WEEDS MANAGEMENT IN A CROP SEQUENCE CONTRIBUTES TO A FIELD-BASED WEED CONTROL STRATEGY IN SUGARBEET

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Summary

1. Preemergence, preemergence followed by postemergence, and postemergence herbicide applications provided very good to excellent control of waterhemp and other grass and broadleaf weeds in corn and soybean.
2. There are more options for control of waterhemp and grass and broadleaf weeds in corn than soybean.
3. Research needs to be expanded to include weed control in cereals since small grains are an important component of the crop sequence in sugarbeet fields.
4. Have a goal of zero tolerance for weed escapes in fields in the sequence to be planted to sugarbeet.

Introduction

Utilization of the Roundup Ready (RR) sugarbeet weed control system revolutionized the control of weeds following its introduction in 2008. While weeds were not regarded as a serious production problem by sugarbeet growers who completed the 2014 annual sugarbeet growers' survey, the percent of growers reporting excellent weed control using glyphosate has trended downward since 2008 and the number of growers reporting good weed control has trended higher. Weed shifts, as a result of selecting for biotypes of weeds with greater glyphosate tolerance, is a natural process but probably has been accelerated by the use of the RR weed control system in multiple crops in the crop sequence and may partially explain results from the sugarbeet growers' survey. Changes in weed communities resulting from biotypes that do not respond the same to glyphosate are occurring and will continue to occur in eastern North Dakota and Minnesota.

Weeds that can be hard to control with glyphosate occur in most sugarbeet producing regions of the Red River Valley and southern Minnesota (Figure 1). Hard-to-control weeds are weeds by which selection pressure from repeated use of glyphosate without interruption by herbicides with other modes of action or other weed management practices has occurred. Hard-to-control weeds in sugarbeet include waterhemp, kochia, common ragweed, and giant ragweed. We know that full glyphosate rates do not always provide complete control of hard-to-control weeds in sugarbeet. We also know that there are only a limited number of tank-mix options for their control in sugarbeet. A concept we have begun to explore is a weeds management strategy where herbicides from multiple herbicide families are used in crops grown in rotation with sugarbeet to indirectly benefit weed control in sugarbeet. Preliminary experiments were conducted in 2014 to investigate the feasibility and experimental design needed for conducting this research with the idea of expanding the approach and assigning the program to a graduate student in 2015.

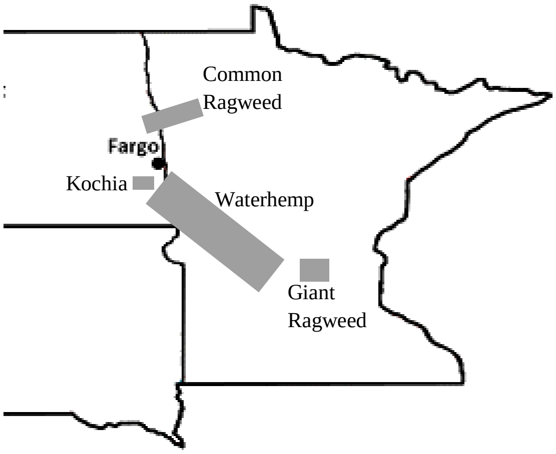
The objectives in 2014 were to provide waterhemp (Amaranthus spp.) and kochia (kochia scoparia) control in corn and soybean utilizing a 'systems approach' that:

1. is not reliant upon Roundup Ready technology
2. provides greater than 90% visual control of waterhemp and kochia season-long
3. utilizes herbicides from herbicide families grouped by mode of action that compliment herbicides used in other crops within the cropping sequence including sugarbeet
4. utilizes herbicides with appropriate rotation restrictions thereby allowing corn, soybean, and sugarbeet to be planted in the crop sequence
5. considers weed control costs per acre including cost of the seed (profitability)

Materials and Methods

Experiments were conducted on natural populations of waterhemp near Herman, MN and on natural populations of kochia and lambsquarters near Barney, ND in 2014. 'DKC 37-38 RIB' RR corn and Peterson Farm Seed

Figure 1. Geographies where various weeds interfere with sugarbeet production in eastern North Dakota and Minnesota.



'L05-11NLL' Liberty Link soybean was seeded in 22 inch rows on May 30 in separate trials at Herman and on May 28 in separate trials at Barney. Herbicide treatments were applied May 30, June 23, and July 2 at Herman and May 28, June 24, and July 2 at Barney. Environmental data at application is recorded in Table 1 for Herman trials and Table 2 for Barney trials.

Table 1. Application information for corn and soybean trials near Herman, MN in 2014.

Application code	A	B	C
Date	May 30	June 23	July 2
Time of Day	1:30 PM	3:00 PM	1:00 PM
Air Temperature (F)	93	78	70
Relative Humidity (%)	35	48	35
Wind Velocity (mph)	7	8	6
Wind Direction	S	W	WNW
Soil Temp. (F at 6")	68	72	65
Soil Moisture	Good	Slightly Wet	Good
Cloud Cover (%)	50	50	5
Corn stage (avg)	PRE	V4 to V5	V7
Soybean stage (avg)	PRE	V1 to V2	V3
Waterhemp (untreated avg)	-	2.5"	5"

Table 2. Application information for corn and soybean trials near Barney, ND in 2014.

Application code	A	B	C
Date	May 28	June 24	July 2
Time of Day	5:30 PM	3:00 PM	4:15 PM
Air Temperature (F)	89	69	70
Relative Humidity (%)	31	61	49
Wind Velocity (mph)	7	4	8
Wind Direction	SE	NW	NW
Soil Temp. (F at 6")	79	65	65
Soil Moisture	Good	Good	Good
Cloud Cover (%)	20	95	40
Corn stage (avg)	PRE	V5	V7
Soybean stage (avg)	PRE	V2 to V3	V3 to V4
Lambsquarters (untreated avg)	-	3"	7"
Redroot pigweed (untreated avg)	-	3"	7"
Kochia (untreated avg)	-	2.5"	6"

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 30 feet in length in a field with moderate to heavy levels of glyphosate-resistant waterhemp. Ammonium sulfate (AMS) in all treatments was a liquid formulation from Winfield Solutions called N-Pak AMS. At Herman, corn or soybean injury were evaluated on June 23, July 2, 10, and 17, and August 27 while weed control was evaluated June 23, July 2, August 27, and September 19. At Barney, corn or soybean injury were evaluated June 25 and July 11, while weed control was evaluated June 25, July 11, and August 22. Soybean yield was taken at Barney October 6 by harvesting the middle two rows by 30-feet long with a Hege combine. All evaluations at both locations were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. Experimental design was randomized complete block with 4 replications at both locations. Data were analyzed with the ANOVA procedure of ARM, version 9.2014.2 software package.

Results and Discussion

Herbicide treatments were identified during consultation with Dr. Richard Zollinger, NDSU Extension Weeds Specialist. Criteria to include a herbicide into the trial included: a) efficacious to waterhemp and kochia, b) were from herbicide families that would complement RR weed system used in sugarbeet and c) would not carry over to other crops planted in the sequence including a next cropping season rotation to sugarbeet.

<u>Weed Control in Corn</u>
Corn injury was evaluated visually at multiple growth stages at Herman and Barney. In general, herbicide treatments containing Status tended to cause more injury than other herbicide treatments, especially at the Barney location (data not presented). Corn injury was negligible from all herbicide treatments by the time corn had reached tasseling.

Grass and small-seed broadleaf weed control was evaluated at multiple time points during the season. Green foxtail pressure at Herman was light but waterhemp pressure at Herman and redroot pigweed and lambsquarters pressure at Barney were moderate to heavy. There were insufficient kochia to evaluate at Barney.

Many herbicide treatments provided between 90 and 100 percent control of green foxtail, waterhemp, lambsquarters and redroot pigweed at canopy closure in corn (Table 3). Herbicide treatments were applied preemergence (PRE), PRE followed by postemergence (POST), or POST in corn. There were several PRE herbicide treatments that contained a chloroacetamide herbicide (Harness or Verdict) for control of grasses in addition to small-seeded broadleaves in corn. Another PRE herbicide, Sharpen, also is efficacious on small seeded broadleaves but has very little grass activity.

Herbicide treatments applied POST and containing atrazine, Laudis, or Status provided broad-spectrum weed control at both locations. Widematch was selected specifically for kochia control. However, the Barney site, while having a very heavy infestation of kochia in 2013, had a very light kochia infestation and a heavy lambsquarters and redroot pigweed infestation in 2014. This emphasizes the importance of scouting and identifying weeds in fields and matching the observed weeds with the appropriate herbicide, especially in the case of POST herbicides.

Herbicide treatments that provide broad-spectrum and season-long control in corn ensure no new seeds will be deposited into the seed bank. Waterhemp and redroot pigweed seed remains viable in the soil for at least five years and lambsquarters for more than 15 years. Setting a goal of zero tolerance for weed escapes in corn and soybean benefits sugarbeet production where herbicide choices are limited and broad-spectrum weed control more difficult.

In addition to efficacy, herbicide treatments were selected based on herbicide site of action and chemical family, crop rotation restrictions, and cost (Table 4). Herbicides were selected from herbicide families including long chain fatty acid inhibitors (15), PPO inhibitors (14), photosystem II inhibitors (5), auxin inhibitors (19) and growth regulators (4). The purpose of including herbicides from a wide range of herbicide families is to complement herbicide families used in other crops in the sequence to reduce selection pressure and weed specie shifts. Also considered was the likelihood of weed resistance occurring to a herbicide family. For example, there has not been any documented incidence of weed resistance occurring with chloroacetamide herbicides. Thus, using them in multiple crops in the crop sequence is a low risk.

Table 3. Visual evaluation of weed control in corn at Herman, MN and Barney, ND in 2014.

Treatment[1]	Application Code[2]	Rate per A	Herman wahe[3] Sept 19	Herman grfx July 14	Barney colq July 11	Barney rrpw July 11
			%			
Harness+Sharpen	A	2 pt+3 fl oz	98	100	94	100
Harness+Clarity / Laudis+atrazine	A / B	2 pt +1 pt / 3 fl oz+12 fl oz	100	100	-[4]	-
Harness+Clarity / Widematch	A / B	2 pt+1 pt / 1.3 pt	-	-	95	99
Harness+atrazine / Status	A / B	2 pt+12 fl oz / 7.5 oz	100	100	100	100
Harness / Widematch	A / B	2 pt / 1.3 pt	-	-	90	99
Harness / Status	A / B	2 pt / 10 oz	100	100	100	100
Harness / Laudis+atrazine	A / B	2 pt / 3 fl oz+12 fl oz	100	100	-	-
Sharpen / Status	A / B	3 fl oz / 7.5 oz	96	95	100	100
Sharpen / Laudis+atrazine	A / B	3 fl oz / 3 fl oz+12 fl oz	99	100	-	-
Sharpen / Status+Warrant+PowerMax	A / B	3 fl oz / 5 oz+4 pt+32 fl oz	100	100	100	100
Sharpen / Widematch	A / B	3 fl oz / 1.3 pt	-	-	80	85
Verdict / Laudis + atrazine	A / B	15 fl oz / 3 fl oz+12 fl oz	100	100	-	-
Verdict / Widematch	A / B	15 fl oz / 1.3 pt	-	-	96	90
Verdict / Status	A / B	15 oz / 7.5 oz	100	99	100	100
Laudis+atrazine	B	3 fl oz+12 fl oz	99	100	100	100
Status+PowerMax	B	10 oz+32 fl oz	100	100	99	100
Widematch+Status+PowerMax / Widematch+Status+PowerMax	B / C	1 pt+5 oz+32 fl oz / 1 pt+5 oz+32 fl oz	-	-	100	100
Laudis+atrazine / Status+PowerMax	B / C	3 fl oz+12 fl oz / 5 oz+32 fl oz	100	100	-	-
PowerMax / PowerMax	B / C	32 fl oz / 32 fl oz	81	100	98	100
LSD (0.05)			**3**	**2**	**7**	**7**

[1]Clarity, Laudis, atrazine (4L), and Status applied with methylated seed oil from Loveland (MSO) at 1.5 pt/A plus N-Pak AMS at 2.5% v/v. Roundup PowerMax applied with Prefer 90 NIS at 0.25% v/v plus N-Pak AMS at 2.5% v/v, alone, or Roundup PowerMax plus co-herbicide applied with high surfactant methylated oil concentrate (HSMOC) at 1 pt/A plus AMS at 2.5% v/v.
[2]Application code refers to information in Tables 1 and 2.
[3]wahe=waterhemp; grfx=green foxtail; colq=common lambsquarters; rrpw=redroot pigweed.
[4]No evaluation as the treatment was not present in that trial and, therefore, is not included in analysis.

The cost per acre for herbicide treatments ranged from $13 to $65 per acre. Cost of weed control is clearly an important consideration and must be included in a weeds management strategy. However, careful consideration should be taken in weighing short term benefits from cheaper weed control programs with long term weed control ramifications that may occur as a result of those cheaper programs.

Herbicides with residues that would not extend to rotational crops, including soybean or sugarbeet, were selected for the trials. Sugarbeet can be planted in the next cropping season following the herbicide treatments used in this experiment. Atrazine residues (12 months) potentially can extend from the corn crop to the soybean crop depending on rainfall conditions, time of application, and atrazine rate.

Table 4. Herbicide family, crop rotation restriction and cost per acre of corn herbicide treatments

Herbicide	Application Timing	Rate per A	Cost[2] $/A	SoA[3] Families	Crop Rotation[1] Sugarbeet	Soybean
Harness+Sharpen	PRE	2 pt+3 fl oz	$44	15+14	NCS	NCS
Harness+Clarity / Laudis+atrazine	PRE / POST	2 pt +1 pt / 3 fl oz+12 fl oz	$54	15+4 / 27+5	10	12
Harness+Clarity / Widematch	PRE / POST	2 pt+1 pt / 1.3 pt	$47	15+4 / 4,4	NCS	10.5
Harness+atrazine / Status	PRE / POST	2 pt+12 fl oz / 7.5 oz	$56	15+5 / 4,19	NCS	12
Harness / Widematch	PRE / POST	2 pt / 1.3 pt	$39	15 / 4,4	NCS	NCS
Harness / Status	PRE / POST	2 pt / 10 oz	$63	15 / 4,19	NCS	NCS
Harness / Laudis+atrazine	PRE / POST	2 pt / 3 fl oz+12 fl oz	$46	15 / 27+5	10	12
Sharpen / Status	PRE / POST	3 fl oz / 7.5 oz	$43	14 / 4,19	6	4
Sharpen / Laudis+atrazine	PRE / POST	3 fl oz / 3 fl oz+12 fl oz	$35	14 / 27+5	10	12
Sharpen / Status+Warrant+PowerMax	PRE / POST	3 fl oz / 5 oz+4 pt+32 fl oz	$54	14 / 4,19+15+9	NCS	NCS
Sharpen / Widematch	PRE / POST	3 fl oz / 1.3 pt	$28	14 / 4,4	6	10.5
Verdict / Laudis + atrazine	PRE / POST	15 fl oz / 3 fl oz+12 fl oz	$46	14,15 / 27+5	10	12
Verdict / Widematch	PRE / POST	15 fl oz / 1.3 pt	$39	14,15 / 4,4	NCS	10.5
Verdict / Status	PRE / POST	15 oz / 7.5 oz	$54	14,15 / 4,19	NCS	4
Laudis+atrazine	POST	3 fl oz + 12 fl oz	$19	27+5	10	12
Status+PowerMax	POST	10 oz+32 fl oz	$41	4,19+9	4	4
Widematch+Status+PMax / Widematch+Status+PMax	POST / POST	1 pt+5 oz+32 fl oz / 1 pt+5 oz+32 fl oz	$65	4,4+4,19+9/ 4,4+4,19+9	4	10.5
Laudis+atrazine / Status+PowerMax	POST / POST	3 fl oz+12 fl oz / 5 oz+32 fl oz	$43	27+5 / 4,19+9	10	12
PowerMax / PowerMax	POST / POST	32 fl oz / 32 fl oz	$13	9 / 9	0	0

[1]Crop rotation restrictions for North Dakota. 2015 North Dakota Weed Control Guide, pages 102-107. Table values = number of months. NCS = next crop season after herbicide application.
[2]Cost per acre as calculated from the 2015 North Dakota Weed Control Guide, pages 118-125. Cost does not include recommended adjuvants
[3]Herbicide Site of Action and Chemical Family for Resistant Weed Management. 2015 North Dakota Weed Control Guide, pages 98-99.

Weed Control in Soybean

Visual assessment of soybean growth reduction and weed control in soybean were evaluated at various times during the growing season. Soybean growth reduction was averaged over locations since soybean responded the same to herbicide treatments at both locations. Soybean injury generally was negligible from the preemergence herbicide treatments followed by Liberty, Basagran or Ultra Blazer (Table 5). However, Cadet alone, Cadet plus Basagran and Cadet following Valor gave soybean injury ranging from 17 to 29%, in mid-July when soybean growth stage ranged from V5 to V7. Cobra also caused soybean stature reduction injury. Growers apply Cadet and Cobra before flowering and report no yield effects. Soybean was harvested at the Barney location and yield data (not presented) tends to support grower feedback. In general, the yield impact from insufficient weed control tended to mask any effect from phytotoxic effects of herbicide.

Herbicide treatments provided broad-spectrum waterhemp, lambsquarters and redroot pigweed control (Table 5). Control generally was best from soil-applied herbicides following POST herbicide treatments. The POST only treatments tended to be less consistent and did not provide broad-spectrum control. As with corn, scouting fields, proper identification of weeds and an understanding of weed biology is very helpful to ensure excellent weed control. Waterhemp control was less than redroot pigweed control and tended to be less than lambsquarters control. We attribute these differences to differences in herbicide efficacy (for example, Cobra is weak on lambsquarters) but also differential emergence of waterhemp which likely emerged later than redroot pigweed and lambsquarters and subsequent to herbicide applications.

Soybean herbicide treatments were selected based on herbicide site of action and chemical family, crop rotation restrictions, and cost (Table 6). Herbicide were selected from herbicide families including long chain fatty acid inhibitors (15), PPO inhibitors (14), photosystem II inhibitors (6), and glutamine synthetase inhibitors (10). Note that a number of PRE and POST herbicide treatments were PPO inhibitors (14). There are not as many herbicide choices in soybean as corn that allow crop rotation to sugarbeet the following season. However, the soybean herbicides used in these trials generally have no rotational impact on crops grown in the rotation including corn or sugarbeet.

Table 5. Visual soybean injury and weed control in soybean at Herman, MN and Barney, ND, 2014.

Treatment[1]	Application Code[2]	Rate per A	2 locations Soybean Injury Jul 14	Herman wahe[3]cntl Sept 19	------Barney------ colq cntl Aug 22	rrpw cntl Aug 22
			-------------------------%-------------------------			
Dual Magnum+Valor / Liberty	A / B	2 pt+3 oz / 29 fl oz	4	96	98	100
Sharpen+Valor / Liberty	A / B	1 fl oz+3 oz / 29 fl oz	0	95	100	98
Verdict+Valor / Liberty	A / B	5 fl oz+3 oz / 29 fl oz	3	93	94	100
Outlook+Verdict+Valor / Liberty	A / B	14 fl oz+5 fl oz+3 oz / 29 fl oz	6	95	100	100
Valor / Cadet / Cadet	A / B / C	3 oz / 0.7 fl oz / 0.7 fl oz	19	77	93	99
Valor / Ultra Blazer / Ultra Blazer	A / B / C	3 oz / 1 pt / 1 pt	6	99	98	100
Valor / Basagran / Basagran	A / B / C	3 oz / 1 pt / 1 pt	4	69	100	100
Verdict / Basagran / Basagran	A / B / C	5 fl oz / 1 pt / 1pt	0	84	76	95
Sharpen + Warrant / Basagran / Basagran	A / B / C	1 fl oz+3 pt / 1 pt / 1 pt	3	81	89	100
Basagran / Basagran	B / C	1 pt / 1 pt	2	0[4]	75	88
Cadet / Cadet	B / C	0.7 fl oz / 0.7 fl oz	17	61	75	86
Cobra / Cobra	B / C	10 fl oz / 10 fl oz	37	69	15	100
Basagran + Cadet / Basagran + Cadet	B / C	0.5 pt+0.7 fl oz / 0.5 pt+0.7 fl oz	29	61	63	86
Liberty / Liberty	B / C	29 fl oz / 29 fl oz	2	95	97	100
LSD (0.05)				**13**	**13**	**8**

[1]Liberty applied with N-Pak AMS at 3 lb/A; Cadet, Basagran, and Cobra applied with MSO at 1.5 pt/A, Ultra Blazer applied with Prefer 90 NIS at 1.5 pt/100 gal.
[2]Application codes refer to information in Tables 1 and 2.
[3]wahe=waterhemp; cntl=control; colq=common lambsquarters; rrpw=redroot pigweed
[4]a misapplication may have occurred

Cost of weed control in soybean ranged from $16 to $69 per acre. In general, herbicides treatments that included a PRE herbicide component were more expense than POST only herbicide treatments. Growers should use due caution when making a short-term financial decision that may have long-term implications. Also, while PPO inhibitor herbicides (14) may be less expense than chloroacetamide herbicides (15), PPO inhibitors have a higher incidence of weed resistance.

Conclusions

A weed control option for control of tough weeds in sugarbeet is weed control throughout the crop sequence. Adapting and using this approach requires development of a strategy for cropping sequence, selecting a diverse array of herbicide treatments and herbicide families, maintaining good record keeping, and a commitment to prevent weed seed from entering the soil seedbank during the ‘non-sugarbeet’ crops. It is important that growers learn about the biology of weeds including temperature, moisture, and tillage patterns that impact the ability of weed seed to break dormancy and their longevity in the soil seedbank.

Table 6. Herbicide family, crop rotation restriction and cost per acre of corn herbicide treatments

Treatment	Application	Rate per A	Cost[2] $/A	SoA[3] Families	Crop Rotation[1] Sugarbeet	Corn
Dual Magnum+Valor / Liberty	PRE / POST	2 pt+3 oz / 29 fl oz	$69	15+14 / 10	5	1
Sharpen+Valor / Liberty	PRE / POST	1 fl oz+3 oz / 29 fl oz	$44	14+14 / 10	4	1
Verdict+Valor / Liberty	PRE / POST	5 fl oz+3 oz / 29 fl oz	$47	14,15+14 /10	NCS	1
Outlook+Verdict+Valor/ Liberty	PRE / POST	14 fl oz+5 fl oz+3 oz / 29 fl oz	$68	15+14,15+14/ 10	NCS	1
Valor / Cadet / Cadet	PRE/POST/POST	3 oz / 0.7 fl oz / 0.7 fl oz	$36	14 / 14 / 14	5	1
Valor / Ultra Blazer / Ultra Blazer	PRE / POST / POST	3 oz / 1 pt / 1 pt	$42	14 / 14 / 14	5	1
Valor / Basagran / Basagran	PRE / POST / POST	3 oz / 1 pt / 1 pt	$46	14 / 6 / 6	5	1
Verdict / Basagran / Basagran	PRE / POST / POST	5 fl oz / 1 pt / 1pt	$35	14,15 / 6 / 6	NCS	1
Sharpen + Warrant / Basagran / Basagran	PRE / POST / POST	1 fl oz+3 pt / 1 pt / 1 pt	$47	14+15 / 6 / 6	NCS	NCS
Basagran / Basagran	POST / POST	1 pt / 1 pt	$26	6 / 6	0	0
Cadet / Cadet	POST / POST	0.7 fl oz / 0.7 fl oz	$16	14 / 14	0	0
Cobra / Cobra	POST / POST	10 fl oz / 10 fl oz	$31	14 / 14	0	0
Basagran + Cadet / Basagran + Cadet	POST / POST	0.5 pt+0.7 fl oz / 0.5 pt+0.7 fl oz	$29	6+14 / 6+14	0	0
Liberty / Liberty	POST / POST	29 fl oz / 29 fl oz	$39	10 / 10	0	0

[1]Crop rotation restrictions for North Dakota. 2015 North Dakota Weed Control Guide, pages 102-107. Table values = number of months. NSC = next crop season after herbicide application.
[2]Cost per acre as calculated from the 2015 North Dakota Weed Control Guide, pages 118-125. Cost does not include recommended adjuvants
[3]Herbicide Site of Action and Chemical Family for Resistant Weed Management. 2015 North Dakota Weed Control Guide, pages 98-99

Sugarbeet growers should carefully consider the number of crops where glyphosate is the primary herbicide for weed control. Glyphosate will be used in sugarbeet. The goal is for growers to compliment glyphosate use in sugarbeet with other herbicides from other families in crops grown in the field in sequence with sugarbeet by using the decision support tools discussed in this paper.

Finally, making weed control decisions can be very complex and is an exercise that requires data from multiple sources. Over time it may be valuable to adapt the decision support systems that growers use in choosing weed control solutions from crop-based to weeds-based and in a format that is readily available to the decision-maker.