Late Season Redroot Pigweed Control in Sugarbeet with Over-the-Top Glyphosate

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ABSTRACT

The benefits and risks of carefully applying glyphosate to large redroot pigweed (*Amaranthus retroflexus* L.) plants without contacting sugarbeet were evaluated. Glyphosate applied to redroot pigweed growing in close association with sugarbeet reduced or tended to reduce sugarbeet (*Beta vulgaris* L.) root yield and extractable sucrose yield when compared to handweeding. Glyphosate injury to sugarbeet was observed despite careful application and plastic bagging of redroot pigweed to prevent the herbicide from dripping onto sugarbeet during or following application. Results suggested that sugarbeet injury was caused by movement of glyphosate from roots of treated redroot pigweed to roots of untreated sugarbeet.

Additional key words: Glyphosate injury, selective application

Sugarbeet growers in eastern North Dakota and Minnesota control annual weeds with a combination of hand labor, tillage, and herbicides. They would prefer to produce sugarbeet without hand labor for weeding. A survey of sugarbeet growers in eastern North Dakota and Minnesota indicated that 23% of the sugarbeet acreage was hand weeded in 2005 (Luecke and Dexter, 2006). Complete control of annual weeds through mechanical or chemical control practices is seldom accomplished despite the excellent herbicides available for weed control in sugarbeet. Weeds which escape initial control efforts may reduce sugarbeet yield, interfere with harvesting, and produce seed to reinfest the following crop. Thus, several over-the-top applicators such as the rope wick, herbicide roller, and recirculating sprayer, which apply glyphosate to weeds growing above the sugarbeet canopy have been investigated as a substitute for late season handweeding (Rasmusson, 1981; Schweizer and Bridge, 1982; Wyse and Habstritt, 1977).

Rasmusson (1981) indicated several disadvantages of applying glyphosate with over-the-top applicators as compared to hand labor for control of weed escapes in sugarbeet: (a) selectivity is based entirely on a height differential between the weed and sugarbeet, thus weeds have competed with sugarbeet for a period of time sufficient to reduce sugarbeet yield before control is possible; (b) weeds the same height or shorter than the sugarbeet canopy are not controlled; (c) weeds killed by glyphosate often remain standing and continue to compete with sugarbeet for light and (d) glyphosate may cause sugarbeet injury following application with over-the-top application methods.

The average cost of handweeding among sugarbeet growers in eastern North Dakota and Minnesota who used handweeding in 2005 was \$27 ha^{-1} and some spent \$200 ha^{-1} (Luecke and Dexter, 2006). The cost of over-the-top glyphosate would vary depending on equipment size, application speed, equipment cost, labor cost, and weed density. However, the cost of over-the-top glyphosate plus application generally would fall between \$10 and \$20 ha^{-1} so savings are possible with glyphosate as compared to handweeding especially in fields with high weed densities.

Redroot pigweed is an annual weed that commonly escapes complete control in sugarbeet fields of eastern North Dakota and Minnesota. Redroot pigweed was identified as the worst weed problem in sugarbeet by 42% of the sugarbeet grower respondents to an annual survey in 2005 (Luecke and Dexter, 2006).

Experiments to determine: (a) the yield benefit from late season redroot pigweed control in sugarbeet and (b) whether glyphosate can be applied to weeds without causing injury to the sugarbeet were conducted from 1979 through 1981.

MATERIALS AND METHODS

Field experiments

"American Crystal Hybrid 17" was seeded in a silty loam soil near Glyndon, Minnesota on May 28, 1979 and "Great Western R-1" was seeded in a silty clay soil on the North Dakota State University Experiment Station at Fargo, North Dakota on May 21, 1980 and May 13, 1981. Sugarbeet seed was placed 3.0 cm deep in rows 56 cm apart. Experimental plots were arranged in a randomized complete block design with six replicates and were four rows wide by 8.0 m long in

1979 and 1980 and were four rows wide by 3.0 m long in 1981. Data was analyzed using SAS. Redroot pigweed was handseeded with table salt shakers directly into the sugarbeet row one to four days following sugarbeet planting and shallowly incorporated into the soil with a triangular hoe. Each replicate was started and completed in a single day. Sugarbeet was thinned after emergence to approximately one plant per 28 cm of row. Redroot pigweed densities were established by marking the desired plants with 10 cm tall plastic stakes and hand removing other weeds. Redroot pigweed densities were maintained and other weeds were removed by handweeding throughout the growing season. Redroot pigweed densities of 3.0 plants/m of row were established in a 15 cm band over the sugarbeet row in each plot, except for a handweeded check which was maintained weed free throughout the growing season. Wheel hoes were used between the rows and weeds were removed within the row with hand hoes plus finger weeding near the sugarbeet plants. A 0.25 ml aliquot of a 50% v/v formulated 360g ae/l glyphosate:water solution was applied by hand with a 1 ml syringe to the most recently expanded leaf of all individual redroot pigweed plants in each treated plot.

The experiment consisted of eight treatments in 1979: (a) handweeded check; (b) glyphosate applied August 1, 8 and 15; (c) hand removal of redroot pigweed on August 8, 15 and 22 and (d) untreated density of 3.0 redroot pigweed m^{-1} (weedy check). Redroot pigweed was removed by hand from the handweeded plots one week following glyphosate application to coincide with the physiological death of glyphosate treated redroot pigweed.

The experiment was expanded in 1980 to include a treatment in which the upper 33% to 50% of individual glyphosate treated redroot pigweed, including the glyphosate treated area, were enclosed in white plastic prior to and for a period of 6 hours following glyphosate application and a treatment in which untreated redroot pigweed were similarly bagged in white plastic. The experiment consisted of ten treatments in 1980: (a) handweeded check; (b) glyphosate applied during the week of August 11 to 15, and August 18 to 22 with and without plastic bagging; (c) plastic bagging during the week of August 11 to 15, and August 18 to 22, without glyphosate treatment; (d) hand removal of redroot pigweed during the week of August 18 to 20, and August 25 to 29 and (e) untreated redroot pigweed at 3.0 plants/m of row (weedy check). Glyphosate was applied to one replicate in the morning and one replicate in the evening for 3 days to complete the six replicates. Redroot pigweed was removed by hand from the handweeded plots one week following the corresponding glyphosate application.

Bagging of redroot pigweed without glyphosate application was deleted from the treatments in 1981. The experiment consisted of seventeen treatments in 1981: (a) handweeded check; (b) glyphosate application with and without plastic bagging on July 20, July 27, August 3, August 10, and August 17; (c) hand removal of redroot pigweed on July 27, August 3, August 19, August 17, and August 24 and (d) untreated pigweed at 3.0 plant/m of row (weedy check). Visual estimates of reduction in sugarbeet top growth biomass from glyphosate injury and sugarbeet stand counts before and after glyphosate applications were made to evaluate damage to sugarbeet in 1980 and 1981.

The center two rows of each plot were harvested to determine sugarbeet root yield and quality on September 21, 1979 at Glyndon, Minnesota, and October 5, 1980 and October 13, 1981 at Fargo, North Dakota. Sugarbeet plants were flailed to remove leaves and petioles and lifted with a tractor mounted one-row harvester. Root weights from each plot were recorded in the field. Extractable sucrose yield, root yield, percent sucrose, and impurity index were determined for sugarbeet. From 10 to 15 roots per plot were used to determine percent tare, sucrose, and impurity content of sugarbeet. Sugarbeet root samples were weighed to determine the gross weight. Dirt and trash were removed by washing roots in mechanical washers to obtain clean weight, and calculate percent tare.

Samples for sucrose and impurity determination were obtained by passing sugarbeet through multiple circular gang saws and collecting the brei. Brei samples were analyzed for sodium, potassium, and amino nitrogen concentration in the sugarbeet. Impurity index, sucrose loss, and extractable sucrose values were calculated using the following formulas from Carruthers et al. (1962) and modified by American Crystal Sugar Company for eastern North Dakota — Minnesota conditions.

Impurity Index =

$$\frac{3.5\,(\text{ppm Na}) + 2.5\,(\text{ppm K}) + 9.5\,(\text{ppm Amino-N})}{\%\ \text{sucrose}}$$

Sucrose loss/ha (kg/ha) =

$$\frac{\text{Impurity index} \times \%\ \text{sucrose} \times \text{sugarbeet yield (kg/ha)} \times 1.5}{1{,}000{,}000}$$

Extractable sucrose (kg/ha) =

$$\left[\text{sugarbeet root yield (kg/ha)} \times \frac{\%\ \text{sucrose}}{100}\right] - \text{sucrose loss/ha}$$

Greenhouse

Sugarbeet and redroot pigweed were grown in 60 by 60 by 60 cm wooden boxes. The boxes were filled with a silty clay soil and sugarbeet was seeded on one side of the boxes and redroot pigweed on the other side. Emerged sugarbeet and redroot pigweed were thinned to three plants per box and were established in rows 30 cm apart. Glass dividers were used to establish separation between sugarbeet and redroot pigweed. The treatments were: 1) no separation between species, 2) sugarbeet tops separated from redroot pigweed tops, 3) sugarbeet roots separated from redroot pigweed roots and 4) sugarbeet roots and tops separated from redroot pigweed roots and tops. A 0.25 ml aliquot of 50% v/v glyphosate: water solution was applied with a syringe to the most recently expanded leaf of 25 cm to 30 cm tall redroot pigweed when sugarbeet had 10 to 12 leaves. The experiment had three replicates and was repeated.

RESULTS AND DISCUSSION

Field experiments

Untreated redroot pigweed at 3.0 plants/m of row (weedy check) reduced sugarbeet root yield and extractable sucrose by 42% as compared to the handweeded check throughout the growing season in 1979 (Table 1). Glyphosate applied August 1 or August 8 to redroot pigweed at 3.0 plants/m of row, killed the redroot pigweed (data not shown) and reduced sugarbeet root yield, extractable sucrose, stand, and percent sucrose as compared to the sugarbeet handweeded throughout the season, weedy check, or plots handweeded on August 8 or August 15. Sugarbeet root yield and extractable sucrose from plots handweeded on August 8 or August 15 were greater than from the weedy check plots. Percent sucrose was similar with the August 8 or August 15 handweeding, full season handweeding and the weedy check. Sugarbeet root yield and extractable sucrose were similar from the weedy check and from plots handweeded August 22 or treated with glyphosate August 15.

Results in 1979 indicated a potential sugarbeet yield benefit from late season hand removal of redroot pigweed if done by August 15 while no benefit was observed from removal of redroot pigweed on August 22 (Table 1). Glyphosate applied to redroot pigweed killed the weeds but also reduced sugarbeet root yield and extractable sucrose yield as compared to sugarbeet handweeded on the same day that glyphosate was applied. Sugarbeet stand also was reduced by glyphosate application compared to the handweeding on the same day. Thus, glyphosate applied to redroot pigweed injured sugarbeet which offset any potential yield increase from late season redroot pigweed control in sugarbeet. The source of glyphosate injury to sugarbeet was not known but dripping from redroot pigweed onto

Table 1. Sugarbeet root yield, percent sucrose, and extractable sucrose as influenced by glyphosate applied to redroot pigweed, handweeding, and redroot pigweed density in 1979.

			Sugarbeet			
Treatment	**Redroot pigweed density**	**Date**	**Sucrose**	**Root Yield**	**Extractable sucrose**	**Stand reduction**
	plants/m		%	Mg/ha	kg/ha	%
Handweeded throughout season	0		15.7a[1]	32.5a[1]	4492a[1]	0
Weedy check	3		15.7a[1]	18.9c	2624cd	8
Glyphosate	3	Aug. 1	14.9b	14.4d	1871e	22
Handweeding	3	Aug. 8	15.3ab	23.7b	3097bc	0
Glyphosate	3	Aug. 8	14.1c	10.2e	1197f	38
Handweeding	3	Aug. 15	15.4ab	26.0b	3594b	0
Glyphosate	3	Aug. 15	15.5ab	16.9cd	2329de	14
Handweeding	3	Aug. 22	15.1ab	17.2cd	2280de	8

[1]Means within a column followed by the same letter do not differ at *P*=0.05 according to Duncan's Multiple Range Test.

sugarbeet leaves during or immediately following application was considered a possible source.

Thus, the experiment was altered in 1980 by adding a treatment at each glyphosate application date where redroot pigweed plants were bagged in white plastic prior to and for 6 hours following treatment to prevent the glyphosate solution from dripping onto the sugarbeet during application and to prevent contact between glyphosate treated leaves and sugarbeet leaves.

Redroot pigweed at 3.0 plant/m of row (weedy check) reduced sugarbeet yield by 37% and extractable sucrose by 36% as compared to yield from the handweeded throughout the season treatment in 1980 (Table 2). Sugarbeet extractable sucrose yield from plots handweeded in August or from plots with glyphosate-treated redroot pigweed was similar to or less than yield from the weedy check and less than yield from the plots handweeded throughout the season. Glyphosate, applied August 18 to 22 to redroot pigweed with or without plastic bagging, reduced sugarbeet root yield and extractable yield compared to hand removal of redroot pigweed on August 18 to 22.

Redroot pigweed in the weedy check reduced sugarbeet stand 2% (Table 2). Sugarbeet stand was reduced 4% by hand removal of redroot pigweed on August 18 to 22 or on August 25 to 29. Glyphosate applied to redroot pigweed with no plastic bagging reduced sugarbeet stand 14% when applied August 11 to 15 and 40% when applied August 18 to 22. Glyphosate applied with plastic bagging reduced sugarbeet stand 9% when applied August 11 to 15 and 28% on August 28 to 22. Sugarbeet injury from glyphosate applied to redroot pigweed August 11 to 15 was visually estimated at 21% without and 23% with plastic bagging. Sugarbeet injury from glyphosate applied August 18 to 22 was visually estimated at 33% without plastic bagging and 34% with plastic bagging. Sugarbeet injury of 1% and stand reduction of 8% was observed where redroot pigweed were bagged August 18 to 22 but no glyphosate was applied. This sugarbeet injury was attributed to glyphosate residue on the plastic bag from a previous treatment.

Glyphosate applied to redroot pigweed on August 18 to 22 reduced sugarbeet root yield and extractable sucrose with or without plastic bagging of treated redroot pigweed as compared to plots handweeded on August 18 to 22. Since plastic bagging did not improve sugarbeet yield, this indicated that drip during application or sugarbeet contact with treated redroot leaves in the 6 hours following application was not the primary cause of sugarbeet injury. Visual observations of sugarbeet injury and sugarbeet stand counts with and without plastic bagging of the redroot pigweed support this conclusion.

Table 2. Sugarbeet root yield, percent sucrose, extractable sucrose, sugarbeet stand, and sugarbeet injury as influenced by glyphosate applied to redroot pigweed, handweeding, and redroot pigweed density in 1980.

Treatment	Redroot pigweed density	Date	Sucrose	Root Yield	Sugarbeet Extractable sucrose	Stand reduction	Injury
	plants/m		%	Mg/ha	kg/ha	------------ %	------------
Handweeded throughout season	0	-	14.4a[1]	43.8a[1]	4715a[1]	0	0
Weedy check	3	-	14.6a	27.6bcd	3018b	2	0
Glyphosate	3	Aug. 11-15	13.7a	24.6cd	2542bcd	14	21
Handweeding	3	Aug. 18-22	13.6a	32.9b	3327b	4	0
Glyphosate	3	Aug. 18-22	13.6a	21.8cd	2175cd	40	33
Glyphosate + plastic bagging	3	Aug. 18-22	13.5a	21.0d	2071d	28	34
Glyphosate + plastic bagging	3	Aug. 11-15	13.9a	22.6cd	2410cd	9	23
Plastic bagging	3	Aug. 11-15	13.9a	25.5cd	2669bcd	1	0
Handweeding	3	Aug. 25-29	13.4a	24.7cd	2412dc	4	0
Plastic bagging	3	Aug. 18-22	13.8a	28.5bc	2956bc	8	1

[1]Means followed by the same letter within a column do not differ at P=0.05 according to Duncan's Multiple Range Test.

A field experiment similar to the 1979 and 1980 experiments was conducted in 1981. Redroot pigweed at a density of 3.0 plants/m of row (weedy check) did not reduce sugarbeet root yield or extractable sucrose when compared to the handweeded check in 1981 (Table 3). The reduced level of redroot pigweed competition in 1981 as compared to 1980 was attributed to an infestation of redroot pigweed by a complex of insects that damaged the roots and stems of redroot pigweed. Dr. Albin Anderson, an entomologist at North Dakota State University, isolated three insects from redroot pigweed stems, roots, and soil immediately surrounding redroot pigweed roots (personal communication). Insects were identified as two members of the order *Coleoptera*, family *Mordellidae* and *Curculianidae*, and one member of the order *Diptera*, family *Agromyzidae*. Further research would be required but was not conducted to determine the biological relationship between these insects and redroot pigweed and for a more complete identification of the insects.

Glyphosate treatment of redroot pigweed did not affect sugarbeet yield, extractable sucrose, or sucrose content in 1981 (Table 3). Glyphosate applied on July 20 reduced sugarbeet stand 5% without and 14% with plastic bagging. Glyphosate applied on July 27 and August 10 reduced sugarbeet stand 13% and 9% respectively, while sugarbeet stand was not affected by glyphosate applied with plastic bagging. Sugarbeet injury from glyphosate applied on July 20 was visually estimated at 11% without and 7% with plastic bagging. Sugarbeet injury from glyphosate applied to redroot pigweed without plastic bagging on July 27 and August 10 was estimated at 3% and 4%, respectively, while sugarbeet was not injured by glyphosate applied with plastic bagging. Plastic bagging of redroot pigweed tended to reduce sugarbeet injury from glyphosate suggesting that some injury was due to dripping of glyphosate during application or from contact between sugarbeet and treated redroot pigweed leaves following application.

The low level of sugarbeet injury from glyphosate application in 1981 was perhaps due to observed insect feeding within the stems of redroot pigweed which prevented or greatly reduced translocation in the vascular system of redroot pigweed. The control of glyphosate-treated redroot pigweed was about 60% in 1981 and was 100% in 1979 or 1980 (data not shown) which also suggests that glyphosate was translocating less in the redroot pigweed plants in 1981 as compared to 1979 or 1980. Westra et al., 1981 indicated that insect feeding reduced the control of quackgrass (*Agropyron repens* L.) from glyphosate due to a reduction of glyphosate translocation. Thus, insect feeding may have reduced translocation of glyphosate within redroot pigweed in 1981. Redroot

Table 3. Sugarbeet root yield, percent sucrose, extractable sucrose, sugarbeet stand, and sugarbeet injury as influenced by glyphosate applied to redroot pigweed, handweeding and redroot pigweed density in 1981.

Treatment	Redroot pigweed density	Date	Sugarbeet				
			Sucrose	Root Yield	Extractable sucrose	Stand reduction	Injury
	plants/m		%	Mg/ha	kg/ha	------------ %	------------
Handweeded throughout season	0	-	14.9a[1]	31.3abc[1]	4093a[1]	0	0
Weedy check	3	-	14.4a	35.8ab	3097a	0	0
Handweeding	3	Jul. 27	14.8a	33.0abc	3679a	0	0
Glyphosate	3	Jul. 20	14.8a	28.6bc	3212a	5	11
Glyphosate + plastic	3	Jul. 20	14.5a	29.1bc	3197a	14	7
Handweeding	3	Aug. 3	14.4a	32.2abc	3313a	0	0
Glyphosate	3	Jul. 27	14.9a	25.1c	2875a	13	3
Glyphosate + plastic	3	Jul. 27	15.0a	31.8abc	3441a	0	0
Handweeding	3	Aug. 10	14.1a	35.0ab	3731a	0	0
Glyphosate	3	Aug. 3	14.8a	37.7a	4254a	0	0
Glyphosate + plastic	3	Aug. 3	14.9a	33.2ab	3786a	0	0
Handweeding	3	Aug. 17	14.7a	31.0abc	3484a	0	0
Glyphosate	3	Aug. 10	14.5a	30.8abc	3406a	9	4
Glyphosate + plastic	3	Aug. 10	14.6a	31.5abc	3479a	0	0
Handweeding	3	Aug. 24	14.7a	35.7ab	4034a	0	0
Glyphosate	3	Aug. 17	15.0a	35.5ab	4039a	0	0
Glyphosate + plastic	3	Aug. 17	14.8a	34.6ab	3924a	0	0

[1]Means followed by same letter within a column do not differ at *P*=0.05 according to Duncan's Multiple Range Test.

pigweed control with applied glyphosate was slower and less complete than had been observed in previous experiments. Reduced translocation of glyphosate into redroot pigweed roots may have been the primary reason less glyphosate injury to sugarbeet was observed in 1981 than in 1979 or 1980. Coupland and Casely (1979); Coupland and Lutman (1982); and Rodriques et al. (1982) reported that glyphosate moves from treated to untreated plants below ground. Evidence indicated that glyphosate rate, weed density, proximity of root system, and soil type influence the extent of glyphosate movement.

Glyphosate was applied in a similar manner at the same rate to similar densities of redroot pigweed in all three years. Thus, if injury to sugarbeet from glyphosate was only due to the dripping of glyphosate solution from treated redroot pigweed leaves during application, or contact between treated leaves and sugarbeet after application, injury to sugarbeet should have been similar in all three years regardless of the condition of redroot pigweed at application. Sugarbeet injury from glyphosate occurred with or without bagging in 1980 so results suggest that glyphosate will move from treated redroot pigweed roots to untreated sugarbeet roots following a directed application of glyphosate.

Greenhouse

Glyphosate applied to redroot pigweed in the greenhouse killed the plants. Sugarbeet grown in the same boxes as glyphosate-treated redroot pigweed showed no glyphosate injury symptoms if the redroot pigweed and sugarbeet roots were separated by a sheet of glass. However, sugarbeet grown in the same boxes as glyphosate-treated redroot pigweed exhibited glyphosate injury symptoms if the redroot pigweed and sugarbeet roots were not separated. Separating sugarbeet tops and glyphosate-treated redroot pigweed had no effect on sugarbeet injury, but the contact between sugarbeet tops and redroot pigweed tops was minimal. Redroot pigweed developed obvious glyphosate injury symptoms before sugarbeet began to show injury in the boxes where sugarbeet and redroot pigweed roots were allowed to grow together. These observations suggest that the sugarbeet plants were taking up glyphosate from dead and dying roots of glyphosate-treated redroot pigweed below the soil surface.

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