	----------------------------	%----------------------------	

RoundUp PowerMax[1]	32	26 c	30 c	28 d
RoundUp PowerMax + Weedar 64[1]	32 + 64	64 b	73 b	88 ab
RoundUp PowerMax + Sharpen[2]	32 + 1	90 a	91 a	98 a
RoundUp PowerMax + Sharpen[2]	32 + 2	89 a	90 a	98 a
RoundUp PowerMax + Sharpen + Valor SX[2]	32 + 1 + 1	99 a	99 a	98 a
RoundUp PowerMax + Sharpen + Valor SX[2]	32 + 1 + 2	97 a	100 a	100 a
RoundUp PowerMax / RoundUp PowerMax[1]	32 / 32	33 c	40 c	50 c
RoundUp PowerMax + Weedar 64 / RoundUp PowerMax + Weedar 64[1]	32 + 64 / 32 + 64	63 b	65 b	78 b
LSD (0.05)		**13**	**13**	**11**

[1]Treatment applied with Prefer 90 NIS at 0.25 % v/v + NPak AMS at 2.5% v/v.
[2]Sharpen and Valor SX applied with methylated seed oil at 1.5 pt/A + NPak AMS at 2.5% v/v.
[3]DAT=Days after treatment.

Conclusion

The previous recommendation to control waterhemp in small grain stubble was 2,4-D at 32 fl oz/A (esther or amine depending on nearby crops) plus RoundUp PowerMax. This recommendation was statistically similar to Sharpen at 1 fl oz/A plus RoundUp PowerMax 22 DAT (days after treatment) but numerically provided waterhemp control 10% less than Sharpen plus RoundUp PowerMax. These results suggest the new recommendation should be Sharpen at 1 fl oz/A plus RoundUp PowerMax at 32 fl oz/A for waterhemp control.

References

Hartzler RG, Buhler DD, Stoltenberg DE (1999) Emergence characteristics of four annual weed species. Weed Science Society of America. 47(5):578-584