Lack of Herbicide Effect on Severity of Aphanomyces Root Rot of Sugarbeet

Troy W. Roebke[1], Carol E. Windels[2], and Alan G. Dexter[3]

[1]Former Research Assistant, North Dakota State University, Fargo 58105; [2]Professor of Plant Pathology, University of Minnesota, Northwest Research and Outreach Center, Crookston 56716; and [3]Professor and Sugarbeet Specialist, North Dakota State University, Fargo 58105 and University of Minnesota, St. Paul 55108

ABSTRACT

Nearly all sugarbeet fields in Minnesota and eastern North Dakota are treated with herbicides. Many of these fields are infested with *Aphanomyces cochlioides*, a soilborne pathogen that has increased in prevalence and severity in the region during unusually wet growing seasons in the 1990s. Trials were conducted in four fields naturally infested with *A. cochlioides* to determine if herbicides commonly applied before planting and after emergence affected stand loss and root rot caused by the pathogen. Herbicides applied and incorporated into soil before planting (cycloate, diethatyl, EPTC, ethofumesate) and those applied after emergence (clopyralid, desmedipham, desmedipham + phenmedipham, triflusulfuron) did not affect severity of disease caused by *A. cochlioides* compared to a hand-weeded control.

Additional key words: *Beta vulgaris* L., black root tip rot, herbicide-plant disease interaction

Aphanomyces cochlioides Drechs. is a soilborne pathogen that causes seedling disease and chronic root rot of sugarbeet (*Beta vulgaris* L.) when soil conditions are warm (optimal at 20 to 30°C) and wet (Leach, 1986, Windels and Lamey, 1998). Unseasonably wet weather in the 1990s has increased the economic importance of this pathogen on sugarbeet in the Red River Valley (RRV) of Minnesota and North Dakota.

Chronic root rot has been more prevalent than seedling disease and varied from mild to severe, depending upon the field, region, local weather conditions and effectiveness of Aphanomyces control practices. Based on a 1999 survey, about 51% of 293,000 ha of land sown to sugarbeet in Minnesota and North Dakota were infested with *A. cochlioides* (B.J. Jacobsen, Montana State University, *personal communication*). When fields are infested, disease management practices become necessary for continued sugarbeet production because the pathogen survives in soil for 10 or more years (Papavizas and Ayers, 1974).

Herbicides are commonly applied in sugarbeet fields in Minnesota and eastern North Dakota for control of broadleaf and grass weed species. According to a 2001 survey, the average sugarbeet field in this region was treated with herbicides 3.7 times and less than 1% of fields were untreated (Dexter and Luecke, 2002). Previous surveys have shown average annual applications of herbicides ranging from 2.7 to 4.6 since 1977 (A.G. Dexter, *personal communication*). When *A. cochlioides* reduces sugarbeet stands, affected areas often are overgrown by weeds. Several of the most common broadleaf weeds also are hosts of *A. cochlioides* including common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.) and kochia (*Kochia scoparia* [L.] Schrad.), which contribute to the build-up of inoculum in soil (Papavizas and Ayers, 1974).

Reports of herbicide-plant disease interactions are numerous, as reviewed by Altman and Campbell (1977). Herbicides increase disease by reducing structural defenses of the plant, stimulating exudations from plants, stimulating pathogen growth and inhibiting soil microflora that compete with pathogens. Herbicides decrease disease by increasing host structural or biochemical defenses and by decreasing growth of pathogens. Whether herbicides increase, decrease or have no effect on plant disease depends on the herbicide, pathogen, crop and environmental conditions (Altman and Campbell, 1977). For example, trifluralin increased Rhizoctonia root rot on cotton (Neubauer and Avizohar-Hershenson, 1973) and Phytophthora root rot on soybean (Duncan and Paxton, 1981); decreased Fusarium wilt on tomato and melon (Cohen *et al.*, 1986); and had no effect on Rhizoctonia root and crown rot of sugarbeet (Ruppel *et al.*, 1982). Glyphosate had no effect on charcoal rot on soybean but when plants were stressed by alachlor, chloramben or 2,4,-DB and soil temperatures were greater than 26^{0}C, the disease increased (Canaday *et al.*, 1986).

An increase in Aphanomyces diseases on sugarbeet has led producers in the RRV of Minnesota and North Dakota to speculate that herbicides stress sugarbeet plants and thereby increase susceptiblility to

A. cochlioides. In field trials, Jacobsen and Hopen (1981) demonstrated that dinoseb and trifluralin reduced Aphanomyces root rot on peas caused by *A. euteiches*, however, similar studies have not been done to document the effect of herbicides on sugarbeet diseases caused by *A. cochlioides*. Our research was conducted to evaluate the effect of herbicides applied before planting and after emergence on sugarbeet stand loss and root rot caused by *A. cochlioides*.

MATERIALS AND METHODS

Experiments were established near Moorhead and Sabin, Minnesota (MN) in 1992 and Moorhead, MN and Arthur, North Dakota (ND) in 1993 in fields with Aphanomyces soil index values (0 to 100 scale, Windels and Nabben-Schindler, 1996) of 76, 52, 54 and 93, respectively. The Moorhead soil was a Fargo fine montmorillonitic frigid, Vertic Haplaquolls with 4.9% organic matter in 1992 and 5.5 % in 1993. The Sabin soil was a Donaldson coarse-loamy over clayey, mixed Aquic Haploborolls with 1.6% organic matter. The Arthur soil was fine semectitic frigid, Typic Epiaquerts with 3.2% organic matter. The same experiments (10 herbicide treatments and a control) were conducted in all fields in a randomized complete block design with four replicates. Each treatment plot was 11 m long with 56 cm between rows and included six rows. The preplant herbicides cycloate, diethatyl, EPTC and ethofumesate were applied at 4.5, 4.5, 2.3 and 3.4 kg a.i.ha^{-1}, respectively, in 160 L water ha^{-1} at 276 kPa through 8002 nozzles and incorporated with a rototiller to an 8-cm depth. 'Maribo 403' sugarbeet was sown 3 cm deep, with 5 cm between seeds on May 15, 1992 and May 15, 1993. Plots (without preplant herbicides) were treated with the postemergence herbicides clopyralid at 0.21, desmedipham at 0.28 or 0.56, desmedipham + phenmedipham at 0.28 + 0.28 or 0.56 + 0.56, and triflusulfuron (+ X-77, 0.25% v/v) at 0.18 kg a.i. ha^{-1} when plants had four true leaves (3 to 4 weeks after planting), with a second application at the same rate 1 week later. Herbicides were applied in 80 L water ha^{-1} at 276 kPa through 8001 nozzles. All herbicides were applied on the center four rows of each plot. Untreated control plots were hand-weeded. Sugarbeet plots were thinned to 20 cm between plants in late June to early July (after all herbicide treatments had been applied) and all plots were weeded by hand for the remainder of the season. Plots were fertilized and maintained following recommend management practices (Cooke and Scott, 1993). Chlorpyrifos (2.19 kg a.i. ha^{-1}) and terbufos (2 kg a.i. ha^{-1}) were applied at seeding in 1992 and 1993, respectively, to control sugarbeet root maggot (*Tetanops myopaeformis* Roeder). Triphenyl tin hydroxide (0.28

kg a.i. ha^{-1}) was applied, as needed, in a 160 L water at 276 Kpa to control leaf spot caused by *Cercospora beticola* Sacc.

Plant stands were counted in the two middle rows of each plot when plants were in the four-leaf stage (3 to 4 weeks after planting and before the first application of postemergence herbicides), 1 to 2 weeks after the second application of postemergence herbicides, immediately after thinning and at harvest (September 24, 1992; September 16-17, 1993). If no aboveground symptoms of Aphanomyces root rot were observed, a few (5-10) plants adjacent to counted rows were removed and inspected for evidence of rot. The two middle rows of each plot were harvested and 10 roots were randomly chosen and assessed for Aphanomyces root rot with a 0 to 7 rating scale where 0 = root clean; 1 = root large, crown slightly scurfy; 2 = root large, tip or root infections (brown, scarred surface) superficial and affect <5% root surface; 3 = 6 to 25% root constricted and rotted or with brown scars on root surface; 4 = 26 to 50% root constricted or rotted or with brown scars on root surface; 5 = 51 to 75% root constricted and rotted or with brown scars on root surface; 6 = >75% root constricted and rotted or with brown scars on root surface; and 7 = root completely rotted and foliage dead (Windels and Nabben-Schindler, 1996). The same roots were analyzed for quality and sucrose content by the American Crystal Sugar Company Quality Laboratory, East Grand Forks, MN.

Data collected at each site were subjected to analysis of variance and if significant ($P < 0.05$), means were separated by a F-protected Least Significant Difference (LSD) test. At Sabin, MN, a few plots were lost from an accidental application of a corn herbicide at the edge of the trial and least squares means were calculated to compensate for missing data. Precipitation data were obtained through the North Dakota Automated Weather Stations.

RESULTS

Preplant and postemergence herbicides had no significant effect on plant stand throughout the season compared to the hand-weeded control in *A. cochlioides*-infested fields located at Moorhead, MN in 1992 and 1993 and at Arthur, ND in 1993. Consequently, stand data were combined for the preplant and postemergence herbicides and compared to the control (Table 1). When stand counts were made at the four-leaf stage, aboveground symptoms of Aphanomyces root rot were not present and seedlings randomly removed from rows adjacent to counted rows showed no evidence of root rot. Plant populations at the four-leaf stage were similar in plots at Arthur, ND and Moorhead, MN in

Table 1. Effect of preplant-incorporated and postemergence-applied herbicide treatments on sugarbeet populations compared to a hand-weeded control in four fields in Minnesota and North Dakota naturally infested with *Aphanomyces cochlioides*.

Location	Treatment†	No. plants ha^{-1} @ 4-leaf stage§	% Change in stand after 2-3 wk§,¶ (+=gain, - = loss)	No. plants ha^{-1} @ thinning§,††	% Reduction @ harvest §,‡‡
Arthur, ND	Control	152,500	- 7	85,200	14
(1993)	Preplant	139,950	- 10	88,000	15
	Postemergence	196,000	- 13	91,950	15
Moorhead, MN	Control	220,350	- 3	88,600	15
(1992)	Preplant	219,550	- 2	87,200	14
	Postemergence	223,600	- 2	89,200	15

† Control was hand-weeded; preplant herbicides included: cycloate at 4.5, diethatyl at 4.5, EPTC at 2.3 and ethofumestate at 3.4 kg a.i. ha^{-1}, respectively); postemergence herbicides were applied at the four-true-leaf stage and 1 week later and included clopyralid at 0.21, desmedipham at 0.28 or 0.56, desmedipham + phenmedipham at 0.28 + 0.28 or 0.56 + 0.56, and triflusulfuron (+ X-77, 0.25%, v/v) at 0.18 kg a.i. ha^{-1}, respectively, for each of two applications.

‡ Excludes EPTC.

§ Each value is based on an average of four replicates for each treatment (one control, four preplant herbicides [EPTC treatment excluded for Sabin site], and six postemergence herbicides).

¶ Change in plant stand 2 to 3 weeks after the first application of postemergence herbicides.

†† Sugarbeet plots were thinned to 20 cm between plants in late June to early July.

‡‡ Stand loss between thinning and harvest. Plots were harvested on September 16, 1993 in Arthur, ND; September 24, 1992 and September 17, 1993 in Moorhead, MN; and September 24, 1992 in Sabin, MN.

* Significantly different, $P < 0.05$.

(continued)

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Location	Treatment†	No. plants ha^{-1} @ 4-leaf stage§	% Change in stand after 2-3 wk§,¶ (+=gain, - = loss)	No. plants ha^{-1} @ thinning§,††	% Reduction @ harvest §,‡‡
loorhead, MN	Control	138,500	- 1	65,150	33
(1993)	Preplant	134,150	<1	73,000	37
	Postemergence	137,500	0	71,400	35
abin, MN	Control	116,900	+ 8	83,500	40
(1992)	EPTC	68,000*	+ 2	61,500*	29
	Preplant‡	105,733	+ 11	83,050	29
	Postemergence	123,450	+ 7	86,050	31

Control was hand-weeded; preplant herbicides included: cycloate at 4.5, diethatyl at 4.5, EPTC at 2.3 and ethofumestate at 3.4 kg a.i. ha^{-1}, respectively); postemergence herbicides were applied at the four-true-leaf stage and 1 week later and included clopyralid at 0.21, desmedipham at 0.28 or 0.56, desmedipham + phenmedipham at 0.28 + 0.28 or 0.56 + 0.56, and triflusulfuron (+ X-77, 0.25%, v/v) at 0.18 kg a.i. ha^{-1}, respectively, for each of two applications.

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Significantly different, $P < 0.05$.

1993 but were higher at Moorhead, MN in 1992 (Table 1) because conditions for germination and emergence were more favorable.

Between the four-leaf stage and 2 to 3 weeks later (in late June), Aphanomyces root rot developed and average stand losses of 10 and 2.3% occurred in plots at Arthur, ND in 1993 and Moorhead, MN in 1992, respectively (Table 1). June precipitation at Arthur was 15 cm and at Moorhead was 18 cm and this moisture favored root infections by *A. cochlioides*. Dying plants had symptoms typical of Aphanomyces root rot (blackened and shriveled hypocotyls and tap roots, stunted plants). In 1993, the Moorhead site showed very low incidence of Aphanomyces root rot, and stand loss was negligible within the first 6 weeks after planting (Table 1).

At Sabin, seedling stands were lower than the other sites because precipitation washed soil into furrows after planting, which reduced and delayed emergence. Stands were lower ($P < 0.05$) in plots pretreated with EPTC compared to the hand-weeded control throughout the season (Table 1). Plant stand data for the other preplant and postemergence herbicides did not differ from the control and thus, were combined (Table 1). Numbers of plants increased between the four-leaf stage and 2 weeks later, with gains of 2, 11, 7 and 8% in the plots treated with EPTC, other preplant herbicides, postemergence herbicides and the control. Symptoms of Aphanomyces root rot were not visible on seedlings when stand counts were recorded in June. In July, the Sabin area received 19.5 cm of precipitation and symptoms of *A. cochlioides* were visually confirmed by inspection of several suspect plants removed from rows not used for collection of data.

Herbicide treatments and the control were similar for plant stand losses occurring between thinning and harvest at Arthur, ND in 1993 and Moorhead, MN in 1992 and 1993, which averaged 15, 15 and 35%, respectively (Table 1). Considerable stand loss occurred at Moorhead in 1993 and was caused by severe water damage when 28 cm of precipitation fell between mid June and late July (including 12 cm on June 15-16). At Sabin, plant losses between thinning and harvest were similar in the EPTC-treated plots (29%) compared to the other preplant-incorporated and postemergence-applied herbicides and the control (Table 1).

Root rot ratings at harvest and yield data were combined across the four locations (Table 2) because herbicide treatments were similar to the hand-weed control at each site and interactions between location and treatments were not significant. Aphanomyces root rot ratings (0 to 7 scale) averaged 4.0 at Arthur, ND; 3.7 and 1.4 at Moorhead, MN in 1992 and 1993, respectively; and 3.2 at Sabin, MN (data not shown). Despite

Table 2. Effect of herbicide treatments on Aphanomyces root rot and sugarbeet yield and quality averaged over four fields in Minnesota and North Dakota naturally infested with *Aphanomyces cochlioides.*

Treatment	Rate (kg ha^{-1})	Root rot index (0-7)¶,††	Yield¶,††		
			m tons ha^{-1}	% sucrose	Rec. sucrose (kg ha^{-1})
Control†	0	3.3	24.2	13.6	2797
Preplant‡					
cycloate	4.5	3.1	28.1	13.4	3201
diethatyl	4.5	3.1	25.3	13.6	2950
EPTC	2.3	3.2	26.2	13.9	3122
ethofumesate	3.4	3.3	26.9	13.7	3151

† Control plots were hand weeded.

‡ Preplant herbicides were applied before planting in 160 L water ha^{-1} at 276 Kpa and incorporated with a rototiller to an 8-cm depth.

§ First application occurred when sugarbeet seedlings reached the four-true-leaf stage and the second was 1 week later. Postemergence herbicides were applied in 80 L water ha^{-1} at 276 Kpa.

¶ Each value is an average of 160 roots rated on a 0 to 7 scale (0 = healthy, 7 = root completely rotted and foliage dead).

†† Each value is an average of four replicates per field; NS = not significantly different, $P < 0.05$.

(continued)

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Treatment	Rate (kg ha^{-1})	Root rot index (0-7)[¶,††]	Yield[¶,††]		
			m tons ha^{-1}	% sucrose	Rec. sucrose (kg ha^{-1})
Postemergence[§]					
clopyralid / clopyralid	0.21/0.21	3.2	25.0	13.2	2789
desmedipham/desmedipham	0.28/0.28	3.2	27.1	14.3	3348
desmedipham/desmedipham	0.56/0.56	3.2	26.9	13.8	3123
desmedipham + phenmedipham / desmedipham + phenmedipham	0.28/0.28	3.2	26.0	13.8	3040
desmedipham + phenmedipham / desmedipham + phenmedipham	0.56/0.56	3.2	25.7	13.7	2978
triflusulfuron + X-77 / triflusulfuron + X-77	0.18 + 0.25% (v/v)/ 0.18 + 0.25% (v/v)	3.1	25.0	13.8	2944
P=0.05		NS	NS	NS	NS

† Control plots were hand weeded.

‡ Preplant herbicides were applied before planting in 160 L water ha^{-1} at 276 Kpa and incorporated with a rototiller to an 8-cm depth.

§ First application occurred when sugarbeet seedlings reached the four-true-leaf stage and the second was 1 week later. Postemergence herbicides were applied in 80 L water ha^{-1} at 276 Kpa.

¶ Each value is an average of 160 roots rated on a 0 to 7 scale (0 = healthy, 7 = root completely rotted and foliage dead).

†† Each value is an average of four replicates per field; NS = not significantly different, $P < 0.05$.

EPTC decreasing stand and presumably stressing plants throughout the growing season at Sabin, roots harvested from these plots displayed the same severity of root rot as did the other herbicide treatments and control (data not shown). Overall, yields were atypically low at all locations, primarily because of the occurrence of Aphanomyces root rot in the plots at Moorhead in 1992, Arthur and Sabin. Plots at Moorhead in 1993 had neglible Aphanomyces root rot but suffered losses because of severe water damage. The control tended to have lower yields than the herbicide treatments because some sugarbeet plants were accidentally removed when control plots were hand weeded.

DISCUSSION

Preplant and postemergence herbicides did not affect sugarbeet stand loss and root rot caused by *A. cochlioides* in fields where the pathogen was active. Stand losses within 6 weeks after planting at these sites were caused by *A. cochlioides* and not herbicide damage. Herbicides decompose within 3 to 4 weeks after application so the possible influence of preplant herbicides on Aphanomyces would have occurred within a month after planting (by mid June). It is unknown if seedlings were infected by *A. cochlioides* within 3 to 4 weeks after planting since no symptoms were observed, but lateral roots could have been infected and symptomless. Since Aphanomyces root rot was observed within 6 weeks after planting, and precipitation was favorable for infection and disease development, timing of postemergence herbicide applications were optimal to potentially affect disease severity.

At Sabin, preplant applications of EPTC reduced sugarbeet stand throughout the season. These losses, however, were attributed to the herbicide and not *A. cochlioides* because no root rot was observed on seedlings during the first 6 weeks after planting when preemergence and postemergence herbicides would be most active. Losses in sugarbeet seedling stands by EPTC tend to occur in fields with low organic matter and low clay contents (Jordan and Day, 1962). The Sabin site had an organic matter content of 1.6% and a coarse-loamy over clay soil type whereas, the Moorhead site had an organic matter content of 4.9 and 5.5% in 1992 and 1993, respectively, and Arthur was at 3.2%. Furthermore, the soils at Moorhead and Arthur also had a higher clay content than the Sabin site. Dry soil conditions enhance EPTC phytotoxicity on sugarbeet and the field at Sabin was drier than the heavy clay soil in fields at the other three locations. Soil incorporation of preplant herbicides likely further dried soil.

Stand losses recorded between thinning and harvest in our studies are not unusual. About 15% stand loss occurs in most sugarbeet fields during this period when large plants out-compete small and weakened plants, regardless of whether Aphanomyces root rot is present or absent (C.E. Windels, *unpublished*). Considerable plant stand losses occurred at Moorhead in 1993 because of water damage. Plots at Arthur, Moorhead (1992) and Sabin had comparable root rot ratings at harvest, but Sabin lost a larger percentage of plants. This is attributable to Aphanomyces root rot, which was enhanced by stresses associated with sandy soils at Sabin.

Aphanomyces soil index values in the four plot sites indicated moderate to high potential for disease, yet despite adequate precipitation during the growing season, disease severity varied from negligible (Moorhead, MN, 1993) to moderately severe (Arthur, ND, 1993). Typically, Aphanomyces soil index values are positively correlated with root rot in the field when weather conditions are favorable for infection and disease development (Beale *et al.*, 2002; Windels and Nabben-Schindler, 1996). With favorable moisture conditions, we anticipated more disease than was observed at the Moorhead, MN site in 1993 (soil index value was 54 and root rot index at harvest was 1.4). These results suggest the soil index value was overestimated because the soil sample collected for the soil bioassay did not represent the plot site, or other unknown factors influenced low disease development.

Overall, our research in three fields where discernable Aphanomyces diseases developed, showed no evidence that preplant or postemergence herbicides affected stand loss or root rot caused by *A. cochlioides*.

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