SUSCEPTIBILITY OF LIBERTY LINK AND ROUNDUP READY AND NEAR-ISOGENIC NON-RESISTANT SUGARBEET CULTIVARS TO CONVENTIONAL POSTEMERGENCE HERBICIDES

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INTRODUCTION

Herbicide use is well recognized as a major cost-effective and reliable tool with the potential for increasing yield; improving crop quality; reducing soil erosion, soil compaction and moisture loss; and for saving fuel, energy, labor and time in sugarbeet (*Beta vulgaris* L.) production. However, herbicide inputs in sugarbeet are often high and currently herbicide systems are very complex including a multitude of herbicide combinations that must be chosen carefully in order to maintain a high degree of sugarbeet safety. To simplify weed control, sugarbeet has been genetically engineered to tolerate broadspectrum non-selective postemergence (POST) herbicides, such as Roundup or Liberty, which would normally be phytotxic to the emerged crop. In addition to Roundup or Liberty, the option of using other current POST sugarbeet herbicides on the genetically engineered cultivars may increase the acceptance of the new cultivars.

Experiments were designed to evaluate the response of Roundup Ready and Liberty Link sugarbeet cultivars to current conventional POST sugarbeet herbicides; to determine the susceptibility of Roundup Ready or Liberty Link sugarbeet cultivars to conventional herbicides in comparison to their respective near isogenic sugarbeet lines (isolines); and to assess if a yield penalty is associated with the herbicide resistance trait in the absence of herbicide use. Sugarbeet isolines are genetically identical to the Roundup Ready or Liberty Link cultivars, except for the gene conferring herbicide resistance.

MATERIALS AND METHODS

Herbicide Susceptibility Experiments. Separate field experiments were conducted near Crookston, MN during 2000 including five Liberty Link and five near isogenic non-resistant sugarbeet cultivars (Experiment 1) or seven Roundup Ready and seven near isogenic non-resistant cultivars (Experiment 2) given in Table 1. The experimental design was a randomized complete block design in a split plot arrangement with four replicates. Herbicides were assigned to the main plots and sugarbeet cultivars to the subplots. Experimental plots measured 35x11 ft consisting of six sugarbeet rows. Sugarbeet cultivars were seeded in 22-inch rows on May 2 and May 3. Counter 15G insecticide was applied modified-in-furrow at 12 lb/A with planting. Plots were sprayed with fungicides for Cercospora leaf spot control (*Cercospora beticola Sacc.*) when necessary. Sugarbeet was hand thinned in each experiment. The conventional herbicide treatments consisted of Betanex at 2 pt/A, Betanex plus Stinger at 2 pt/A + 0.33 pt/A, Betanex plus UpBeet at 2 pt/A + 0.6 oz/A, and Betanex plus UpBeet plus Stinger plus Select plus Scoil respectively at 0.5 pt/A + 0.125 oz/A + 0.08 pt/A + 0.12 pt/A + 1.5% v/v (micro-rate). Except in the micro-rate, the rate of Betanex in treatments was increased with each subsequent application (2/2.5/3 pt/A) in an attempt to cause sugarbeet injury. POST herbicides were applied three or four times (micro-rate) at a one week interval, all starting when sugarbeet was in the cotyledon growth stage. The center four rows were sprayed with herbicides in 17 gal/A at 40 psi through 8002 flat fan nozzles with a CO_2 pressurized bicycle-wheel-type sprayer. Dates, environmental conditions, and sugarbeet size when herbicides were applied are presented in Table 2. All plots were hand weeded from the last herbicide application until harvest so that competition from late emerging weeds would not interfere with sugarbeet yield. Plots were evaluated for visible sugarbeet injury from herbicide treatments at seven and 21 days after the last herbicide application. The two center rows of each plot were harvested on October 2 and 3 and sucrose and extractable sugar content determined from harvested sugarbeet roots.

Table 1. Evaluated sugarbeet cultivars in the herbicide susceptibility experiments.

Experiment 1		Experiments 2	
Cultivars			
Non-resistant	Resistant	Non-resistant	Resistant
Beta 2012	Beta 2012 LL[a]	HM Horizon	HM Horizon RR[b]
Beta 4546	Beta 4546 LL	HM Resist	HM Resist RR
Beta 8088	Beta 8088 LL	HM Valley	HM Valley RR
Beta 8757	Beta 8757 LL	HM 7054	HM 7054 RR
Beta 992	Beta 992 LL	HM 8277	HM 8277 RR
		Beta 2012	Beta 2012 RR
		Beta 8757	Beta 8757 RR

[a] LL = Liberty Link sugarbeet.
[b] RR = Roundup Ready sugarbeet.

Table 2. Environmental conditions and sugarbeet stage at time of herbicide application at Crookston, MN.

Date		May 17	May 25	June 1	June 8
Time	LL sugarbeet[a]	11:30 am	10:00 am	2:00 pm	11:30 am
	RR sugarbeet[b]	2:00 pm	12:30 pm	3:30 pm	12:45 pm
Air temperature (ºF)		62	69	69	74
6" Soil temperature (ºF)		56	60	59	65
Relative humidity (%)		60	40	84	5
Wind speed (mph)		13	3	3	15
Wind direction		N	W	N	NW
Soil moisture		Good	Dry	Good	Dry
Sugarbeet.stage (v)[c]	LL sugarbeet	1.0	1.0 - 2.0	3.0 - 5.50	4.75 - 7.50
	RR sugarbeet	1.0	1.0 - 2.0	3.0 - 4.75	4.00 - 7.50

[a] LL sugarbeet = Liberty Link sugarbeet cultivars.
[b] RR sugarbeet = Roundup Ready sugarbeet cultivars.
[c] v1.0 = Cotyledonary sugarbeet, v2.0 = sugarbeet with two unrolled true leaves, v2.5 = sugarbeet with two unrolled true leaves plus a third leaf 50% unrolled.

RESULTS AND DISCUSSION

This research did not attempt to compare Liberty Link cultivars with Roundup Ready cultivars or to compare non-resistant isolines of Liberty Link to isolines of Roundup Ready cultivars.

Experiment 1. Untreated hand weeded sugarbeet showed no or negligible injury 7 days after the last weeding (DALW), averaged over all tested Liberty Link and conventional cultivars, (Table 3). All herbicide treatments injured sugarbeet cultivars significantly compared with hand weeded sugarbeet. However, the reported sugarbeet injury ratings ranged from 4 to 13%, and this relatively low level of injury would not be expected to result in sugarbeet yield loss.

'Beta 2012' was most tolerant to the micro-rate and Betanex + UpBeet but only the Betanex + UpBeet treatment caused significantly less injury than Betanex alone or Betanex in combination with Stinger (Table 3). Betanex + Stinger, Betanex + UpBeet or the micro-rate caused similar injury to 'Beta 4546' but significantly less than Betanex alone. 'Beta 8088' was equally tolerant to Betanex, Betanex + UpBeet and the micro-rate and significantly greater injury of 11% was observed with Betanex + Stinger. Betanex, Betanex + UpBeet and the micro-rate were similar in injury to 'Beta 8757'. Betanex + UpBeet resulted in less injury than Betanex + Stinger or the micro-rate which rated 10 and 9%, respectively. No significant injury differences were evident among herbicides used on 'Beta 992'.

Among all cultivars, 'Beta 4546' was most susceptible to Betanex alone. All other cultivars showed a similar response to Betanex. Injury from Betanex + Stinger to 'Beta 4546', 'Beta 8088', 'Beta 8757' and 'Beta 992' was similar. 'Beta 2012' was significantly less susceptible to Betanex + Stinger than 'Beta 8088' but injury was similar when compared with the remaining cultivars. Betanex + UpBeet injured 'Beta

4546' more than 'Beta 2012' but sugarbeet injury to 'Beta 2012', 'Beta 8088', 'Beta 8757' and 'Beta 992' was similar. Injury from the micro-rate to 'Beta 4546', 'Beta 8088', 'Beta 8757' and 'Beta 992' was similar and 'Beta 2012" was significantly less injured than 'Beta 4546' or 'Beta 8757'.

Table 3. Sugarbeet injury as affected by treatment and cultivar 7 days after the last treatment (DALT), averaged over non-resistant and Liberty Link cultivars.

	Cultivar				
Treatment	Beta 2012	Beta 4546	Beta 8088	Beta 8757	Beta 992
	% injury				
Hand weeded	0	1	0	0	0
Betanex	8	13	6	8	8
Betanex + Stinger	7	10	11	10	8
Betanex + UpBeet	4	9	6	6	6
Micro-rate	5	9	6	9	6
LSD_1 (0.05)[a]	3				
LSD_2 (0.05)[b]	4				

[a] LSD_1 (0.05) = LSD to compare means of weed control treatments within the same cultivar (columns).
[b] LSD_2 (0.05) = LSD to compare means of cultivars within the same weed control treatment (rows).

Although individual sugarbeet cultivars showed differences in injury from conventional POST herbicide treatments (Table 3), the Liberty Link cultivars and their respective non-resistant isolines at 7 DALT or 21 DALT were injured similarly by the tested herbicide treatments (Table 4). However, averaged over all weed control treatments, sugarbeet cultivars without the gene for Liberty resistance differed significantly in sugarbeet injury 7 DALT from the respective Liberty Link cultivars (Table 5). Non-resistant 'Beta 4546' and 'Beta 8088' were more susceptible to conventional POST sugarbeet herbicides and hand weeding than Liberty Link 'Beta 4546' and 'Beta 8088'. In contrast, non-resistant 'Beta 2012' was less susceptible than Liberty Link 'Beta 2012'. Non-resistant cultivars of 'Beta 8757' and 'Beta 992' were similarly affected by herbicides and hand weeding compared to the Liberty Link cultivars. Because of the observed inconsistency in cultivar injury and the fact that injury ratings were agronomically considered low, no true association between the resistance gene and cultivar susceptibility is suggested.

'Beta 4546' with and without resistance to Liberty was the most susceptible cultivar averaged over all weed control treatments. Non-resistant 'Beta 2012' ranked lowest in injury among all other non-resistant cultivars, whereas 'Beta 8088' represented the most tolerant Liberty Link cultivar. Injury ratings 21 DALT showed no significant differences in sugarbeet injury from treatments between the Liberty Link and their respective non-resistant isolines and among non-resistant and among Liberty Link cultivars (Table 5).

Table 4. Injury to non-resistant and Liberty Link sugarbeet from weed control treatments, averaged over cultivars.

	Cultivar			
Treatment	Non-resistant	Liberty Link	Non-resistant	Liberty Link
	% injury 7 DALT[a]		% injury 21 DALT	
Hand weeded	1	0	3	6
Betanex	9	9	5	6
Betanex + Stinger	10	8	3	2
Betanex + UpBeet	6	6	6	5
Micro-rate	8	6	7	5
LSD_1 (0.05)[b]	NS		NS	
LSD_2 (0.05)[c]	NS		NS	

[a] DALT = Days after the last treatment.
[b] LSD_1 (0.05) = LSD to compare means of weed control treatments within non-resistant or Liberty Link (LL) cultivars (columns).
[c] LSD_2 (0.05) = LSD to compare means of non-resistant versus LL cultivars within the same weed control treatment (rows).

Table 5. Injury to non-resistant and Liberty Link sugarbeet, averaged over weed control treatments.

	Cultivar			
	Non-resistant	Liberty Link	Non-resistant	Liberty Link
	% injury 7 DALT[a]		% injury 21 DALT	
Beta 2012	3	6	5	5
Beta 4546	10	8	5	4
Beta 8088	7	4	3	5
Beta 8757	7	6	5	6
Beta 992	5	6	4	4
LSD (0.05)[b]	2		NS	

[a] DALT = Days after the last treatment.
[b] LSD (0.05) = LSD to compare means within the non-resistant or LL cultivar (columns) and to compare means of the non-resistant and the same LL cultivar (rows).

Herbicide treatments caused significantly greater sugarbeet injury 21 DALT than hand weeding, averaged over all non-resistant and resistant sugarbeet cultivars (Table 6). The micro-rate resulted in less sugarbeet injury than Betanex or Betanex + UpBeet. Betanex + UpBeet also caused greater injury than Betanex + Stinger.

Of all tested sugarbeet cultivars, 'Beta 8757' was injured the most, averaged over weed control treatments, followed by 'Beta 2012' (Table 7). 'Beta 4546', 'Beta 8088' and 'Beta 992' showed similar injury response and were all less susceptible than 'Beta 2012' or 'Beta 8757'.

Table 6. Sugarbeet injury from weed control treatments, averaged over cultivars 21 DALT.

Treatment	Sugarbeet injury
	%
Hand weeded	2
Betanex	6
Betanex + Stinger	5
Betanex + UpBeet	7
Micro-rate	4
LSD (0.05)	2

Table 7. Injury of sugarbeet cultivars, averaged over weed control treatments 21 DALT.

Sugarbeet cultivar	Sugarbeet injury
	%
Beta 2012	5
Beta 4546	4
Beta 8088	4
Beta 8757	6
Beta 992	4
LSD (0.05)	1

Plots planted to non-resistant sugarbeet cultivars produced extractable sucrose similar to plots of Liberty Link cultivars, averaged over weed control treatments (data not presented). However, individual sugarbeet cultivars were differently affected by weed control treatments when averaged over non-resistant and resistant cultivars (Table 8). For example, Betanex reduced extractable sucrose in 'Beta 2012' compared to Betanex + UpBeet or the micro-rate. None of the weed control treatments caused significant extractable sucrose loss in 'Beta 4546', 'Beta 8757' or 'Beta 992'. Hand weeded 'Beta 8088' yielded less extractable sucrose than the same cultivar treated with either Betanex alone or Betanex + Stinger. This suggests that hand weeding could have injured the sugarbeet, although not visibly (Table 3).

Betanex + UpBeet caused significant yield loss in 'Beta 8088' compared to Betanex + Stinger or Betanex alone (Table 8). This does not agree with observed injury ratings from Betanex + Stinger, Betanex + UpBeet and Betanex (Table 3) suggesting that sugarbeet recovered from the injury and other, cultivar-specific factors may have altered extractable sucrose yield.

Hand weeding or Betanex + UpBeet similarly affected extractable sucrose yield when compared across cultivars (Table 8). 'Beta 8088' treated with Betanex gave higher extractable sucrose than 'Beta 2012'. 'Beta 8757' treated with Betanex + Stinger yielded less extractable sucrose than 'Beta 4546' or 'Beta 8088'. 'Beta 992' was the lowest-yielding among all micro-rate-treated cultivars and produced less extractable sucrose than 'Beta 4546' or 'Beta 2012'.

Table 8. Extractable sucrose yield as affected by sugarbeet cultivar and weed control treatment, averaged over non-resistant and Liberty Link cultivars.

	Cultivar				
Treatment	Beta 2012	Beta 4546	Beta 8088	Beta 8757	Beta 992
	extractable sucrose, lb/A				
Hand weeded	8950	9030	8530	8760	8550
Betanex	8280	8650	9330	8880	8740
Betanex + Stinger	8690	9160	9370	8400	8700
Betanex + UpBeet	9120	9050	8460	8790	8880
Micro-rate	9070	9400	8700	8790	8300
LSD (0.05)[a]	790				
LSD (0.05)[b]	690				

[a] LSD_1 (0.05) = LSD to compare means of weed control treatments within the same cultivar (columns).
[b] LSD_2 (0.05) = LSD to compare means of cultivars within the same weed control treatment (rows).

Sugarbeet root yield was reduced in micro-rate treated 'Beta 8088' compared to Betanex + Stinger (Table 9). However, cultivars responded differently to the same herbicide. 'Beta 4546', 'Beta 8088' or 'Beta 8757' gave higher root yield than 'Beta 2012' when treated with Betanex. 'Beta 8088' treated with Betanex + Stinger gave greater sugarbeet root yield than 'Beta 2012' or 'Beta 8757'. The micro-rate significantly reduced sugarbeet root yield in 'Beta 992' compared to 'Beta 4546'. A similar result was observed with the micro-rate on extractable sucrose produced by 'Beta 992' compared to 'Beta 4546' (Table 8).

Sugarbeet root yield for all cultivars was similar from hand weeded plots and plots receiving Betanex + UpBeet, averaged over non-resistant and resistant cultivars (Table 9). This agrees with the data reported on extractable sucrose production of individual sugarbeet cultivars (Table 8).

Table 9. Sugarbeet root yield as affected by cultivar and weed control treatment, averaged over non-resistant and Liberty Link cultivars.

	Cultivar				
Treatment	Beta 2012	Beta 4546	Beta 8088	Beta 8757	Beta 992
	root yield, T/A				
Hand weeded	26.2	26.7	26.4	27.1	26.3
Betanex	23.8	26.8	28.4	27.6	25.9
Betanex + Stinger	25.1	27.3	28.8	25.6	26.4
Betanex + UpBeet	26.8	27.2	26.2	26.6	26.0
Micro-rate	26.8	28.2	26.0	26.3	25.1
LSD (0.05)[a]	2.6				
LSD (0.05)[b]	2.8				

[a] LSD_1 (0.05) = LSD to compare means of weed control treatments within the same cultivar (columns).
[b] LSD_2 (0.05) = LSD to compare means of cultivars within the same weed control treatment (rows).

The results in Table 10 are intended to demonstrate whether the gene conferring resistance to Liberty in Liberty Link cultivars altered certain sugarbeet responses. In the absence of herbicides, hand weeded non-resistant isolines and hand weeded resistant Liberty Link cultivars differed in observed sugarbeet injury 7 DALW but had similar sugarbeet population, root yield, sugarbeet injury 21 DALW and extractable sucrose yield. Despite significantly greater sugarbeet injury in hand weeded non-resistant 'Beta 4546' versus the Liberty Link cultivar, the low injury rating of 3% is of no agronomic importance and most likely can be contributed to a random effect. Therefore, in the absence of herbicide use, the lack of differences for the observed traits in Liberty Link and respective non-resistant isolines indicates that the resistance gene did not affect plant population, yield or sugarbeet injury from hand weeding.

Table 10. Hand weeded non-resistant and Liberty Link sugarbeet.

Sugarbeet cultivar[a]		Sgbt popl	Root yield	Sgbt injury 7 DALW[b]	Sgbt injury 21 DALW	Extr sucrose
		plants/70 ft	T/A	%		lb/A
Beta 2012	S	96	26.4	0	4	8840
	R	89	26.0	0	4	9060
Beta 4546	S	99	26.3	3	5	8630
	R	89	27.1	0	4	9440
Beta 8088	S	93	27.0	0	4	8870
	R	90	25.8	0	3	8180
Beta 8757	S	86	27.7	0	5	8850
	R	95	26.4	0	3	8670
Beta 992	S	93	26.4	0	4	8670
	R	90	26.1	0	4	8440
LSD (0.05)[c]		NS	NS	2	NS	NS

[a] Sugarbeet cultivar S = non-resistant sugarbeet; R = Liberty Link resistant sugarbeet.
[b] DALW = Days after the last weeding.
[c] LSD (0.05) = LSD for cultivar x resistance interaction.

Experiment 2. Sugarbeet population was affected by weed control treatments (Table 11). Plant population of 'Beta 8757' was reduced by Betanex + UpBeet as compared to Betanex + Stinger. 'HM 8277' treated with the micro-rate had fewer plants per 70 ft than hand weeded 'HM 8277' or 'HM 8277' treated with Betanex, Betanex + Stinger or Betanex + UpBeet. Hand weeding damaged 'HM Resist and caused significantly lower sugarbeet populations than the same cultivar receiving Betanex alone or in combination. A similar effect was observed in 'HM Valley', where hand weeding reduced sugarbeet populations more than Betanex or Betanex + Stinger.

Table 11. Sugarbeet population as affected by cultivar and weed control treatment, averaged over non-resistant and resistant cultivars.

	Cultivar						
Treatment	Beta 2012	Beta 8757	HM 7054	HM 8277	HM Horizon	HM Resist	HM Valley
	plants per 70 ft						
Hand weeded	91	88	99	105	90	95	88
Betanex	88	85	102	101	92	105	97
Betanex + Stinger	86	93	100	110	95	106	97
Betanex + UpBeet	90	84	103	111	91	105	90
Micro-rate	83	85	96	93	96	100	96
LSD (0.05)[a]	9						
LSD (0.05)[b]	13						

[a] LSD_1 (0.05) = LSD to compare means of weed control treatments within the same cultivar (columns).
[b] LSD_2 (0.05) = LSD to compare means of cultivars within the same weed control treatment (rows).

Among all cultivars, hand weeding reduced sugarbeet populations more severely in 'Beta 2012', 'Beta 8757', 'HM Horizon' and 'HM Valley' than in 'HM 8277' (Table 11). 'Beta 2012' and 'Beta 8757' treated with Betanex had significantly lower sugarbeet populations than Betanex treated 'HM 7054', 'HM 8277' and 'HM Resist'. 'Beta 2012', 'Beta 8757', HM Horizon' and 'HM Valley' treated with Betanex + Stinger had lower plant populations than 'HM 8277'. 'Beta 2012' also had lower sugarbeet populations than 'HM 7054' or 'HM Resist'. Sugarbeet populations of 'Beta 2012', 'Beta 8757' and 'HM Valley' were reduced, similar to Betanex + Stinger, by Betanex + UpBeet compared with 'HM 7054', 'HM 8277' and 'HM Resist'. Sugarbeet populations of 'HM Horizon' were also negatively affected by Betanex + UpBeet and resulted in fewer plants than 'HM 8277' or 'HM Resist'. The micro-rate reduced sugarbeet stands of 'Beta 2012' versus 'HM 7054', 'HM Horizon', 'HM Resist' or 'HM Valley' and of 'Beta 8757' versus 'HM Resist'.

Sugarbeet populations differed between non-resistant and Roundup Ready cultivars, averaged over weed control treatments (Table 12). The Roundup Ready cultivars of 'Beta 2012', 'Beta 8757', 'HM Horizon' and 'HM Valley' had lower sugarbeet populations than their non-resistant isolines. This difference may be due to percent germination of the Roundup Ready cultivars compared to commercial conventional non-resistant sugarbeet seed but information about germination percentage of the seed lot was not available. Roundup Ready 'HM 8277' produced more plants per 70 ft than the same non-resistant isoline.

Except 'HM Horizon', which had a lower sugarbeet population than 'Beta 2012', sugarbeet population was similar among the non-resistant cultivars (Table 12). Sugarbeet population of 'Beta 2012' and 'Beta 8757' was less than the population of other Roundup Ready cultivars. Resistant 'HM 8277' and 'HM Resist' had greater sugarbeet populations than 'HM Horizon' and 'HM Valley'; and 'HM 8277' had a higher plant population than 'HM 7054'.

Extractable sucrose from the Roundup Ready was less than from the non-resistant isolines only with 'HM Horizon' (Table 12). Rather than attributing this yield reduction to the effect of the resistance gene, perhaps the lower plant population in the resistant 'HM Horizon' may explain the yield difference.

Non-resistant 'Beta 2012' and 'HM Horizon' yielded more extractable sucrose than 'Beta 8757', 'HM 7054', 'HM 8277' and 'HM Horizon'. 'HM 7054' was the lowest-yielding cultivar among all Roundup Ready sugarbeet, whereas 'Beta 2012' was the highest-yielding Roundup Ready cultivar. These results are contrary to the sugarbeet population data for individual Roundup Ready cultivars (Table 12). The highest-yielding Roundup Ready 'Beta 2012' had the fewest plants per 70 ft indicating the ability of individual sugarbeet within the rows to compensate for yield in a non-uniform sugarbeet stand. Of all tested Roundup Ready cultivars, only 'HM 7054', averaged over weed control treatments, produced significantly less sugarbeet root yield than other cultivars (Table 13) and 'HM 7054' was also the lowest-yielding cultivar for extractable sucrose (Table 12).

Table 12. Sugarbeet population and extractable sucrose yield of non-resistant and Roundup Ready sugarbeet, averaged over weed control treatments.

	Cultivar			
	Non-resistant	Roundup Ready	Non-resistant	Roundup Ready
	plants per 70 ft		extractable sucrose, lb/A	
Beta 2012	102	73	8610	8890
Beta 8757	98	76	8050	8540
HM 7054	100	99	8020	7540
HM 8277	101	107	8020	8180
HM Horizon	96	90	8640	8050
HM Resist	100	104	8080	8500
HM Valley	97	90	8180	8620
LSD (0.05)[a]	6		520	

[a] LSD (0.05) = LSD to compare means within the non-resistant or RR cultivar (columns) and to compare means of the non-resistant and the same RR cultivar (rows).

Table 13. Root yield of sugarbeet cultivars, averaged over weed control treatments.

Sugarbeet cultivar	Root yield
	T/A
Beta 2012	25.1
Beta 8757	25.0
HM 7054	22.9
HM 8277	24.5
HM Horizon	24.5
HM Resist	24.3
HM Valley	24.4
LSD (0.05)	1.1

All hand weeded sugarbeet cultivars showed similar injury 7 DALT but injury from the tested herbicides varied among cultivars (Table 14). Except Betanex + Stinger applied to 'HM Valley', all other herbicides caused significantly greater injury on non-resistant and resistant cultivars than hand weeding. 'HM Resist' was most tolerant to Betanex compared to significantly greater injury from Betanex in 'Beta 8757', 'HM 8277' or 'HM Horizon'. 'HM 8277' was most severely injured by Betanex at 19%; significantly more than injury ratings from 'Beta 2012', 'HM 7054' and 'HM Valley'. Betanex + Stinger was least injurious on 'HM Valley'. Significantly more sugarbeet injury was observed with all other cultivars except 'HM 8277' and 'HM Horizon'. 'HM 8277' was more tolerant to Betanex + Stinger than 'Beta 8757'. The highest sugarbeet injury from Betanex + UpBeet was 13% with 'Beta 8757', which significantly exceeded injury ratings for 'HM Resist' or 'HM Valley' at 7%. Similar to Betanex + Stinger or Betanex + UpBeet, 'Beta 8757' was most susceptible to the micro-rate and more severely injured than 'Beta 2012', 'HM 7054', 'HM Resist' or 'HM Valley'.

'Beta 2012', 'Beta 8757' and 'HM 7054' were similarly injured across all tested herbicides with ratings ranging between 9 and 14%. 'HM 8277' was injured more by Betanex than other weed control treatments. 'HM Horizon' had greater injury from Betanex than from Betanex + Stinger or the micro-rate. 'HM Resist' was injured less with Betanex + UpBeet or the micro-rate than with Betanex + Stinger. 'HM Valley' tolerated Betanex + Stinger better than Betanex alone.

Table 14. Sugarbeet injury 7 DALT as affected by weed control treatment and cultivar, averaged over non-resistant and Roundup Ready cultivars.

	Treatment				
Sugarbeet cultivar	Hand weeded	Betanex	Betanex + Stinger	Betanex + UpBeet	Micro-rate
	% injury				
Beta 2012	3	11	11	10	9
Beta 8757	5	14	14	13	15
HM 7054	1	13	12	12	9
HM 8277	1	19	8	9	11
HM Horizon	2	15	9	12	10
HM Resist	1	8	12	7	6
HM Valley	1	10	5	7	7
LSD (0.05)[a]	6				
LSD (0.05)[b]	5				

[a] LSD_1 (0.05) = LSD to compare means within weed control treatments for different cultivars (columns).
[b] LSD_2 (0.05) = LSD to compare means of weed control treatments within the same cultivar (rows).

When contrasting the susceptibility of non-resistant versus the same Roundup Ready sugarbeet to various herbicides, Roundup Ready cultivars were injured more severely by all herbicide treatments except the micro-rate (Table 15). This indicates that the insertion of the Roundup Ready gene may affect the ability of the Roundup Ready cultivar to tolerate conventional POST sugarbeet herbicides. However,

no such interaction was determined for injury evaluations 21 DALT (Table 15), suggesting that sugarbeet metabolism to inactivate the herbicides was temporarily suppressed.

Within the non-resistant or Roundup Ready sugarbeet, hand weeding caused less injury 7 DALT than herbicides (Table 15). No difference in the response of non-resistant sugarbeet to several herbicides was determined. Roundup Ready sugarbeet, averaged over all cultivars, was most susceptible to Betanex alone but equally tolerant to all herbicide combinations with Betanex or the micro-rate. Injury from various weed control treatments at 21 DALT was similar within non-resistant or Roundup Ready sugarbeet and no differences in sugarbeet injury were observed between non-resistant and Roundup Ready cultivars.

Table 15. Injury to non-resistant and Roundup Ready sugarbeet from weed control treatments, averaged over cultivars.

	Cultivar			
Treatment	Non-resistant	Roundup Ready	Non-resistant	Roundup Ready
	% injury 7 DALT		% injury 21 DALT	
Hand weeded	1	3	7	6
Betanex	8	17	10	11
Betanex + Stinger	7	14	7	8
Betanex + UpBeet	6	14	11	10
Micro-rate	7	12	12	9
LSD (0.05)[a]	3		NS	
LSD (0.05)[b]	6		NS	

[a] LSD_1 (0.05) = LSD to compare means within the non-resistant or RR cultivar for different weed control treatments (columns).

[b] LSD_2 (0.05) = LSD to compare means of the non-resistant and RR cultivar for the same weed control treatment (rows).

Although data on sugarbeet injury 21 DALT as reported in Table 16 show significant differences among hand weeding or herbicides and cultivars, none of the levels of sugarbeet injury would be considered large enough to reduce yield. Betanex, Betanex + UpBeet and the micro-rate caused greater sugarbeet injury compared to hand weeding. Betanex + Stinger resulted in significantly less injury than Betanex + UpBeet or the micro-rate.

Table 16. Sugarbeet injury as affected by weed control treatments, averaged over cultivars.

Treatment	Sugarbeet injury 21 DALT
	%
Hand weeded	7
Betanex	10
Betanex + Stinger	8
Betanex + UpBeet	11
Micro-rate	11
LSD (0.05)	3

Table 17 presents the effect of the resistance gene in hand weeded Roundup Ready cultivars and non-resistant isolines. Sugarbeet population was less in the resistant ‘Beta 2012’, ‘Beta 8757’ or ‘HM Horizon’ compared to the respective non-resistant isolines, which is probably due to lower seed germination as discussed earlier. However, sugarbeet population did not significantly affect root yield or extractable sucrose in the Roundup Ready or the non-resistant ‘Beta 2012’. Root yield and extractable sucrose increased in the Roundup Ready ‘Beta 8757’ despite fewer plants per 70 ft. A reduction in sugarbeet root yield and extractable sucrose yield was observed in the Roundup Ready “HM Horizon’ versus the same non-resistant isoline. Similar to ‘Beta 8757’, sugarbeet root yield and extractable sucrose were greater with the resistant than with the non-resistant ‘HM Valley’. Hand weeding caused negligible injury 7

DALW. However, the resistant cultivars of 'Beta 2012', 'Beta 8757' and 'HM 8277' were damaged more severely than their respective non-resistant isolines. Sugarbeet injury from hand weeding was similar for resistant or non-resistant cultivars 21 DALW.

Table 17. Hand weeded non-resistant and Roundup Ready sugarbeet.

Sugarbeet cultivar[a]		Sgbt popl	Root yield	Sgbt injury 7 DALW[b]	Sgbt injury 21 DALW	Extr sucrose
		plants/70 ft	T/A	%		lb/A
Beta 2012	S	106	25.8	0	7	9190
	R	75	25.4	6	5	9030
Beta 8757	S	101	22.7	1	10	7490
	R	76	27.7	8	5	9390
HM 7054	S	99	21.7	0	7	7540
	R	98	21.9	2	6	7450
HM 8277	S	101	24.3	0	7	8060
	R	108	24.9	3	7	8140
HM Horizon	S	99	26.4	2	5	9190
	R	82	21.8	2	7	7440
HM Resist	S	95	24.1	0	3	8250
	R	95	24.7	1	7	8410
HM Valley	S	93	20.2	1	11	7080
	R	83	23.3	1	4	8370
LSD (0.05)[c]		13	3.2	3	NS	1190

[a] Sugarbeet cultivar S = non-resistant sugarbeet; R = Roundup Ready sugarbeet.
[b] DALW = Days after the last weeding.
[c] LSD (0.05) = LSD (0.05) for cultivar x resistance interaction.

CONCLUSIONS

With the advent of Liberty Link and Roundup Ready and the respective non-resistant isolines, weed control without yield-reducing injury from current conventional POST sugarbeet herbicides is possible. However, individual sugarbeet cultivars differed in sugarbeet population, extractable sucrose and root yield due to interactions with various weed control treatments. Therefore, weed control programs in variety performance trials on evaluated Liberty Link or Roundup Ready cultivars of this study should consider the use of Liberty or Roundup, respectively, rather than conventional herbicides in order to avoid misleading herbicide effects. The inconsistency in the response patterns of the resistant and non-resistant cultivars suggests no apparent effect of the gene conferring resistance to either Liberty or Roundup on sugarbeet yield.

The results of this study were generated from a single year and location and results may vary under different environmental conditions. Furthermore, conclusions are limited and generalizations should only be made to the tested cultivars and herbicide treatments.

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