Weed Control and Glyphosate-tolerant Sugarbeet Response to Herbicide Treatments

Abdel O. Mesbah[1] and Stephen D. Miller[2]

[1]*University of Wyoming Powell Research and Extension Center*
747 Road 9, Powell, WY 82435
[2]*University of Wyoming Plant Science Department*
P.O. Box 3354, Laramie, WY 82071

ABSTRACT

Field experiments were conducted in 1998 and 1999 at two Wyoming locations, Powell and Torrington Research and Extension Centers, to evaluate weed control efficacy and glyphosate-tolerant sugarbeet response to glyphosate alone and in combination with residual herbicides. Weed control with a single glyphosate application was inadequate for all species except wild mustard. Two sequential applications starting at 2-, 4-, and 6-leaf sugarbeet with a two week interval between applications provided more than 90% weed control. Similar weed control was provided with three applications starting at 2- or 4-leaf sugarbeet with one or two week intervals between applications, respectively. Residual herbicides followed by one or two applications of glyphosate starting at 4-leaf sugarbeet provided excellent weed control. No sugarbeet injury was recorded with glyphosate alone. However, sugarbeet injury with treatments containing residual herbicides ranged from 0 to 10%. With glyphosate alone, sugarbeet root yield increased as the number and frequency of applications increased. Highest yields were obtained with two or three applications of glyphosate starting at 2- or 4-leaf sugarbeet. Similar yields were obtained with residual herbicides in combination with one or two applications of glyphosate starting at 4-leaf sugarbeet. None of the treatments, including the weedy check, affected sucrose content. Sucrose yield differed among treatments and corresponded to sugarbeet root yield.

Additional Key Words: Ethofumesate, desmedipham, phenmedipham,

s-metholachlor, cycloate, redroot pigweed, wild mustard, wild buckwheat, hairy nightshade, common lambsquarters, kochia, green foxtail.

Weed management is an important aspect of sugarbeet production. Uncontrolled weeds in sugarbeet dramatically reduce yield (Schweizer 1981; Schweizer and Bridge 1982; Mesbah et al. 1994). Current herbicides labeled for use in sugarbeet are limited by their crop safety, weed spectrum, time of application, and weed size. As a result, sugarbeet growers rely upon preplant and postemergence herbicides plus two to three cultivations and hand weeding to control weeds in sugarbeet fields. The development of genetically modified sugarbeet that is herbicide tolerant has the potential to provide growers with a tool to produce sugarbeet without hand labor and with less or no cultivation.

Glyphosate is a non-selective, foliar applied herbicide that has activity on a wide range of broadleaf and grass species (Mousdale and Coggins 1991; Franz et al. 1997). Glyphosate inhibits the growth of treated plants by interfering with aromatic amino acid biosynthesis through inhibition of 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase (Shah et al. 1986). The inhibition of EPSP leads to depletion of tryptophan, tyrosine, and phenylalanine amino acids necessary for protein synthesis (WSSA 2002). Glyphosate has been widely used for vegetation management in noncrop environments for several years (Lanie et al. 1994; Malik et al. 1989; Wilson et al. 1985).

Glyphosate tolerance is achieved by transferring a gene or genes from unrelated organisms into traditional crop plants (Kishore et al. 1992; Wilcut et al. 1996). This technology has been used in many crops such as soybean [*Glycine max* (L.) Merr.] (Delannay et al. 1995), corn (*Zea mays* L.) (Johnson et al. 1998), cotton (*Gossypium hirsutum* L.) (Keeling et al. 1996), and sugarbeet (*Beta vulgaris* L.) (Madsen 1993). The development of these crops opened the window for new weed management strategies that are economically and environmentally friendly (Burnside 1992; Culpepper and York 1997; Wyse 1992).

Researchers have investigated weed control and glyphosate-tolerant sugarbeet response to glyphosate in many regions of the United States (Dexter and Luecke 1997; Wilson 1998; Guza et al. 2002; Morishita et al. 1999; Norris and Roncoroni 1999; Wilson et al. 2002). A general review of these studies showed that weed control and sugarbeet yields with two glyphosate applications, starting at 2-leaf sugarbeet with a two week interval between applications, were greater than with single application and similar to three applications. The same result was achieved with residual herbicides followed by one glyphosate application. Compared to the current standard program, weed control and sugarbeet yield were similar or greater with multiple applications of glyphosate.

The objectives of this study were to a) evaluate weed control and glyphosate-tolerant sugarbeet response to multiple applications of glyphosate alone at different timings, b) evaluate the effectiveness of glyphosate combined with residual herbicides, and c) compare glyphosate treatments to the standard weed control program under furrow and sprinkler irrigation.

MATERIALS AND METHODS

Field experiments were conducted in 1998 and 1999 at two locations to evaluate weed control and glyphosate-tolerant sugarbeet response to glyphosate. At each location, experiments were located in different fields each year.

At the Powell Research and Extension Center (PREC) in northwestern Wyoming, the soil type was a Garland clay loam (fine, mixed, mesic typic Haplargid, 40% sand, 24% silt and 36% clay) with 1.2% organic matter and pH 7.2. Sugarbeet seeds were planted to stand in rows spaced 56-cm apart on May 5, 1998 and April 26, 1999. Glyphosate-tolerant sugarbeet cultivars were Empire RR in 1998 and HM Pillar RR in 1999. The experiment was established under furrow irrigation and experimental units consisted of six sugarbeet rows, each 10-m long. Prevalent weed species at this site were redroot pigweed (*Amaranthus retroflexus* L.), wild mustard (*Sinapis arvensis* L.), kochia [*Kochia scoparia* (L.) Schrad.], wild buckwheat (*Polygonum convolvulus* L.), and green foxtail [*Setaria viridis* (L.) Beauv.]. Weed infestations were uniform throughout the experimental site and varied from light (2 to 4 plants/m of row) to heavy (7 to 10 plants/m of row), depending on the species.

At the Torrington Research and Extension Center (TREC) in southeastern Wyoming, the soil type was a sandy loam (mixed, mesic, Ustic, Torripasmment-Valentine series, 78% sand, 13% silt and 9% clay) with 1.4% organic matter and pH 7.6. Sugarbeet seeds were planted to stand in rows spaced 76-cm apart on May 14, 1998 and April 19, 1999. Glyphosate-tolerant sugarbeet cultivars were Empire RR in 1998 and HM 1605 RR in 1999. The experiment at this location was established under sprinkler irrigation and experimental units were four sugarbeet rows, each 10-m long. Prevalent weed species at this site were common lambsquaters (*Chenopodium album* L.), hairy nightshade (*Solanum sarrachoides* L.), redroot pigweed, kochia, and green foxtail. Weed infestations were uniform throughout the experimental site and varied from light to heavy, depending on the species.

At both locations, a randomized complete block design with three replications was used. Preplant incorporated herbicides consisted of ethofumesate, s-metolachlor, and cycloate applied in an 18-cm band during the planting operation and incorporated with a power take-off (PTO) driven rotary incorporator operating at 3 to 4 cm deep. Postemergence treatments consisted of multiple applications at various timings of glyphosate alone or in combination with s-metolachlor, triflusulfuron, or triflusulfuron plus ammonium sulfate (AMS) at 2.5 kg/ha applied with a CO^2 pressurized knapsack sprayer delivering 180 L/ha at 276 kPa. Glyphosate treatments consisted of one, two, or three applications starting at 2-, 4-, or 6-leaf sugarbeet with one or two week intervals between applications. Glyphosate treatments were compared to an untreated check, hand-weeded check, and a standard treatment. The standard treatment consisted of desmedipham-phenmedipham plus triflusulfuron applied three times starting at 2-leaf sugarbeet with one week interval between applications. Herbicide treatments, rates, and time of application are presented in Table 1.

Sugarbeet injury was evaluated visually 21 days after the last application by comparing each herbicide treatment to the hand-weeded check and using a rating scale of 0 (no injury) to 100 (dead). Weed control was determined by counting weed seedlings in a 3-m by 8-cm band from each of the two middle rows. Based on the number of weeds in the weedy check, weed counts from each treatment were converted to percent control. Sugarbeet plants were topped and harvested by hand from the two center rows by mid October. Sugarbeet weight and sugar content were determined by the Western Sugar Laboratory, Billings, MT and Holly Sugar Laboratory, Torrington, WY.

Data were analyzed using analysis of variance and means were separated by Fisher's Protected Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Weed Control

There was no significant year by treatment interaction for weed control or sugarbeet yield at either site. Therefore, the data were combined over years for each location. Weed density following herbicide treatments was lower in treated plots than in weedy checks (Table 2, 3). At both locations, weed control with glyphosate only ranged from 72 to 100% depending on the weed species and number of applications. The single application of glyphosate applied at 4-leaf sugarbeet provided less weed

Table 1. Herbicide treatments, rates, and application timing at Powell and Torrington Research and Extension Centers, 1998-1999.

Treatment[1]	Rate	Timing[2] Powell	Torrington
	kg ai/ha	Leaf no.	Leaf no.
Glyphosate	0.84	4	4
Glyphosate	0.84	2/6	2/6
Glyphosate	0.84	4/8	4/8
Glyphosate	0.84	6/10	6/10
Glyphosate	0.84	2/4/6	2/4/6
Glyphosate	0.84	4/8/12	4/8/12
Ethofumesate/glyphosate	1.13/0.84	PPI/4	PPI/4
Ethofumesate/glyphosate/glyphosate	1.13/0.84/0.84	PPI/4/8	PPI/4/8
Ethofumesate/glyphosate	1.70/0.84	--	PPI/4
Ethofumesate/glyphosate/glyphosate	1.70/0.84/0.84	--	PPI/4/8
S-metolachlor/glyphosate	1.40/0.84	PPI/4	PPI/4
Cycloate/glyphosate	1.13/0.84	PPI/4	--
Cycloate/glyphosate/glyphosate	1.13/0.84/0.84	PPI/4/8	--
Glyphosate/s-metolachlor+glyphosate	0.84/1.4+0.84	2/10	--
S-metolachlor+glyphosate/glyphosate	1.40+0.84/0.84	2/10	--
Glyphosate+triflusulfuron	0.84+0.018	--	2/6
Glyphosate+triflusulfuron+AMS	0.84+0.018	--	2/6
Desm-phen+Triflusulfuron	0.37+0.018	2/4/6	2/4/6

[1] Desm-phen = commercial premix of desmedipham+ phenmedipham; AMS = ammonium sulfate at 2.5 kg/ha.
[2] 2, 4, 6, 8, 10, and 12 = sugarbeet leaf number at time of application; PPI = preplant incorporated.

Table 2. Weed control in response to glyphosate timings, number of applications, and combinations with residual herbicides, under furrow irrigation. Powell Research and Extension Center, 1998-1999.

	Application		Weed control				
Treatment[1]	Rate	Timing[2]	Redroot pigweed	Wild mustard	Kochia	Wild buckwheat	Green foxtail
	kg ai/ha	leaf no.	--------------------	--------------------	%--------------------	--------------------	--------------------
Glyphosate	0.84	4	80	90	82	72	84
Glyphosate	0.84	2 / 6	95	100	100	88	98
Glyphosate	0.84	4 / 8	98	100	100	96	100
Glyphosate	0.84	6 / 10	100	100	100	100	100
Glyphosate	0.84	2 / 4 / 6	98	100	100	98	99
Glyphosate	0.84	4 / 8 / 12	100	100	100	100	100
Ethofumesate / glyphosate	1.13 / 0.84	PPI / 4	91	95	100	90	90
Cycloate / glyphosate	1.13 / 0.84	PPI / 4	90	97	92	84	95
S-metolachlor / glyphosate	1.40 / 0.84	PPI / 4	90	97	100	92	90
Ethofumesate / glyphosate / glyphosate	1.13 / 0.84 / 0.84	PPI / 4 / 8	100	100	100	96	100
Cycloate / glyphosate / glyphosate	1.13 / 0.84 / 0.84	PPI / 4 / 8	94	100	97	100	96
S-metolachlor+glyphosate / glyphosate	1.40+0.84 / 0.84	2 / 10	94	100	100	98	98
Glyphosate / s-metolachlor+glyphosate	0.84 / 1.4+0.84	2 / 10	95	100	98	100	100
Desm-phen+triflusulfuron (Standard)	0.37+0.018	2 / 4 / 6	92	100	74	80	90
Hand weeded check	--	--	100	100	100	100	100
Weedy check[3]	--	--	8.3	5.2	2.5	3.7	7.4
LSD (5%)	--	--	8	NS	12	15	NS

[1] Desm-phen = commercial premix of desmedipham+phenmedipham; / = split application.

[2] 2, 4, 6, 8, 10, and 12 = sugarbeet leaf number at time of application; PPI = preplant incorporated.

[3] Weed density expressed as number of plants/m of row in an 8-cm band.

Table 3. Weed control in response to glyphosate timings, number of applications, and combinations with residual herbicides, under sprinkler irrigation. Torrington Research and Extension Center, 1998-1999.

Treatment[1]	Application Rate	Application Timing[2]	Weed control: Redroot pigweed	Wild mustard	Kochia	Wild buckwheat	Green foxtail
	kg ai/ha	leaf no.	%				
Glyphosate	0.84	4	82	79	80	78	82
Glyphosate	0.84	2 / 6	98	97	98	100	95
Glyphosate	0.84	4 / 8	96	100	100	100	96
Glyphosate	0.84	6 / 10	100	100	100	100	100
Glyphosate	0.84	2 / 4 / 6	100	100	100	100	96
Glyphosate	0.84	4 / 8 / 12	100	100	100	100	100
Ethofumesate / glyphosate	1.13 / 0.84	PPI / 4	94	90	90	90	96
Ethofumesate / glyphosate	1.70 / 0.84	PPI / 4	100	89	98	100	97
S-metolachlor / glyphosate	1.40 / 0.84	PPI / 4	96	94	90	92	95
Ethofumesate / glyphosate / glyphosate	1.13 / 0.84/ 0.84	PPI / 4 / 8	98	100	100	100	98
Ethofumesate / glyphosate / glyphosate	1.70 / 0.84/ 0.84	PPI / 4 / 8	100	100	100	100	100
Glyphosate+triflusulfuron	0.84 + 0.018	2 / 6	96	99	100	100	97
Glyphosate+triflusulfuron+AMS	0.84 + 0.018	2 / 6	95	100	100	100	98
Desm-phen+triflusulfuron (Standard)	0.37+0.018	2 / 4 / 6	92	89	100	67	71
Hand weeded check	--	--	100	100	100	100	100
Weedy check[3]	--	--	2.4	10	2.5	2.5	6.3
LSD (5%)	--	--	NS	11	13	16	14

[1] AMS = ammonium sulfate at 2.5 kg/ha; Desm-phen = commercial premix of desmedipham+phenmedipham; / = split application.
[2] 2, 4, 6, 8, 10, and 12 = sugarbeet leaf number at time of application; PPI = preplant incorporated.
[3] Weed density expressed as number of plants/m of row in an 8-cm band.

control than the standard treatment except for kochia. Kochia control with the standard treatment was lower than with a single application of glyphosate due to the presence of acetolactate synthase (ALS)-resistant kochia at both sites. Two sequential glyphosate applications starting at 2-, 4-, or 6-leaf sugarbeet with a two week interval between applications provided better overall weed control than the single glyphosate application and the standard treatment. Weed control with three sequential glyphosate applications was similar to two sequential applications. Since glyphosate has no soil residual activity, the level of weed control observed was influenced by weeds that germinated after the final glyphosate application. Other experiments with glyphosate-tolerant sugarbeet also have shown that two glyphosate applications starting at 2-leaf sugarbeet provided greater than 96% weed control (Dexter and Luecke 1997). Wilson (2002) reported that weed control was inadequate with a single application and excellent with two or three sequential applications.

Weed control with ethofumesate, cycloate, or s-metolachlor applied preplant incorporated followed by one application of glyphosate applied at 4-leaf sugarbeet was equal or greater than the standard program and similar to two glyphosate applications. Similar control was observed when a second glyphosate application was applied to 8-leaf sugarbeet. At the PREC, two sequential applications of glyphosate provided more than 94% weed control when tank mixed with s-metholachlor at 2- or 10-leaf sugarbeet. At the TREC, tank mixing glyphosate with triflusulfuron at 2- and 6-leaf sugarbeet provided more than 95% weed control. Adding AMS did not affect glyphosate plus triflusulfuron efficacy. Guza et al. (2002) showed that tank mixing AMS with glyphosate did not increase weed control.

Sugarbeet Response.

No significant sugarbeet injury was observed with glyphosate alone (Table 4, 5). However, some injury was recorded with treatments containing residual herbicides. At the PREC, the highest sugarbeet injury (10%) was recorded with the mixture s-metolachlor plus glyphosate applied at 2-leaf sugarbeet, while ethofumesate at the rate of 1.7 kg/ha caused the greatest injury (8%) at the TREC.

Sugarbeet root yield was greater in all treated plots compared to the weedy check (Table 4, 5). With glyphosate alone, sugarbeet root yield tended to increase as the number of glyphosate applications increased from one to two, starting at 2- or 4-leaf sugarbeet. Two sequential applications starting at 6-leaf sugarbeet provided excellent weed control but sugarbeet yield was similar to the single glyphosate

Table 4. Roundup ready sugarbeet response to glyphosate timings, number of applications, and combinations with residual herbicides, under furrow irrigation. Powell Research and Extension Center, 1998-1999.

Treatment[1]	Application Rate	Application Timing[2]	Weed control: Redroot pigweed	Weed control: Wild mustard	Weed control: Kochia	Weed control: Wild buckwheat	Weed control: Green foxtail
	kg ai/ha	leaf no.	%				
Glyphosate	0.84	4	0	39.3	15.7	6,162	
Glyphosate	0.84	2 / 6	0	45.8	15.4	6,892	
Glyphosate	0.84	4 / 8	0	45.3	15.9	7,036	
Glyphosate	0.84	6 / 10	0	40.8	15.5	6,316	
Glyphosate	0.84	2 / 4 / 6	0	46.3	16.1	7,457	
Glyphosate	0.84	4 / 8 / 12	0	45.5	16.0	7,280	
Ethofumesate / glyphosate	1.13 / 0.84	PPI / 4	3	44.4	16.0	7,110	
Cycloate / glyphosate	1.13 / 0.84	PPI / 4	0	43.5	15.6	6,786	
S-metolachlor / glyphosate	1.40 / 0.84	PPI / 4	5	44.0	15.7	6,908	
Ethofumesate / glyphosate / glyphosate	1.13 / 0.84 / 0.84	PPI / 4 / 8	3	46.2	15.4	7,119	
Cycloate / glyphosate / glyphosate	1.13 / 0.84 / 0.84	PPI / 4 / 8	3	46.0	16.1	7,406	
S-metolachlor + glyphosate / glyphosate	1.40+0.84 / 0.84	2 / 10	10	40.3	16.3	6,561	
Glyphosate / s-metolachlor + glyphosate	0.84 / 1.4+0.84	2 / 10	7	42.8	15.9	6,802	
Desm-phen + triflusulfuron (Standard)	0.37+0.018	2 / 4 / 6	3	41.0	15.6	6,391	
Hand weeded check	--	--	0	46.0	16.0	7,360	
Weedy check	--	--	0	19.5	16.2	3,153	
LSD (5%)	--	--	4.4	4.1	NS	1,009	

[1] Desm-phen = commercial premix of desmedipham+phenmedipham; / = split application.

[2] 2, 4, 6, 8, 10, and 12 = sugarbeet leaf number at time of application; PPI = preplant incorporated.

Table 5. Roundup ready sugarbeet response to glyphosate timings, number of applications, and combinations with residual herbicides, under sprinkler irrigation. Torrington Research and Extension Center, 1998-1999.

	Application		Weed control				
Treatment[1]	Rate	Timing[2]	Redroot pigweed	Wild mustard	Kochia	Wild buckwheat	Green foxtail
	kg ai/ha	leaf no.	-%-				
Glyphosate	0.84	4	0	55.3	13.1	7,232	
Glyphosate	0.84	2 / 6	0	64.5	13.2	8,491	
Glyphosate	0.84	4 / 8	0	63.5	13.4	8,394	
Glyphosate	0.84	6 / 10	0	60.3	13.7	8,236	
Glyphosate	0.84	2 / 4 / 6	0	64.3	13.5	8,706	
Glyphosate	0.84	4 / 8 / 12	0	63.5	13.3	8,180	
Ethofumesate / glyphosate	1.13 / 0.84	PPI / 4	5	63.8	13.3	8,466	
Ethofumesate / glyphosate	1.70 / 0.84	PPI / 4	7	59.0	13.6	7,995	
S-metolachlor / glyphosate	1.40 / 0.84	PPI / 4	0	63.3	13.2	8,362	
Ethofumesate / glyphosate / glyphosate	1.13 / 0.84 / 0.84	PPI / 4 / 8	5	62.5	13.4	8,393	
Ethofumesate / glyphosate / glyphosate	1.70 / 0.84 / 0.84	PPI / 4 / 8	8	57.2	13.4	7,648	
Glyphosate + triflusulfuron (Standard)	0.84 + 0.018	2 / 6	0	64.2	13.4	8,602	
Glyphosate + triflusulfuron + AMS	0.84 + 0.018	2 / 6	0	64.8	13.3	8,638	
Desm-phen + triflusulfuron	0.37+0.018	2 / 4 / 6	3	56.9	13.2	7,516	
Hand weeded check	--	--	0	63.5	13.2	8,357	
Weedy check	--	--	0	15.5	13.7	2,118	
LSD (5%)	--	--	3	5.1	NS	1,034	

[1] AMS = ammonium sulfate at 2.5 kg/ha; Desm-phen = commercial premix of desmedipham+phenmedipham; / = split application.

[2] 2, 4, 6, 8, 10, and 12 = sugarbeet leaf number at time of application; PPI = preplant incorporated

application and the standard treatment. This suggests that weeds were able to compete with sugarbeet for at least 4 weeks after emergence before they were removed with the first application of glyphosate at 6-leaf sugarbeet. Mesbah et al. (1994) have shown that weeds competing with sugarbeet for 3.5 weeks after sugarbeet emergence reduced root yield by 5%. Yields from three sequential applications were similar to those from two sequential applications at 2- or 4-leaf sugarbeet.

When glyphosate was combined with residual herbicides, sugarbeet root yield responded to the degree of injury and type of residual herbicide used. At the PREC, sugarbeet root yield from plots treated with ethofumesate or s-metolachlor preplant incorporated followed by one or two glyphosate applications starting at 4-leaf sugarbeet with 2 week interval between applications was similar to the hand weeded check and to treatments containing two glyphosate applications starting at 2- or 4-leaf sugarbeet, but significantly different than the standard treatment. At the TREC, the combination ethofumesate at the rate of 1.13 kg/ha followed by one glyphosate application tended to yield higher than when ethofumesate at 1.7 kg/ha was used. Yield with the combination glyphosate plus triflusulfuron with or without AMS was similar to two glyphosate applications starting at 2- or 4-leaf sugarbeet. Sucrose content among all treatments was not different. However, sucrose yield was different among treatments and this difference was primarily related to sugarbeet root yield differences.

This study shows that growers can use glyphosate-tolerant sugarbeet to efficiently grow sugarbeet. Two applications of glyphosate alone starting at 2 or 4-leaf sugarbeet with a two week interval between applications provided more than 88% weed control and increased sugarbeet root yield, compared to the standard treatment. Similar results were achieved with ethofumesate or s-metolachlor applied preplant and followed by one application of glyphosate at 4-leaf sugarbeet. Compared to the standard herbicide program, growing glyphosate-tolerant sugarbeet will reduce number of applications and herbicide cost, and will increase production.

LITERATURE CITED

Burnside, O. C. 1992. Rationale for developing herbicide-resistant crops. Weed Technol. 6:621-625.

Culpepper, A. S. and A. C. York. 1997. Weed management in no-tillage bromoxynil-tolerant cotton (*Gossypium hirsutum*). Weed Technol. 11:335-345.

Delannay, X., T. T. Bauman, D. H. Beighley. 1995. Yield evaluation of a glyphosate-tolerant soybean line after treatment with glyphosate. Crop Sci. 35:1461-1467.

Dexter, A. G. and J. L. Luecke. 1997. Weed control in transgenic sugarbeet in North Dakota and Minnesota. Proc. North Cent. Weed Sci. Soc. 52:142-143.

Franz, J. E., M. K. Mao, and J. A. Sikorski. 1997. *Glyphosate A Unique Global Herbicide*. American Chemical Society, Washington, DC.

Guza, C. J., C. V. Ransom, and C. Mallory-Smith. 2002. Weed control in glyphosate-resistant sugarbeet (*Beta vulgaris* L.). J. Am. Soc. Sugar Beet Technol. 39:109-123.

Johnson, W. G., P. R. Bradley, and S. E. Hart. 1998. Weed management in glyphosate and glufosinate-tolerant corn. Weed Sci. Soc. Am. Abstr. 38:5.

Keeling, J. W., P. I. Dotray, C. L. Jones, and S. L. Sunderland. 1996. Post-emergence weed management in Roundup Ready™ cotton for the Texas southern high plains. Proc. South. Weed Sci. Soc. 49:52-53.

Kishore, G. M., S. R. Padgette, and R. T. Fraley. 1992. History of herbicide-tolerant crops, methods of development and current state of the art-emphasis on glyphosate tolerance. Weed Technol. 6:626-634.

Lanie, A. J., J. L. Griffin, P. R. Vidrine, and D. B. Reynolds. 1994. Herbicide combinations for soybean (*Glycine max*) planted in stale seedbed. Weed Technol. 8:17-22.

Madsen, K. H. 1993. Weed control in glyphosate-tolerant sugarbeets (*Beta vulgaris* L.). Weed Sci. Soc. Am. Abstr. 33-16.

Malik, J., G. Barry, and G. M. Kishore. 1989. The herbicide glyphosate. Biofactors 2:17-25.

Mesbah, A. O., S. D. Miller, K. J. Fornstrom, and D. E. Legg. 1994. Kochia (*Kochia scoparia*) and green foxtail (*Setaria viridis*) interference in sugarbeets (*Beta vulgaris*). Weed Technol. 8:754-759.

Morishita, D. W., M. J. Wille, and R. W. Downard. 1999. Weed control in glyphosate-resistant sugarbeets. Proc. West. Soc. Weed Sci. 52:120.

Mousdale, D. M. and J. R. Coggins. 1991. Amino acid synthesis. In R. C. Kirkwood (ed.) Target Site for Herbicide Action. New York: Plenum Press. pp. 29-50.

Norris, R. F. and J. A. Roncoroni. 1999. Performance of glufosinate and glyphosate for weed control in transgenic sugarbeets in California. Proc. West. Soc. Weed Sci. 52:121.

Shah, D. M., R. B. Horsch, H. J. Klee, et al. 1986. Engineering herbicide tolerance in transgenic plants. Science 233:478-481.

Schweizer, E. E. 1981. Broadleaf weed interference in sugarbeets (*Beta vulgaris*). Weed Sci. 29:128-133.

Schweizer, E. E. and L. D. Bridge. 1982. Sunflower (*Helianthus annuus*) and velvetleaf (*Abutilon theophrasti*) interference in sugarbeets (*Beta vulgaris*). Weed Sci. 30:514-519.

Wilcut, J. W., H. D. Coble, A. C. York, and D. W. Monks. 1996. The niche for herbicide-resistant crops in U.S. agriculture. *In* S. O. Duke (ed.) Herbicide resistant crops: agricultural, environmental, economic, regulatory, and technical aspects. Boca Raton, FL: CRC Press. pp.213-230.

Wilson, H. P., T. E. Hines, R. R. Bellinder, and J. A. Grande. 1985. Comparisons of HOE-39866, SC-0024, paraquat, and glyphosate in no-till corn (*Zea mays*). Weed Sci. 33:531-536.

Wilson, R. G. 1998. Glyphosate and glufosinate for weed control in herbicide tolerant sugarbeet. Proc. West. Soc. Weed Sci. 51:102.

Wilson, R.G., C. D. Yonts, and J. A. Smith. 2002. Influence of glyphosate and glufosinate on weed control and sugarbeet (*Beta vulgaris*) yield in herbicide tolerant sugarbeet. Weed Technol. 16:66-73

[WSSA] Weed Science Society of America. 2002. Herbicide Handbook, 8th ed. Lawrence, KS: Weed Science Society of America. p. 231-234.

Wyse, D. L. 1992. Future impact of crops with modified herbicide resistance. Weed Technol. 6:665-668