Impact of Injury from Late Season Sequential Glufosinate Applications on Sugarbeet Yield

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ABSTRACT

Experiments were conducted to determine if sugarbeet (*Beta vulgaris L.*) injury from sequential glufosinate treatments starting later than three weeks after the sugarbeet cotyledon stage caused yield loss, and to assess cumulative phytotoxic effects from sequential glufosinate treatments at various rates. Sugarbeet plots were hand weeded until glufosinate treatments started so that sugarbeet yield loss with late season glufosinate treatments, if any, could be attributed to herbicide injury rather than prolonged early season weed competition. Visible sugarbeet injury was greater when glufosinate treatments were started at three, four, six, or seven weeks after the sugarbeet cotyledon stage rather than one week after the cotyledon stage. The absence of a difference in sugarbeet root yield and extractable sucrose, regardless of glufosinate application starting time, suggests that sugarbeet either partially grew out of the observed leaf chlorosis or that late-appearing visible injury had no adverse effect on yield traits. Regardless of the rate, sugarbeet treated with glufosinate either one or four times had similar root yield and extractable sucrose, which confirms the lack of any significant cumulative phytotoxic effect on sugarbeet yield from multiple glufosinate applications.

Additional Key Words: *Beta vulgaris L.*, weed competition, leaf chlorosis.

Efficient and safe weed management systems continue to be a key in producing maximum sugarbeet yield. Current herbicide options in sugarbeet do not guarantee weed-free production even under optimum conditions (Dexter and Zollinger 2003). Approximately 53% of surveyed sugarbeet growers in eastern North Dakota and Minnesota considered weeds as their most serious production problem in 2002 (Dexter and Luecke 2003).

Problems associated with current postemergence (POST) sugarbeet herbicide weed control systems include treatment application flexibility and yield-reducing, herbicide-induced sugarbeet injury. Maximum weed control efficiency with the combination of currently available POST conventional herbicides requires the first treatment to be applied to small weeds and to sugarbeet at the cotyledon to two-leaf growth stage (Dexter and Zollinger 2003; Platte et al. 1998). Very small weeds are most susceptible to POST herbicides (Dawson 1977; Hendrick et al. 1974). However, the use of early season full-rate POST herbicides in sequential applications can injure the crop because sugarbeet seedlings have a low tolerance to some sugarbeet herbicides (Dexter and Zollinger 2003; Miller and Fornstrom 1988, 1989; Schweizer 1980; Wicks and Wilson 1983). Sugarbeet plants are most susceptible to POST herbicide applications starting at the cotyledon growth stage, and less injury occurs from treatments at the two- to four; four- to six; or six- to eight-leaf stage (Wicks and Wilson 1983; Wilson 1998). POST treatments of desmedipham and ethofumesate applied prior to the two-leaf stage injured sugarbeet plants in the greenhouse (Eshel et al. 1976). Scott et al. (1976) observed similar field responses with phenmedipham. Commercial applications of desmedipham and phenmedipham in some circumstances harmed sugarbeet plants (Bray 1983; Norris 1974; Preston and Briscoe 1983; Prodoehl et al. 1992; Winter and Wiese 1978).

Although sugarbeet plants gain herbicide tolerance as they grow larger (Dexter and Zollinger 2003; Norris 1991), weeds also gain tolerance with size (Edmund Jr. and York 1987; Lee and Oliver 1982; Ritter and Coble 1984; Weinlaeder and Dexter 1972). Desmedipham applied at the six-leaf sugarbeet growth stage failed to satisfactorily control large weeds (Eshel et al. 1976).

In order to reduce sugarbeet injury from full-rate POST herbicides, low-rate herbicide combinations (micro-rates) were registered for use in sugarbeet in North Dakota and Minnesota in 1998 and 1999, and registered for the entire United States in 2000 (EPA Reg. No 45639-86). The micro-rate requires three to five applications at five- to seven-day intervals starting when weeds are in the cotyledon stage to achieve greatest weed control (Dexter and Zollinger 2003). Typically, the micro-rate combines desmedipham at 90 g ha^{-1} plus triflusulfuron at 4 g ha^{-1} plus clopyralid at 30 g ha^{-1} plus clethodim at 30 g ha^{-1} plus a methylated seed oil adjuvant (MSO) at 1.5% v/v in the tank mix. MSO must be added to the micro-rate to enhance weed control with the low herbicide rates.

The lack of glufosinate selectivity in non-transformed sugarbeet has restricted glufosinate use on emerged plants. Low use-rates, high degree of safety to non-target organisms, rapid degradation in the environment with minimal residue persistence in soil, negligible residues in crops, unique mode of action, application flexibility, and excellent efficacy on a broad weed spectrum are the main advantages of glufosinate over some of the currently available sugarbeet herbicides (Ahrens 1994; Vasil 1996). Genes for resistance to glufosinate isolated from soil bacteria have been inserted into conventional sugarbeet lines to allow glufosinate use in-season with a low risk of crop injury (D'Halluin et al. 1992; Vasil 1996).

The literature regarding sugarbeet tolerance to POST glufosinate is inconsistent. For example, Thorsness et al. (1998) saw no visible sugarbeet injury with glufosinate treatments applied from emergence to the 10-leaf sugarbeet stage. Wevers (1998) agreed that timing of glufosinate treatments, even at double rates, did not affect crop injury nor weed control efficacy. Wilson (1999) reported less early season sugarbeet injury from glufosinate in glufosinate-resistant sugarbeet compared with conventional POST herbicides such as the combination of desmedipham plus phenmedipham plus triflusulfuron.

Studies on glufosinate-resistant sugarbeet conducted in eastern North Dakota and Minnesota demonstrated extractable sucrose yield from glufosinate-treated sugarbeet exceeding that of sugarbeet treated with desmedipham plus triflusulfuron plus clopyralid with five start times (Dexter and Luecke 1998). The earliest first sequential herbicide treatment was made at the sugarbeet cotyledon stage, and the latest started four weeks thereafter. All sugarbeet plots were treated three times with a one-week interval between applications. Sugarbeet injury from glufosinate was negligible regardless of application starting times. Similar studies during 1998 and 1999 revealed reduced sugarbeet yield when the first sequential glufosinate treatment was delayed until four weeks or one week after the cotyledon stage in 1998 and 1999, respectively (Rothe 2002). Sequential glufosinate applications starting two weeks or later after the sugarbeet cotyledon stage visibly injured sugarbeet while injury was negligible with treatments starting at the cotyledon- and cotyledon-plus-one-week stage. As the rate increased from 0.2 to 0.4 and 0.8 kg ha^{-1}, glufosinate had to be applied to younger sugarbeet to avoid sugarbeet injury.

Timing of glufosinate application did not affect weed control efficacy, but temporary leaf damage, especially after glufosinate applications at the nine-leaf stage and beyond, was also noted by Bückmann et al. (2000). This observation agrees with the conclusion made by Regitnig and Nitschelm (1998) that application timing of high glufosinate rates affected crop injury more than weed control. They observed significant leaf chlorosis to glufosinate-resistant sugarbeet at one location after the third application of POST glufosinate at 0.4 kg ha^{-1} shortly before row closure. None of the glufosinate-resistant sugarbeet experiments have investigated the effect of glufosinate-induced sugarbeet damage on sugarbeet yield components. Therefore, the objective of this research was to determine if injury to glufosinate-resistant sugarbeet from late season glufosinate treatments caused yield loss; and to assess cumulative phytotoxic effects from glufosinate at various rates.

MATERIALS AND METHODS

Field studies were conducted near St. Thomas, ND and Crookston, MN, in 2000. A third experiment near Fargo, ND, was terminated prior to harvest because of flooding, and therefore will not be discussed.

Glufosinate-resistant 'Beta 2012' sugarbeet was seeded 3 cm deep and 7.6 cm apart in 56-cm wide rows with a conventional sugarbeet planter. Individual experimental units consisted of six 11-m-long sugarbeet rows of which the two outer rows were untreated. Terbufos was applied modified in-furrow at seeding for root maggot [*Tetanops myopaeformis* (Röder)] control. Fungicides for Cercospora leaf spot (*Cercospora beticola* Sacc.) control, and additional root maggot insecticides were sprayed throughout the growing season when necessary. Sugarbeet at the seedling stage was hand thinned to 4 to 5 plants per m of row. Planting, thinning, and harvest dates are listed in Table 1.

Glufosinate was applied to sugarbeet four times or one time at 0.2, 0.4, and 0.8 kg ai. ha^{-1}, where 0.4 kg ha^{-1} represents the 1X or normal use rate. Multiple glufosinate treatments were at one-week intervals beginning one, three, or four weeks after the sugarbeet cotyledon stage. Single glufosinate treatments were applied six or seven weeks after the sugarbeet cotyledon stage, or at the same time as the last application of the multiple glufosinate treatments that started three or four weeks after the sugarbeet cotyledon stage. These treatments permitted comparison

Table 1. Glufosinate-resistant sugarbeet in 2000.

Location	Planting date	Hand-thinning date	Harvest date
St. Thomas, ND	April 27	July 5	September 28
Crookston, MN	May 2	June 30	October 3

of phytotoxic effects from single versus multiple glufosinate applications. Plots treated four times with glufosinate starting one week after the sugarbeet cotyledon stage were compared to plots treated four times starting three or four weeks after the sugarbeet cotyledon stage.

All plots were hand weeded prior to the first glufosinate application to minimize weed interference with sugarbeet yield and to detect treatment effects in the absence of weeds. Non-herbicide-treated plots were included for yield and sugarbeet injury comparisons and were regularly hand weeded until either six or seven weeks after the sugarbeet cotyledon stage. Plots treated with glufosinate at three or six weeks after the sugarbeet cotyledon stage were compared to plots that were hand weeded until six weeks after the sugarbeet cotyledon stage. Hand weeding stopped at the same time as the last glufosinate application. Plots receiving glufosinate at either four or seven weeks after the sugarbeet cotyledon stage were compared to untreated plots that were hand weeded until seven weeks after the sugarbeet cotyledon stage. Late season weed competition was eliminated when necessary to keep all plots weed-free until harvest.

Glufosinate was applied to the four inside rows in 160 L ha^{-1} water at 280 kPa through 8002 flat fan nozzles using a CO_2-pressurized bicycle-wheel-type plot sprayer traveling at 4.8 km h^{-1}. Treatment dates, environmental conditions, and sugarbeet growth stage at the time of application or hand weeding were recorded (Table 2).

Sugarbeet injury in the center four rows was scored visually on a scale of 0 to 100 (0 = no leaf chlorosis, or biomass reduction; and 100 = complete kill) approximately 7 and 21 days after the last of all herbicide treatments (DALT) were applied. For this purpose, the glufosinate-treated and hand-weeded center rows were compared to the two outer untreated rows of each plot. Sugarbeet populations were determined by counting roots in the two center harvested rows of each plot. Harvested roots were weighed in the field, and 10 to 15 uniform, visibly disease-free roots were taken from each plot. Percent tare, impurity, and sucrose content in these sugarbeet samples were determined by the American Crystal Sugar Company research laboratory at Moorhead, MN, using standard laboratory procedures developed by the company.

The experimental design was a randomized complete block with five replicates. Experiments were combined over locations based on homogeneous error mean squares obtained from the single analysis of variance (ANOVA) tested according to Barlett's Chi-square test. According to the research objectives, certain pre-determined treatment pairs were compared using single-degree-of-freedom contrasts at the 0.05 level of significance.

Table 2. Environmental conditions and sugarbeet growth stage at the time of glufosinate application in 2000.

	Location							
	St. Thomas	Crookston	St. Thomas	Crookston	St. Thomas	Crookston	St. Thomas	Crookston
Glufosinate application[†]	Date		Air temperature		Relative humidity		Sugarbeet growth stage	
			--------------C--------------		--------------%--------------		--------------V[‡]--------------	
Cotyledon + 1 week	05/24	05/26	22	17	38	65	1.0 - 2.0	2.0 - 3.0
Cotyledon + 2 weeks	05/31	06/02	17	21	42	60	1.0 - 6.5	3.0 - 6.0
Cotyledon + 3 weeks	06/07	06/09	24	33	56	26	2.0 - 7.7	6.5 - 8.5
Cotyledon + 4 weeks	06/16	06/19	12	21	88	100	4.5 - 10.7	9.7 - 12.5
Cotyledon + 5 weeks	06/22	06/26	22	20	65	59	5.5 - 12.5	11.5 - 14.7
Cotyledon + 6 weeks	06/29	07/03	27	27	55	80	7.5 - 14.7	13.0 - 18.7
Cotyledon + 7 weeks	07/06	07/10	23	31	78	58	10.5 - 12.7	14.7 - 19.7

[†]Glufosinate was applied in reference to the sugarbeet development stage beginning at one, three, four, six, and seven weeks after the sugarbeet cotyledon stage. Glufosinate treatments starting at one, three, and four weeks after the cotyledon stage were applied four times in one-week intervals. For example, the "Cotyledon + 1 week" starting time treatment included glufosinate applications at Cotyledon + 1 week, Cotyledon + 2 weeks, Cotyledon + 3 weeks, and Cotyledon + 4 weeks. Glufosinate treatments were applied only once starting at six and seven weeks after the cotyledon stage.

[‡]V1.0 = sugarbeet cotyledon stage, V2.0 = sugarbeet with two unrolled true leaves, and V2.5 = sugarbeet with two unrolled true leaves and a third leaf 50% unrolled, etc.

RESULTS AND DISCUSSION

A contrast analysis of early season versus late season glufosinate application starting times across locations and averaged over glufosinate rates, indicated no significant effect on sugarbeet population and root yield (Table 3). Glufosinate applied four times starting one week after the cotyledon stage of sugarbeet, on average, injured plants 0 to 4%, whereas injury was up to 26% when glufosinate application sequences started three weeks or later after the cotyledon stage. Despite the increased sugarbeet injury 7 and 21 DALT due to late season sequential glufosinate applications, extractable sucrose per hectare was similar in early- and late-treated sugarbeet. The absence of a difference in sugarbeet root yield and extractable sucrose, regardless of glufosinate application starting time, suggests that sugarbeet either partially overcame the observed leaf chlorosis or that late-appearing significant visible injury had no adverse effect on sugarbeet yield traits. Sugarbeet recovery from glufosinate injury within two weeks after application was observed by Nitschelm and Regitnig (1997).

Glufosinate applied four times at 0.2 kg ha^{-1} (0.5X) did not injure sugarbeet at 7 DALT when treatments were started at one week rather than three or more weeks after the cotyledon stage (Table 3). Although sugarbeet injury 21 DALT was significantly greater in late season glufosinate treatments compared with early season treatments, these relatively low levels of injury would not be expected to reduce sugarbeet yield. All plots had similar sugarbeet populations, and produced similar root and extractable sucrose yield. Glufosinate at 0.4 and 0.8 kg ha^{-1} applied four times starting at three weeks or later after the sugarbeet cotyledon stage caused greater visible sugarbeet injury 7 and 21 DALT than glufosinate application sequences starting at one week after the cotyledon stage, but sugarbeet populations, root, and extractable sucrose yields were not affected.

Sugarbeet yield loss associated with sequential glufosinate applications starting three weeks or later after the sugarbeet cotyledon stage was observed in previous experiments during 1998 and 1999 (Rothe 2002). Based on the results shown in Table 3, sugarbeet yield loss in the previous research was not due to the greater, visible herbicide-induced sugarbeet injury from late season treatments compared to minimal injury from glufosinate treatments starting at the cotyledon stage or one week later. Competition from uncontrolled weeds prior to the first of the late season sequential glufosinate applications probably caused the yield reduction, illustrating the need to eliminate weeds early in the growing season for maximum sugarbeet yield. Weed competition in this experiment was eliminated through hand weeding until glufosi-

Table 3. Late versus early season glufosinate application starting times, combined over Crookston, MN, and St. Thomas, ND, 2000.

Glufosinate-starting-time treatment comparison[†]			Glufosinate rate	Sugarbeet population	Root yield	Sugarbeet injury 7 DALT[‡]	Sugarbeet injury 21 DALT	Extractable sucrose
			kg ha^{-1}	plants/100 m	t ha^{-1}	%	%	kg ha^{-1}
C+1	vs	C+3 C+4 C+6 C+7	0.2, 0.4, 0.8[§]	NS	NS	(4 vs 16)*	(2 vs 13)*	NS
C+1	vs	C+3 C+4 C+6 C+7	0.2	NS	NS	NS	(2 vs 6) *	NS
C+1	vs	C+3 C+4 C+6 C+7	0.4	NS	NS	(3 vs 14)*	(0 vs 13)*	NS
C+1	vs	C+3 C+4 C+6 C+7	0.8	NS	NS	(4 vs 26)*	(3 vs 21)*	NS

[†]Abbreviations: C = Cotyledon stage of sugarbeet. C+1, 3, 4, 6, or 7 indicate the number of weeks after the sugarbeet cotyledon stage at which the first glufosinate application was made. Glufosinate was applied four times starting at C+1, C+3, and C+4 at approximately one-week intervals and only once at C+6 or C+7.

[‡]Abbreviation: DALT = days after the last treatment.

[§]Each glufosinate-starting-time treatment was averaged over the three glufosinate rates.

NS=Contrast was non-significant at the 0.05 probability level.

*Contrast was significant at the 0.05 probability level.

nate treatments were started while weeds were allowed to grow unhindered until the first herbicide treatment in the 1998 and 1999 experiments (Rothe 2002). This research indicates that glufosinate-resistant sugarbeet recovered from the significant visible injury caused by late season sequential glufosinate applications without a significant effect on sugarbeet yield.

The cumulative effect of sequential multiple glufosinate applications on sugarbeet yield was compared to the effect from single glufosinate treatments. The number of glufosinate applications, averaged over all herbicide rates, influenced sugarbeet population and sugarbeet injury 7 DALT (Table 4). Sugarbeet populations were greater in plots that received four sequential glufosinate applications averaged over starting times, including three and four weeks after the sugarbeet cotyledon stage than in plots that were treated once with glufosinate averaged over starting times, including six and seven weeks after the cotyledon stage. Plots that were sprayed only once as opposed to four sequential glufosinate applications were hand weeded over a longer period of time, with the last hand weeding completed when sugarbeet had approximately 12 or 19 leaves (Table 2), respectively, for multiple and single glufosinate applications. The longer period of hand weeding may have caused greater physical sugarbeet damage and removed more sugarbeet plants.

Sugarbeet population was less in plots receiving a single rather than four glufosinate treatments at 0.4 and 0.8 kg ha^{-1} but plots treated one or four times at 0.2 kg ha^{-1} had similar populations. (Table 4). An early activation of the resistance mechanism by sugarbeet plants in response to multiple early season glufosinate treatments may have made the plants more tolerant to glufosinate while a single late season glufosinate application at increased rates may have overwhelmed the poorly or inadequately activated resistance mechanism within a few sugarbeet plants. Observations of visible injury symptoms indicated that small sugarbeet plants were inherently more tolerant to glufosinate than larger plants. The reason for sugarbeet stand loss in some treatments is not known but the remaining sugarbeet populations were adequate and yield was not affected.

Averaged over glufosinate rates, sugarbeet injury 7 DALT was slightly greater with multiple glufosinate treatments starting at three and four weeks after the sugarbeet cotyledon stage compared with single glufosinate treatments at six and seven weeks after sugarbeet had cotyledons (Table 4). The number of glufosinate applications, averaged over herbicide rates, did not affect sugarbeet root yield nor extractable sucrose yield. Sugarbeet plots that were treated four times and, there-

Table 4. Effect of multiple versus single glufosinate applications on sugarbeet, combined over Crookston, MN, and St. Thomas, ND, 2000.

Glufosinate applications[†]			Glufosinate	Sugarbeet	Root	Sugarbeet injury		Extractable
Four		One	rate	population	yield	7 DALT[‡]	21 DALT	sucrose
			kg ha^{-1}	plants/100 m	t ha^{-1}	--------------- %	---------------	kg ha^{-1}
C+3 C+4	vs	C+6 C+7	0.2, 0.4, 0.8[§]	(395 vs 376)*	NS	(19 vs 13)*	NS	NS
C+3 C+4	vs	C+6 C+7	0.2	(386 vs 390)NS	NS	NS	NS	NS
C+3 C+4	vs	C+6 C+7	0.4	(390 vs 371)*	NS	NS	NS	NS
C+3 C+4	vs	C+6 C+7	0.8	(410 vs 370)*	NS	(Loc x C)#	NS	NS

[†]Abbreviations: C = Cotyledon stage of sugarbeet. C+3, 4, 6, or 7 indicate the number of weeks after the sugarbeet cotyledon stage at which the first glufosinate application was made. Glufosinate was applied four times starting at C+3 and C+4 at approximately one-week intervals and only once at C+6 or C+7.

[‡] Abbreviation: DALT = days after the last treatment.

[§] Each glufosinate-starting-time treatment was averaged over three glufosinate rates.

* Contrast was significant at the 0.05 probability level.

NS=Contrast was non-significant at the 0.05 probability level.

#The location-by-contrast interaction was significant at the 0.05 probability level but was due to magnitude rather than rank in treatment.

fore, received four times the amount of the tested glufosinate rate produced yield similar to sugarbeet treated only once.

Sugarbeet treated with glufosinate at 0.2 and 0.4 kg ha^{-1} had similar injury regardless of the number of applications (Table 4). The contrast effect and its interaction with the location were significant for sugarbeet injury 7 DALT with glufosinate at 0.8 kg ha^{-1} but the significance was due to magnitude. At both locations, sugarbeet injury was greater with multiple glufosinate applications than with single applications (data not shown).

Regardless of the rate, plots treated with glufosinate either one or four times gave similar sugarbeet root yield and extractable sucrose (Table 4). This observation confirms the lack of any significant cumulative phytotoxic effect on sugarbeet yield from multiple glufosinate applications.

For each rate comparison, including all glufosinate treatments at any starting time, the lower of the two glufosinate rates consistently caused less sugarbeet injury 7 and 21 DALT (Table 5). A decline in sugarbeet injury was observed between 7 and 21 DALT for all treatment comparisons, indicating partial recovery from visible herbicide-induced symptoms. Sugarbeet population, root yield, and extractable sucrose were not affected by glufosinate rate, averaged over all glufosinate starting times.

Corresponding pairs of glufosinate-treated and hand-weeded sugarbeet plots, averaged over glufosinate rates, are compared in Table 6. Sugarbeet population, root yield, and extractable sucrose were similar among all plots, regardless of treatment. Glufosinate caused significantly greater sugarbeet injury than hand weeding (Table 6). The significant location-by-contrast interaction for sugarbeet injury 7 DALT was due to magnitude rather than treatment rank based on the observation that hand-weeded sugarbeet in both treatment comparisons were injured less than hand-weeded plus glufosinate-treated sugarbeet at Crookston, MN, and St. Thomas, ND (data not shown). Results in this research indicate that sugarbeet yield was not negatively affected regardless of the number of sequential glufosinate applications and glufosinate rate.

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Table 5. Rate effect of glufosinate on sugarbeet stand, injury, and yield, averaged over glufosinate starting times, and combined over Crookston, MN, and St. Thomas, ND, 2000.

Glufosinate rate treatment comparison†	Sugarbeet population	Root yield	Sugarbeet injury 7 DALT‡	Sugarbeet injury 21 DALT	Extractable sucrose
kg ha^{-1}	plants/100 m	t ha^{-1}	%	%	kg ha^{-1}
0.2 vs 0.4					
C+1 C+3 C+4 C+6 C+7 vs C+1 C+3 C+4 C+6 C+7	NS	NS	(7 vs 12)*	(5 vs 10)*	NS
0.2 vs 0.8					
C+1 C+3 C+4 C+6 C+7 vs C+1 C+3 C+4 C+6 C+7	NS	NS	(7 vs 22)*	(5 vs 17)*	NS
0.4 vs 0.8					
C+1 C+3 C+4 C+6 C+7 vs C+1 C+3 C+4 C+6 C+7	NS	NS	(12 vs 22)*	(10 vs 17)*	NS

†Abbreviations: C = Cotyledon stage of sugarbeet. C+1, 3, 4, 6, or 7 indicate the number of weeks after the sugarbeet cotyledon stage at which the first glufosinate application was made. Glufosinate was applied four times starting at C+1, C+3, and C+4 at approximately one-week intervals and only once at C+6 or C+7.

‡ Abbreviation: DALT = days after the last treatment.

NS=Contrast was non-significant at the 0.05 probability level.

* Contrast was significant at the 0.05 probability level.

Table 6. Effect of hand weeding and hand weeding plus glufosinate on sugarbeet stand, injury, and yield, combined over Crookston, MN, and St. Thomas, ND, 2000.

Treatment[†]			Glufosinate	Sugarbeet	Root	Sugarbeet injury		Extractable
HW+ Glufosinate		Hand weeding	rate[‡]	population	yield	7 DALT[§]	21 DALT	sucrose
			kg ha^{-1}	plants/100 m	t ha^{-1}	--------------- %	---------------	kg ha^{-1}
C+6	vs	C+6	0.2, 0.4, 0.8	NS	NS	Loc x C#	NS	NS
C+3	vs	C+6	0.2, 0.4, 0.8	NS	NS	Loc x C#	NS	NS
C+7	vs	C+7	0.2, 0.4, 0.8	NS	NS	(16 vs 2)*	NS	NS
C+4	vs	C+7	0.2, 0.4, 0.8	NS	NS	(24 vs 2)*	NS	NS

[†] Abbreviations: HW+Glufosinate C+3, C+4, C+6, and C+7 = Plots that were hand weeded at weekly intervals starting at the sugarbeet cotyledon stage until 3, 4, 6, and 7 weeks thereafter, respectively. The last hand weeding was immediately followed by glufosinate applications. Glufosinate was applied four times starting at C+3 and C+4 at approximately one-week intervals and only once at C+6 or C+7; therefore, C+3 and C+4 treatments ended at the same time as C+6 and C+7 treatments, respectively.

[‡] Each glufosinate-starting-time treatment was averaged over three glufosinate rates.

[§] Abbreviation: DALT = days after the last treatment.

NS=Contrast was non-significant at the 0.05 probability level.

The location-by-contrast interaction was significant at the 0.05 probability but was due to magnitude rather than rank in treatments.

* Contrast was significant at the 0.05 probability level.

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