Influence of Population Densities of *Heterodera schachtii* on Sugar Beets Grown in Microplots

Th. H. A. OLTHOF[1]

Abstract: High initial population densities of *Heterodera schachtii* larvae (36 and 108/gm of soil) greatly retarded the seedling emergence of sugar beet 'Monogerm CSF 1971' in Vineland fine sandy loam. In comparison with controls, initial population densities (P_i's) of 1.7, 3.0, 6.2, and 14.4 larvae/gm of soil respectively reduced the weight of storage roots by 38, 56, 64, and 92%. Weights of tops also decreased with increases in P_i; weights of tap and small feeder roots tended to be higher at all P_i's except the highest. Sucrose percentage was not affected by any initial nematode density. The populations were lower at midseason than at seeding, and at harvest had increased greatly, with respective populations of 339, 402, 222, and 140 larvae/gm of soil. At harvest, cysts/gm of soil and cysts/gm of root were respectively 4.4 and 72, 6.1 and 99, 6.1 and 191, and 5.8 and 140. The maximum rate of multiplication was 150-200, and maximum density was 400 larvae/gm of soil. The high pathogenicity and multiplication rate of the nematode was attributed to optimum temperature conditions and soil type. *Key Words:* sugar beet nematode, *Beta vulgaris*, crop losses.

In Canada, the sugar beet nematode, *Heterodera schachtii* Schmidt, has been a problem on sugar beets in two counties in southwestern Ontario (18) and in southern Alberta (8). Distribution is widespread in eight other counties in southern Ontario (18). The relation of sugar beet response to preplant densities of *H. schachtii* in the field has been studied in the Netherlands (3), Germany (16), England (4), and U.S.A. (2). Yield losses varied with climate and soil type (19), time of seeding (16), and soil temperature (12). Nematode multiplication rate varies with initial density (19), soil moisture and texture (13), soil temperature (12, 13), depth in the soil (19), and size of root of the host (4).

This work was done to assess the response of sugar beets to different population densities of *H. schachtii* in Vineland fine sandy loam, and to determine nematode multiplication rate on this host.

MATERIALS AND METHODS

The origin of the population of *H. schachtii* and the method of rearing large numbers of larvae have been described (9). Also reported (9) have been the means of obtaining the four population densities in Vineland fine sandy loam, the experimental design (5 treatments, 20 replications), and installation of the microplots and moisture-temp sensors.

One day after tiles were filled with soil (10 kg), five sugar beet seeds (*Beta vulgaris* L., 'Monogerm CSF 1971') were planted per tile. Because emergence failed at the two highest densities, all microplots were reseeded 18 days later; 10 seeds, presoaked in water for 24 h, were planted per microplot. Initial nematode population densities (P_i) were determined from soil samples at the time of reseeding and extracted for 1 week by the Baermann pan method (9). Ten and seventeen days after reseeding, the respective numbers of plants per microplot were reduced to three and one. Addition of air-dried groundbed soil to each microplot, fertilization, and root maggot control followed previous practices (9).

Population densities of the nematode (P_m) were determined 35 days after reseeding, at about midseason (9). Yield and growth data were taken at crop maturity, 18 weeks after reseeding. The pointed tap roots (including adhering feeder roots) were cut off from the commercial storage roots, and their weights were recorded separately. Sugar content was determined on each of five beets from each treatment. Also determined (9) was the final population of larvae and cysts in the soil and the number of cysts on the roots. A favorable moisture supply was maintained in the root zone throughout the growing period by natural rainfall supplemented with irrigation when necessary.

Received for publication 24 August 1977.

[1] Nematologist, Research Branch, Agriculture Canada, Research Station, Vineland Station, Ontario, L0R 2E0. Thanks are due Dr. P. Bergen and Mr. J. W. Hall of Canadian Sugar Factories, Taber, Alberta, for advice, seeds, and sucrose analyses; and Mr. D. Keunen for technical assistance.

RESULTS

When the tiles were filled (June 1), the four population densities of *H. schachtii* larvae were 4, 12, 36, and 108/gm of soil. Since the two highest densities caused almost complete failure in seedling emergence, all microplots were reseeded 18 days later. By this time, the P_i's had declined to 1.7, 3.0, 6.2, and 14.4 larvae/gm of soil, and seedling emergence was suppressed little if at all.

At harvest (Oct. 22), the respective weights of the storage roots were 38, 56, 64, and 92% lower than in the uninfested control (Table 1). Beet yields were plotted against the logarithm of the P_i (Fig. 1A), and the regression coefficient was calculated ($r = -0.6530$, $P = 0.01$). Weights of plant tops also decreased with increase in P_i (Table 1). Weights of tap root and small feeder roots tended to be greater than in the check at all P_i values except the highest. Percent sucrose in the storage roots was not affected by any nematode density (Table 1).

By 35 days after reseeding, soil populations had declined to 0.7, 1.7, 5.0, and 11.9/gm of soil from the respective levels at 18 days (1.7, 3.0, 6.2, and 14.4) (Table 2). At harvest, the respective densities had increased to 339, 402, 222, and 140/gm (Table 2). When the logarithm of the P_i was plotted against the logarithm of the final soil population densities (P_f), estimates for the maximum rate of multiplication [*a* in Seinhorst's (15) equation for sedentary nematodes] of 150–200, and for the maximum density, *M* (14), 400 larvae/gm of soil, were derived graphically from the extrapolated curve (Fig. 1B).

TABLE 1. Effects of *Heterodera schachtii* on growth and yield of sugar beets.[a]

P_i[b] (no. of larvae per gm soil)	Weight of tops (gm)	Weight of storage roots (gm)	Weight of tap- and small feeder roots (gm)	% sugar
Control	1,225	2,008	17	12.0
1.7	959	1,246	27	12.6
3.0	725	890	22	12.7
6.2	663	715	21	13.0
14.4	268	164	12	12.3
LSD P = 0.05	250	320	6	N.S.

[a]Average of 20 plants.
[b]P_i = initial population density of larvae.

TABLE 2. Effects of sugar beets on *Heterodera schachtii*.

P_i[a] (no. of larvae per gm soil)	Larvae per gm soil		Cysts per gm soil	Cysts per root system (1000's)[b]	Cysts per gm root[b]
	P_m[a]	P_f[b]	P_f[b]		
1.7	.7	339	4.4	1.6	72
3.0	1.7	402	6.1	2.3	99
6.2	5.0	222	6.1	4.4	191
14.4	11.9	140	5.8	1.6	140
LSD P = 0.05		78	1.2	1.4	50

[a]Based on 10 replicates.
[b]Based on 20 replicates.
P_i = initial population density of larvae.
P_m = 35 days.
P_f = 126 days.

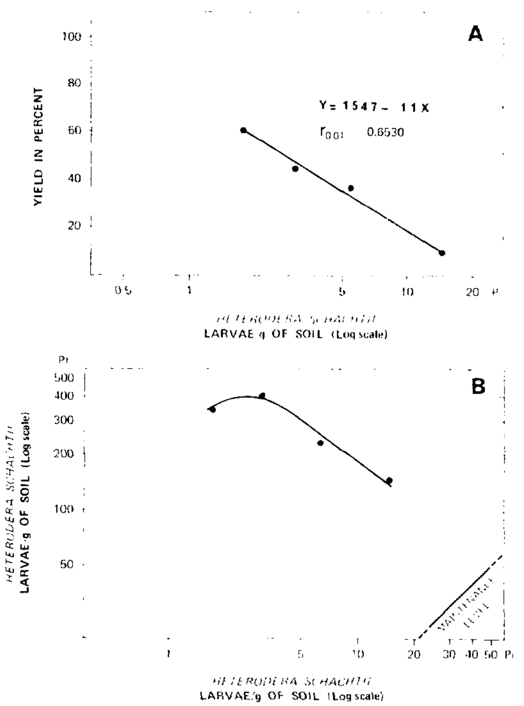

FIG. 1. *A)* Relations between yield of sugar beets (weight of storage roots) and initial density (P_i) of *Heterodera schachtii* larvae/gm of soil ($y = 1547 - 0.11x$). *B)* Relations between final density (P_f) and initial density (P_i) of *Heterodera schachtii* larvae on sugar beets.

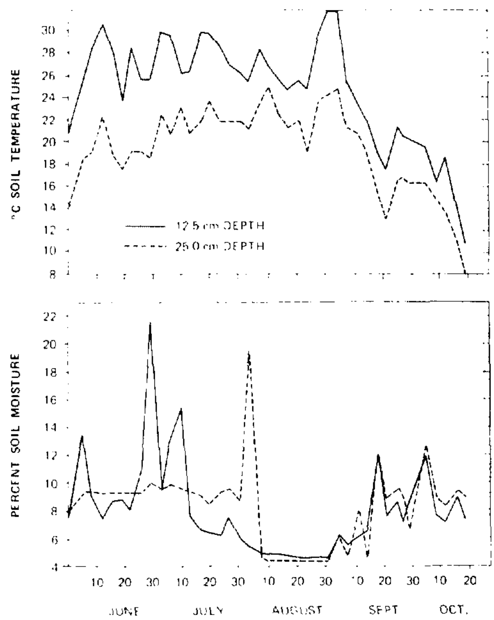

FIG. 2. Soil temperature and soil moisture in microplots cropped to sugar beets at Vineland Station, Ontario, in 1973. Monitored twice weekly.

The numbers of cysts/gm of soil at termination of the experiment were higher at P_i values of 3.0, 6.2, and 14.4/gm than at 1.7/gm. The numbers of cysts per root system or per gm of root increased with increasing densities except at the highest P_i.

Soil temperature, measured twice weekly, averaged about 25 C during the first 3 months of growth and then declined to about 10 C at the end of October (Fig. 2). Except during a 3-week dry spell in August, soil moisture averaged 8–10% for most of the growing season (Fig. 2). This level was intermediate between the permanent wilting point (5%) and field capacity (22%) of this soil type.

DISCUSSION

The straight regression line ($y = 1547 - 0.11x$) produced by plotting plant yield against the logarithm of the P_i's (Fig. 1A) agreed with lines found in several other nematode/plant studies (10). Yields were comparable to those in Idaho and Utah, where losses of about 40% were associated with P_i's of 0.7 to 2.2 larvae/cm^3 of soil (5), and were greater than in California, where a P_i of 40 larvae/gm of soil caused a loss of 75% (7). Losses were also much greater than in the Netherlands, where economic damage is probable from P_i's of 3 to 10 eggs or larvae/cm^3 of soil (3), and in England, where an "economic ceiling level" of 10 eggs/gm of soil has been suggested (4).

The destructiveness of the nematode in this experiment is probably caused by late seeding and high soil temperatures, since sugar beets can germinate and grow at temperatures below optimum for nematodes (12). Beets were sown about 1 month later than is usual in Ontario (1). Since the 25 C temperature at seeding was optimal for the nematode (12, 13), the rootlets were probably invaded without delay. Massive invasion at the high P_i's probably caused the striking suppression in seedling emergence, as reported earlier (11). When beets were reseeded, the P_i's had dropped significantly yet yield losses still exceeded losses normally observed at comparable densities and early seeding. In Germany, a P_i of 12 eggs and larvae/cm^3 of soil caused a 10% loss in sugar yield from late-seeded beets, whereas almost 50/cm³ were required to cause the same loss in early-seeded beets (16). Sugar beets become less susceptible to damage by *H. schachtii* as they grow older and larger (6).

Sucrose content, although unaffected by the nematode (Table 1), as noted elsewhere (17), was low, possibly because of the relatively short total growing period (18 weeks, vs 27 weeks in growers' practice). Sucrose percent has been shown to increase gradually as harvest date is delayed (1).

The high mortality of larvae at the start of the experiment is largely accounted for by the death of seedlings with larvae trapped in their roots, absence of a host, high temperatures desiccating the soil shortly after the first seeding, and removal of seedlings during thinning. The population had increased little by midseason, but by harvest had increased tremendously. The maximum density, or *M*, compared fairly closely with that given by Seinhorst (14) for *H. schachtii* on sugar beets, whereas the maximum rate of multiplication, or *a* (15), was considerably higher than that of Seinhorst, probably because reproduction of *H. schachtii* was promoted by optimum temperature conditions and the fine-textured soil-type, as shown elsewhere (13).

This experiment has shown that relatively low P_i's of *H. schachtii* can severely damage late-seeded sugar beets grown in Vineland fine sandy loam. It lends support to the recommendation (19) that early seeding reduces damage of beet fields by *H. schachtii.*

LITERATURE CITED

1. BALDWIN, C. S., J. F. DAVIS, and C. E. BROADWELL. 1965. An analysis of production practices of sugar beet farmers, 1961-63. Quart. Bull. Mich. Agric. Exp. Stn. 48:36-63.
2. GRIFFIN, G. D. 1974. Determination of Heterodera schachtii populations and their relation to economic losses of sugar beets. J. Nematol. 6:141 (Abstr.)
3. HEIJBROEK, W. 1973. Beta vulgaris—Heterodera schachtii FAO Manual, Crop Loss Assessment Method, Ser. 262. Suppl. 1. Spec. Method 111.
4. JONES, F. G. W. 1965. Beet eelworm. Pages 189-198. *In* J. F. Southey, ed. Plant Nematology, No. 7, 2nd edition. Techn. Bull. Minist. Agric., London.
5. JORGENSON, E. C. 1969. Control of the sugar beet nematode, Heterodera schachtii, on sugar beets with organophosphate and carbamate nematicides. Pl. Dis. Rep. 53:625-628.
6. JORGENSON, E. C., and J. R. MUSSELMAN. 1966. Influence of seedling age on susceptibility of sugar beet to Heterodera schachtii. Phytopathology 56:883-884 (Abstr.)
7. KONTAXIS, D. G., I. J. THOMASON, P. YU, and B. SMITH. 1975. Chemical control of the sugar beet cyst nematode. Calif. Agr. Dec.: 6-7.
8. LILY, C. E., A. M. HARPER, and E. J. HAWN. 1961. Discovery of the sugar beet nematode in Western Canada. Can. Plant Dis. Surv. 41:288.
9. OLTHOF, T. H. A., J. W. POTTER, and E. A. PETERSON. 1974. Relationship between population densities of Heterodera schachtii and losses in vegetable crops in Ontario. Phytopathology 64:549-554.
10. OOSTENBRINK, M. 1966. Major characteristics of the relation between nematodes and plants. Meded. Landbouwhogeschool Wageningen 66-4:3-46.
11. POLYCHRONOPOULOS, A. G., and B. F. LOWNSBERY. 1968. Effect of Heterodera schachtii on sugar beet seedlings under monoxenic conditions. Nematologica 14:526-534.
12. RASKI, D. J., and R. T. JOHNSON. 1959. Temperature and activity of the sugar beet nematode as related to sugar beet production. Nematologica 4:136-141.
13. SANTO, G. S., and W. J. BOLANDER. 1976. Effects of soil temperature and soil type on the reproduction of Heterodera schachtii and Meloidogyne hapla on sugar beets. J. Nematol 8:301-302 (Abstr.).
14. SEINHORST, J. W. 1967. The relationships between population increase and population density in plant parasitic nematodes. III. Definition of the term host, host status and resistance. IV. The influence of external conditions on the regulation of population density. Nematologica 13:429-442.
15. SEINHORST, J. W. 1970. Dynamics of populations of plant parasitic nematodes. Annu. Rev. Phytopathol. 8:131-156.
16. STEUDEL, W., and R. THIELEMANN. 1970. Weitere Untersuchungen zur Frage der Empfindlichkeit von Zuckerruben gegen den Rubennematoden (Heterodera schachtii Schmidt). Zucker 23:106-109.
17. THIELEMANN, R., and W. STEUDEL. 1973. Neunjahrige Erfahrungen mit Monokultur von Zuckerruben auf mit Heterodera schachtii (Schmidt) Verseuchtem Boden. Nachrichtenbl. Deutsch. Pflanzenschutzd. 25: 145-149.
18. TOWNSHEND, J. L., and T. H. A. OLTHOF. 1967. The sugar beet nematode, Heterodera schachtii, Schmidt, and other plant-parasitic nematodes on rhubarb in Ontario. Can. Plant Dis. Surv. 47:14-16.
19. WEISCHER, B., and W. STEUDEL. 1973. Nematode diseases of sugar beet. Pages 49-65. *In* J. M. Webster. ed. Economic Nematology. Academic Press, New York.