Weed Control in Glyphosate-resistant Sugarbeet (*Beta vulgaris* L.)

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ABSTRACT

A two-year study examined weed control in glyphosate-resistant sugarbeet with various glyphosate rates and application timings, and glyphosate in combination with residual herbicides or ammonium sulfate (AMS). Treatments that included two or three applications of glyphosate regardless of rate or glyphosate applied once in combination with dimethenamid-p resulted in redroot pigweed, common lambsquarters and hairy nightshade control equal to, or greater than, a standard herbicide program. The addition of AMS to glyphosate did not affect weed control efficacy. A single application of glyphosate did not provide season long weed control in 1998, but was effective in controlling all weeds but redroot pigweed in 1999. Generally, sugarbeet root yield was similar in plots treated with glyphosate or standard herbicide programs.

Additional Key Words: Desmedipham, ethofumesate, phenmedipham, dimethenamid-p, sethoxydim, triflusulfuron, redroot pigweed, common lambsquarters, barnyardgrass, hairy nightshade.

Weed control in sugarbeet (*Beta vulgaris* L.) is difficult and expensive requiring repeated applications of four to five herbicides during the growing season to control weeds in current production systems. Sugarbeet is sensitive to many herbicides, so herbicides that control a wide range of weeds often are not registered for sugarbeet production. Lower cost herbicides that control a wider range of weeds would benefit sugarbeet producers.

Glyphosate is a non-selective, postemergence, systemic herbicide that has activity on a wide range of broadleaf and grass species

(Franz et al. 1997; Krausz et al. 1996; Steckel and DeFelice 1995). In greenhouse studies, barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), common ragweed (*Ambrosia artemisiifolia* L.), fall panicum (*Panicum dichotomiflorum* Michx.), giant foxtail (*Setaria faberi* Herrm.), and large crabgrass (*Digitaria sanguinalis* (L.) Scop.) biomass was reduced by 50% at rates of glyphosate ranging from 0.064 to 0.12 kg ae/ha (Tharp et al. 1999). Glyphosate applied in field trials, at rates as low as 0.56 kg ae/ha, controlled annual weeds such as giant foxtail, fall panicum, redroot pigweed (*Amaranthus retroflexus* L.), and velvetleaf (*Abutilon theophrasti* Medic.) (Krausz et al. 1996). Common lambsquarters (*Chenopodium album* L.), giant foxtail, and velvetleaf control was greater than 90% with glyphosate at rates as low as 0.21 kg ae/ha (Ateh and Harvey 1999). Although glyphosate has activity on a wide range of annual and perennial weeds, some weeds are more difficult to control with glyphosate than others (Jordan et al. 1997; Yonce and Skroch 1989). Glyphosate does not have soil activity and soil residual herbicides combined with glyphosate have increased weed control in glyphosate-resistant corn (Tharp and Kells 2002) and glyphosate-resistant soybean (Scott et al. 1998; Vangessel et al. 2001).

Glyphosate-resistant crop species have been produced by the insertion of herbicide resistance genes (Shah et al. 1986; Kishore et al. 1992). Crops with resistance to glyphosate that are grown commercially in the United States include corn (*Zea mays* L.), soybean (*Glycine max* (L.) Merrill), cotton (*Gossypium* spp.), and canola (*Brassica napus* L.) (Ritter and Menbere 1998; Culpepper and York 1999; Harker et al. 2000). In addition, glyphosate-resistant sugarbeet has been developed but has not been used in commercial production (Dexter and Luecke 1997; Gasser 1989; Kishore et al. 1992).

Weed control in glyphosate-resistant sugarbeet has been examined in different regions of the United States. Glyphosate at 0.84 kg ae/ha, applied two or three times, resulted in 95 to 100% control of redroot pigweed, green foxtail (*Setaria viridis* (L.) Beauv.), wild oat (*Avena fatua* L.), wild mustard (*Brassica kaber* (D.C.) L.C. Wheeler), prostrate pigweed (*Amaranthus blitoides* S. Wats.), kochia (*Kochia scoparia* (L.) Schrad.), common lambsquarters, hairy nightshade (*Solanum sarrachoides* L.), and annual sowthistle (*Sonchus oleraceus* L.) (Dexter and Luecke 1997; Wilson 1988; Mesbah and Miller 1999; Morishita et al. 1999). A single postemergence application of glyphosate at rates of 0.70 to 0.84 kg ae/ha did not provide season-long weed control in glyphosate-resistant sugarbeet (Morishita et al. 1999; Norris and Roncoroni 1999). Averaged over different weed stages at the initial application, weed control and sugarbeet yield was greater with two glyphosate applications compared to a single application, but was not increased by a third glyphosate application. When averaged over the number of applications, glyphosate was most effective applied initially to 10 cm weeds compared to applications to 3 cm or 25 cm weeds (Wilson et al. 2002).

The objective of this research was to determine the effect of glyphosate rates and application timings, and the effectiveness of glyphosate combined with residual herbicides or AMS for weed control in glyphosate-resistant sugarbeet grown under furrow irrigation in Eastern Oregon.

MATERIALS AND METHODS

Field experiments were conducted at the Malheur Experiment Station near Ontario, OR. Experiments were located in different fields each year. Fields were prepared in the fall by moldboard plowing and hilling the soil. The tops of the hills were leveled in the spring to provide a uniform seed bed for planting. The soil was a silt loam with 2.4 % organic matter content and pH 7.0 in 1998, and a silt loam with 1.4 % organic matter content and pH 7.9 in 1999. The glyphosate-resistant sugarbeet variety 'HM Pillar RR' was planted April 22, 1998 and April 12, 1999. Sugarbeet was planted in 56 cm rows with a seed spacing of 5 cm within the row. Terbufos (S-[[(1,1-dimethylethyl)thio]methyl] O,O-diethyl phosphorodithioate) was applied for insect control in both years at 112 mg ai/m of row one day after planting. Plots were 2.2 m wide by 7.3 m long and were arranged in a randomized complete block design with three replicates. Sugarbeet was furrow irrigated. In both years trials were irrigated the day after planting to ensure sugarbeet germination. In 1998 the second irrigation was on June 9. In 1999, because of dry conditions, the second irrigation was one week after the first to ensure uniform sugarbeet germination. Trials were irrigated at 7- to 10-day intervals from June through the first week of September in both years. The trial in 1999 was irrigated on May 13 and 27, whereas the 1998 trial was not irrigated in May due to above average rainfall. Cultivation was used to control weeds and maintain irrigation furrows. Cultivations were made on June 9, June 23, and July 1, 1998 and May 10, May 26, June 16, and July 1, 1999. After sugarbeet reached the four- to six-leaf stage, the sugarbeet stand was thinned to a 20 cm spacing between plants. Sugarbeet was sidedressed with 235 kg N/ha in the form of urea June 5, 1998, and June 15, 1999. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L/ha at 207 kPa.

Sugarbeet injury was evaluated visually 14 and 28 days after the final herbicide application. Weed control was evaluated visually 28 days after the final herbicide application and one month before harvest.

Glyphosate treatments were compared to an untreated control and a standard herbicide program. The standard herbicide program consisted of ethofumesate applied preplant incorporated, followed by a premixture of ethofumesate, desmedipham, and phenmedipham (1:1:1 ratio) applied to cotyledon stage sugarbeet, followed by this premixture tank-mixed with triflusulfuron applied to 2- to 4-leaf sugarbeet, followed by this premixture tank-mixed with triflusulfuron and sethoxydim applied to 8- to 12-leaf sugarbeet. Treatments and herbicide rates are presented in Table 1. Preplant incorporated ethofumesate was applied April 3,

Table 1. Herbicide treatments for the glyphosate rates, timings, and combinations study, 1998 and 1999.

Treatment†	Rate‡	Timing
	kg ae/ha	leaf§
Glyphosate + AMS	0.41 + 2.8	cot + 2-4 + 8-12
Glyphosate	0.41	cot + 2-4 + 8-12
Glyphosate	0.63	cot + 2-4 + 8-12
Glyphosate	0.84	cot + 2-4 + 8-12
Glyphosate fb	0.84	cot + 2-4
Glyphosate + ethofumesate	0.84 + 1.12	8-12
Glyphosate	0.84	2-4
Glyphosate + ethofumesate	0.84 + 1.12	2-4
Glyphosate + dimethenamid-p	0.84 + 0.72	2-4
Ethofumesate fb	1.12	PPI
Glyphosate	0.84	2-4 + 8-12
Ethofumesate fb	1.12	PPI
Glyphosate	0.41	2-4 + 8-12
Ethofumesate fb	1.12	PPI
Glyphosate + AMS	0.41 + 2.8	2-4 + 8-12
Standard herbicide program		
Ethofumesate fb	1.12	PPI
EDP fb	0.28	cot
EDP+triflusulfuron fb	0.37 + 0.0175	2-4
EDP+triflusulfuron+sethoxydim	0.37 + 0.0175 + 0.34	8-12

† Abbreviations: AMS, ammonium sulfate; EDP, commercial premix of ethofumesate desmedipham + phenmedipham; fb, followed by.

‡ All treatments except glyphosate are in kg ai/ha.

§ Sugarbeet leaf stage at time of application. Abbreviations: PPI, preplant incorporated; cot, cotyledon; 2-4, two to four leaf; 8-12, 8 to 12 leaf. PPI, cotyledon, 2-4 leaf, and 8-12 leaf applications were made April 3, May 3, May 23, and June 15, 1998 and April 7, May 1, May 18, and May 26, 1999.

1998, and April 7, 1999. Postemergence applications to cotyledon, 2- to 4-leaf, and 8- to 12-leaf sugarbeet were made on May 3, May 23, and June 15, 1998 and May 1, May 18, and May 26, 1999. Weed and sugarbeet height and weed density at the cotyledon and 2- to 4-leaf applications are presented in Table 2.

Sugarbeet was defoliated mechanically and harvested using a mechanical, single-row harvester October 15, 1998, and October 6 and 7, 1999. The center two rows of each plot were lifted and weighed for sugarbeet root yield. Yields were adjusted to allow for a 5% tare. Sixteen sugarbeet roots from each plot were randomly sampled to determine sucrose content and purity. Percent sucrose extraction was estimated using empirical equations (Carruthers et al. 1962). Parameters evaluated were sugarbeet root yield, sucrose content, gross sucrose production, percent sucrose extraction, kilograms of estimated recoverable sucrose per hectare, and grams of estimated recoverable sucrose per gram of sugarbeet. Data were analyzed using analysis of variance and means were separated using Fisher's protected LSD (P=0.05).

RESULTS AND DISCUSSION

Weed control ratings in 1998 were taken after the sugarbeet plants were defoliated by hail on July 4, 1998. The hailstorm removed some of the sugarbeet and weed leaves. The sugarbeet canopy reformed approximately two to four weeks after the hailstorm. Weed control comparisons were still valid since the hail damage was uniform across the trial.

For all weed species, control with glyphosate was greater than or equal to control with the standard herbicide program 28 days after the final herbicide application (Table 3). Increasing the rate of glyphosate from 0.41 to 0.84 kg/ha improved pigweed control at the September evaluation, but control of all other species was not affected by glyphosate rate. The addition of AMS did not affect glyphosate efficacy. Pigweed and barnyardgrass control with a single application of glyphosate to 2- to 4-leaf sugarbeet was less than provided by the standard and other glyphosate treatments in September 1998. Hairy nightshade control with a single application to 2- to 4-leaf sugarbeet was also less than all other treatments ($P<0.1$). Since glyphosate has no soil residual activity, less redroot pigweed, hairy nightshade, and barnyardgrass control observed with glyphosate applied a single time to 2- to 4-leaf sugarbeet was due to weeds that germinated after the glyphosate application, or weeds that were covered by sugarbeet leaves when the glyphosate was applied. The addition of ethofumesate or dimethenamid-p to the single glyphosate

Table 2. Sugarbeet heights and weed heights and densities at initial herbicide application.

	Crop and weed height and density at initial herbicide applications†									
	Cotyledon					2- to 4-leaf				
Year	BEAVA	AMARE	CHEAL	SOLSA	ECHCG	BEAVA	AMARE	CHEAL	SOLSA	ECHCG
	plant height (cm)									
1998	1.9	0.6	1.3	0.6	0.6	6.4	3.8	5.0	3.8	5.0
1999	0.6	0.6	1.3	0.6	0.6	3.8	1.3	3.8	2.5	2.5
	plant density (no/m^2)									
1998	-	31	19	138	0	-	19	16	195	8
1999	-	8	13	27	5	-	14	20	49	5

†Crop and weed codes are as follows: BEAVA, sugarbeet; AMARE, redroot pigweed; CHEAL, common lambsquarters; SOLSA, hairy nightshade; ECHCG, barnyardgrass

Table 3. Weed control in response to glyphosate rates, timings, and combinations with residual herbicides, 1998.

			Weed control							
			Redroot pigweed		Common lambsquarters		Hairy nightshade		Barnyardgrass	
Treatment[†]	Rate[‡]	Timing[§]	28 DAT	Sept.	28 DAT	Sept.	28 DAT	Sept.[¶]	28 DAT	Sept.
	kg ae/ha	Leaf	%							
Glyphosate + AMS	0.41 + 2.8	cot + 2-4 + 8-12	98	92	98	97	98	92	96	85
Glyphosate	0.41	cot + 2-4 + 8-12	98	83	97	97	98	98	94	87
Glyphosate	0.63	cot + 2-4 + 8-12	98	95	98	98	98	98	97	92
Glyphosate	0.84	cot + 2-4 + 8-12	98	98	98	98	98	98	98	97
Glyphosate fb	0.84	cot + 2-4	98	96	98	97	98	94	98	97
Glyphosate + etho	0.84 + 1.12	8-12								
Glyphosate	0.84	2-4	93	68	98	98	94	63	93	68
Glyphosate + etho	0.84 + 1.12	2-4	98	91	98	98	98	98	97	90
Glyphosate + dimeth	0.84 + 0.72	2-4	98	90	97	98	95	94	98	98
Ethofumesate fb	1.12	PPI	98	97	98	98	98	95	98	98
Glyphosate	0.84	2-4 + 8-12								
Ethofumesate fb	1.12	PPI	98	95	98	98	97	98	98	94
Glyphosate	0.41	2-4 + 8-12								
Ethofumesate fb	1.12	PPI	98	97	98	98	98	95	97	95
Glyphosate + AMS	0.41 + 2.8	2-4 + 8-12								
Ethofumesate fb	1.12	PPI	97	89	98	98	80	93	75	85
EDP fb	0.28	cot								
EDP + trif fb	0.37 + 0.0175	2-4								
EDP + trif + seth	0.37 + 0.0175 + 0.34	8-12								
Untreated			-	-	-	-	-	-	-	-
LSD(0.05)			NS	12	NS	NS	5	17	NS	11

[†] Abbreviations: AMS, ammonium sulfate; etho, ethofumesate; EDP, commercial premix of ethofumesate + desmedipham + phenmedipham; trif, triflusulfuron; seth, sethoxydim; fb,followed by.

[‡] All treatments except glyphosate are in kg ai/ha.

[§] Sugarbeet leaf stage at time of application. Abbreviations: PPI, preplant incorporated; cot, cotyledon; 2-4, two to four leaf; 8-12, 8 to 12 leaf.

[¶] LSD (P = 0.10) for this column only.

application provided increased control of all three species. Scott et al. (1998) demonstrated that the residual activity of dimethenamid applied with glyphosate in glyphosate-tolerant soybeans increased barnyardgrass control 17 to 35% 8 weeks after treatment. In 1999, all treatments provided similar weed control at 28 DAT and in September; except for a single application of glyphosate combined with ethofumesate, which gave less common lambsquarters control compared to other treatments at the September evaluation (Table 4). Although not different among treatments in September, pigweed control with a single application of glyphosate alone or in combination with ethofumesate began to decline earlier in the season compared to other treatments. On July 12, 1999, redroot pigweed control with these treatments was less than all other treatments except a single application of glyphosate combined with dimethenamid-p (data not shown).

In both years, weed control equal to or greater than the standard herbicide program was obtained with a single application of glyphosate applied in combination with dimethenamid-p, or with two or three applications of glyphosate. A single application of glyphosate alone did not control redroot pigweed, hairy nightshade or barnyardgrass in 1998, but controlled all weeds except redroot pigweed in 1999. The lower control of hairy nightshade and barnyardgrass with a single glyphosate application in 1998 compared to 1999 could have resulted from weeds that were able to grow above the canopy following the hailstorm in 1998 or from higher weed pressures in 1998. The addition of ethofumesate to glyphosate applied to 8- to 12-leaf sugarbeet as the last of three sequential glyphosate applications did not increase weed control compared to three sequential applications of glyphosate alone, suggesting that weeds did not emerge after the 8- to 12-leaf sugarbeet growth stage.

No significant sugarbeet injury was observed with any herbicide treatment in 1998 (Table 5). In 1999, postemergence treatments containing ethofumesate resulted in 12 to 25% sugarbeet injury 14 days after the herbicide application (Table 6), while no significant injury was observed with any treatment 28 days after application (data not shown). All plots treated with herbicides had increased sugarbeet root yields, gross sucrose production, and estimated recoverable sucrose per hectare compared to the untreated control. However, no differences in sucrose content, extractable sucrose, or estimated recoverable sucrose per kilogram of sugarbeet were detected between the herbicide treatments and the untreated control. Sugarbeet root yield, gross sucrose production, and estimated recoverable sucrose per hectare were similar between the glyphosate treatments and the standard treatment. In 1998, sugarbeet root yield, gross sucrose, and estimated recoverable sucrose production

Table 4. Weed control in response to glyphosate rates, timings, and combinations with residual herbicides, 1999.

Treatment†	Rate‡	Timing§	Weed control							
			Redroot pigweed		Common lambsquarters		Hairy nightshade		Barnyardgrass	
			28 DAT	Sept.	28 DAT	Sept.	28 DAT	Sept.	28 DAT	Sept.
	kg ae/ha	Leaf	%							
Glyphosate + AMS	0.41 + 2.8	cot + 2-4 + 8-12	100	90	100	100	100	100	100	95
Glyphosate	0.41	cot + 2-4 + 8-12	100	92	100	100	100	100	100	95
Glyphosate	0.63	cot + 2-4 + 8-12	100	88	100	100	100	100	100	98
Glyphosate	0.84	cot + 2-4 + 8-12	99	89	100	98	99	100	100	97
Glyphosate fb Glyphosate + etho	0.84 0.84 + 1.12	cot + 2-4 8-12	100	89	100	97	100	98	100	97
Glyphosate	0.84	2-4	94	78	100	100	99	92	100	98
Glyphosate + etho	0.84 + 1.12	2-4	97	82	100	93	97	100	100	95
Glyphosate + dimeth	0.84 + 0.72	2-4	99	89	100	97	100	97	100	96
Ethofumesate fb Glyphosate	1.12 0.84	PPI 2-4 + 8-12	100	90	100	97	100	97	100	100
Ethofumesate fb Glyphosate	1.12 0.41	PPI 2-4 + 8-12	100	91	100	100	99	97	100	93
Ethofumesate fb Glyphosate + AMS	1.12 0.41 + 2.8	PPI 2-4 + 8-12	100	87	100	100	100	97	100	98
Ethofumesate fb EDP fb EDP + trif fb EDP + trif + seth	1.12 0.28 0.37 + 0.0175 0.37 + 0.0175 + 0.34	PPI cot 2-4 8-12	100	95	98	100	98	100	99	93
Untreated			-	-	-	-	-	-	-	-
LSD(0.05)			NS	NS	NS	4	NS	NS	NS	NS

† Abbreviations: AMS, ammonium sulfate; etho, ethofumesate; EDP, commercial premix of ethofumesate + desmedipham + phenmedipham; trif, triflusulfuron; seth, sethoxydim; fb,followed by.

‡ All treatments except glyphosate are in kg ai/ha.

§ Sugarbeet leaf stage at time of application. Abbreviations: PPI, preplant incorporated; cot, cotyledon; 2-4, two to four leaf; 8-12, 8 to 12 leaf.

Table 5. Sugarbeet injury and yield with glyphosate rates, timings, and combinations with residual herbicides, 1998.

			Injury[¶]	Sugarbeet					
Treatment[†]	Rate[‡]	Timing[§]	14 DAT	Root yield	Sucrose content	Gross sucrose	Extraction	Estimated recoverable sucrose	
	kg ae/ha	Leaf	%	kg/ha	%	kg/ha	%	kg/ha	g/kg
Glyphosate + AMS	0.41 + 2.8	cot + 2-4 + 8-12	0	84,246	16.02	13,499	90.33	12,198	145
Glyphosate	0.41	cot + 2-4 + 8-12	0	78,736	16.27	12,812	90.04	11,539	147
Glyphosate	0.63	cot + 2-4 + 8-12	0	83,305	15.98	13,304	90.63	12,059	145
Glyphosate	0.84	cot + 2-4 + 8-12	0	83,507	16.02	13,375	90.32	12,083	145
Glyphosate fb	0.84	cot + 2-4	0	86,262	16.08	13,868	90.54	12,559	146
Glyphosate + etho	0.84 + 1.12	8-12							
Glyphosate	0.84	2-4	3	75,062	15.93	11,946	90.24	10,780	144
Glyphosate + etho	0.84 + 1.12	2-4	0	78,915	16.16	12,757	89.98	11,481	145
Glyphosate + dimethenamid-p	0.84 + 0.72	2-4	0	82,409	16.05	13,223	90.56	11,975	145
Ethofumesate fb	1.12	PPI	0	83,148	16.63	13,822	91.08	12,591	151
Glyphosate	0.84	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	0	82,588	16.24	13,405	90.27	12,103	147
Glyphosate	0.41	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	0	83,865	16.16	13,552	90.53	12,267	146
Glyphosate + AMS	0.41 + 2.8	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	5	77,817	15.78	12,265	90.12	11,054	142
EDP fb	0.28	cot							
EDP + trif fb	0.37 + 0.0175	2-4							
EDP + trif + seth	0.37 + 0.0175 + 0.34	8-12							
Untreated			0	26,051	15.90	4,132	90.81	3,745	144
LSD(0.05)			NS	5,868	0.67	1,029	NS	979	NS

[†] Abbreviations: AMS, ammonium sulfate; etho, ethofumesate; EDP, commercial premix of ethofumesate + desmedipham + phenmedipham; trif, triflusulfuron; seth, sethoxydim; fb,followed by.

[‡] All treatments except glyphosate are in kg ai/ha.

[§] Sugarbeet leaf stage at time of application. Abbreviations: PPI, preplant incorporated; cot, cotyledon; 2-4, two to four leaf; 8-12, 8 to 12 leaf.

[¶] Abbreviation: DAT, days after the final herbicide application.

Table 6. Sugarbeet injury and yield with glyphosate rates, timings, and combinations with residual herbicides, 1999.

			Injury[¶]	Sugarbeet					
Treatment[†]	Rate[‡]	Timing[§]	14 DAT	Root yield	Sucrose content	Gross sucrose	Extraction	Estimated recoverable sucrose	
	kg ae/ha	Leaf	%	kg/ha	%	kg/ha	%	kg/ha	g/kg
Glyphosate + AMS	0.41 + 2.8	cot + 2-4 + 8-12	0	88,928	17.79	15,813	92.85	14,682	165
Glyphosate	0.41	cot + 2-4 + 8-12	0	83,305	17.91	14,911	92.72	13,825	166
Glyphosate	0.63	cot + 2-4 + 8-12	0	84,358	17.67	14,887	92.93	13,833	164
Glyphosate	0.84	cot + 2-4 + 8-12	0	82,096	18.04	14,794	93.08	13,770	168
Glyphosate fb	0.84	Cot + 2-4	25	84,358	17.66	14,895	92.90	13,836	164
Glyphosate + etho	0.84 + 1.12	8-12							
Glyphosate	0.84	2-4	0	81,558	17.95	14,626	92.91	13,587	167
Glyphosate + etho	0.84 + 1.12	2-4	12	78,579	17.87	14,040	93.04	13,064	166
Glyphosate + dimethenamid-p	0.84 + 0.72	2-4	3	85,769	17.92	15,357	92.93	14,271	166
Ethofumesate fb	1.12	PPI	0	87,180	17.73	15,458	93.00	14,380	165
Glyphosate	0.84	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	0	85,411	17.85	15,242	92.99	14,172	166
Glyphosate	0.41	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	0	82,790	17.85	15,555	93.16	14,474	164
Glyphosate + AMS	0.41 + 2.8	2-4 + 8-12							
Ethofumesate fb	1.12	PPI	13	85,411	17.54	14,982	92.97	13,929	163
EDP fb	0.28	cot							
EDP + trif fb	0.37 + 0.0175	2-4							
EDP + trif + seth	0.37 + 0.0175 + 0.34	8-12							
Untreated			0	18,614	18.22	3,432	93.47	3,186	170
LSD(0.05)			3	8,728	NS	1,304	0.69	1,006	NS

[†] Abbreviations: AMS, ammonium sulfate; etho, ethofumesate; EDP, commercial premix of ethofumesate + desmedipham + phenmedipham; trif, triflusulfuron; seth, sethoxydim; fb,followed by.

[‡] All treatments except glyphosate are in kg ai/ha.

[§] Sugarbeet leaf stage at time of application. Abbreviations: PPI, preplant incorporated; cot, cotyledon; 2-4, two to four leaf; 8-12, 8 to 12 leaf.

[¶] Abbreviation: DAT, days after the final herbicide application.

per hectare were among the lowest when glyphosate was applied once to 2- to 4-leaf sugarbeet compared to other glyphosate treatments. Sugarbeet yields were similar from plots with a single application of glyphosate or multiple applications of glyphosate without AMS in 1999. This differs from the results of Wilson et al. (2002) that demonstrated when averaged over several stages of weed growth at application, a single application of glyphosate, was unable to prevent sugarbeet yield loss. In 1999, sugarbeet root yield was lower in plots treated with a single application of glyphosate in combination with ethofumesate compared to three applications of glyphosate combined with AMS, but was similar to all other treatments. This yield difference could be related to early season sugarbeet injury or to reduced weed control from the glyphosate plus ethofumesate combination. Glyphosate plus ethofumesate also had lower estimated recoverable sucrose compared to glyphosate applied in combination with AMS or following PPI ethofumesate. Glyphosate applied alone had reduced estimated recoverable sucrose compared to glyphosate plus AMS applied three times. Despite reduced weed control in 1998 and the early decline of redroot pigweed control in 1999, the single glyphosate application produced yields equal to the standard treatment in both years. This is not surprising since the single application of glyphosate in 1998 and 1999 provided greater than 90% control of all weeds for approximately 10 and 12 weeks after planting. Research has shown that maintaining sugarbeet weed free for 8 to 12 weeks after planting prevented yield loss (Dawson 1965; Wicks and Wilson 1983).

Glyphosate-resistant sugarbeet is a tool that will help sugarbeet growers produce sugar efficiently. Comparable weed control and sugar yields were achieved with a single application of glyphosate in combination with dimethenamid-p and the standard program. The single glyphosate combination with dimethenamid-p eliminated three herbicide applications compared to the standard program. Reducing the number of trips through the field not only reduces application costs, but also provides significant timesavings compared to conventional weed control programs. Reduced traffic in the field may also reduce soil compaction. Weed control programs in glyphosate-resistant sugarbeet allow flexibility in application timing and offers potential savings in herbicide costs (Wilson et al. 2002). Using glyphosate may simplify weed control in sugarbeet production systems since many growers are familiar with using glyphosate for weed control in other cropping systems.

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