

Effect of Plant Age and Transplanting Damage on Sugar Beets infected by *Heterodera schachtii*

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Abstract: Sugar beet (*Beta vulgaris* L. cv. Monogerm C.S.F. 1971) seeds sown into Vineland fine sandy loam, infested with 15,500 *H. schachtii* juveniles/pot, showed little growth during an 11-week test in the greenhouse. Seedlings transplanted at 2, 4, and 6 weeks of age had 32, 30, and 31% less top weight and 71, 68, and 59% less root weight, respectively, compared to controls grown in nematode-free soil. Nematode reproduction in both direct-seeded and transplanted sugar beets was limited and related to root weight. Shoot/root ratios were increased by the nematodes in all nematode-infested beets compared to those grown in soil without nematodes. In contrast to seeding or transplanting sugar beets into nematode-infested Vineland fine sandy loam, an inoculation of Beverly fine sandy loam supporting 0 (seeds), 2-, 4-, and 6-week-old sugar beet seedlings with 7,400 juveniles/pot, followed by 11 weeks of growth in the growth-room, resulted in top weight losses of only 13, 3, 18, and 15% and losses in root weight of 44, 38, 36, and 38%, respectively. Nematode reproduction was high and all shoot/root ratios were increased by the nematode compared to the noninoculated controls. These experiments have shown that sugar beets sown into nematode-infested soil are damaged much more heavily by *H. schachtii* juveniles than seeds inoculated with the nematode immediately following sowing. Results indicate that an increase in tolerance of sugar beets to attack by *H. schachtii* does not occur beyond the first 2 weeks of growth and that transplanting damage lowers the tolerance of seedlings to nematode attack. **Key words:** sugar beet cyst nematode, age tolerance, transplanting damage, host-parasite relationship. *Journal of Nematology* 15(4):555-559. 1983.

Enhanced tolerance of sugar beets (*Beta vulgaris* L.) to attack by the sugar beet cyst nematode (*Heterodera schachtii* Schmidt) with increasing age or size of the plant is well documented (5,10,17). Sugar beets are usually sown as early in the spring as possible so that the seedlings will attain this enhanced tolerance by the time temperatures are optimum for the nematode (2,5,13).

With some crops intolerant of cool temperatures, age and size are attained by setting transplants in the field when temperatures permit. Transplanting, however, often causes severe damage to root systems through the loss of many fine feeder roots. Seinhorst and Olthof (unpublished) showed that transplanting strongly decreased the tolerance of tobacco to attack by the root lesion nematode, *Pratylenchus penetrans* (Cobb).

This study compares the age-related increase in tolerance (as seen in sugar beets) to the possible decrease in tolerance due to transplanting damage (as observed in tobacco) with sugar beets as a model crop.

MATERIALS AND METHODS

Each greenhouse or growthroom experiment, using sugar beet, *Beta vulgaris* L. cv. Monogerm C.S.F. 1971, consisted of four treatments (seedling age) replicated 12 times (pots) and arranged in a randomized block design on the bench. All data were analyzed by Duncan's new multiple-range test or analysis of variance.

Greenhouse: Three batches of 24 sugar beet seedlings, each sown 2 weeks apart, were grown singly in 2.5-cm clay pots filled with potting soil. Six weeks after the first sowing, half of the seedlings in each batch were transplanted with some adhering soil into 10-cm clay pots filled with 600 g of Vineland fine sandy loam (61% sand, 28% silt, 11% clay, pH 5.7, organic matter 3.2%) infested with 15,500 *H. schachtii* juveniles/pot; numbers of nematodes were based on 2-week extraction with the Baermann pan method (16). To serve as controls, the other half were transplanted into similar soil steam-sterilized previously for 30 min at 120 C. Immediately after transplanting, another batch of 24 10-cm clay pots filled with either nematode-infested or steam-sterilized Vineland fine sandy loam were seeded to sugar beets at 5-6 seeds/pot and thinned to one seedling/pot 10 days later. All pots, ranging from freshly seeded

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pots to those containing 6-week-old plants, were kept for an additional 11 weeks at mid-summer temperatures in the greenhouse. Upon termination of the experiment, weights of tops and roots were determined and juveniles, extracted from the soil for 2 weeks, were counted.

Growthroom: Ninety-six 10-cm clay pots were each filled with 600 g of Beverly fine sandy loam (comparable in soil texture to Vineland fsl) containing 6% moisture, covered with aluminum foil, and kept at 22.5 C. Twenty-four pots were sown each with four sugar beet seeds, presoaked in water for 24 hours, and then placed in a growthroom at 22.5 C, 75% R.H., and 160–215 hlx. Seeding was repeated twice at 2-week intervals. In order to obtain large amounts of inoculum, *H. schachtii* juveniles were extracted with a combination of the Fenwick can method (3) and the Baermann pan method (16) from heavily infested Vineland fine sandy loam cropped to cabbage. At inoculation, the pots containing 6-, 4-, or 2-week-old plants were thinned to one seedling/pot and the remaining 24 pots were seeded. In half the pots (12 of each plant age), *H. schachtii* juveniles were pipetted in water at 7,400/pot into four holes in the soil surrounding each seedling or seed; the other 12 pots (controls) received water only. After inoculation, plants were grown for 11 weeks in the growthroom and top and root weights were determined and final juvenile densities (P_f) in the soil counted as before.

RESULTS

Greenhouse: Practically no growth at all was made when seeds were sown directly into nematode-infested soil (Table 1). Regardless of age at which seedlings were initially exposed to nematode attack, top and root weight of nematode-infected plants differed significantly from the uninfected control. There was no age-related difference in final top weight in plants 4 or 6 weeks old at the time of transplanting into infested soil.

Age effects on root weight of the controls were similar to top weight; however, root weight of nematode-infected seedlings increased with age until 6 weeks.

The shoot/root (S/R) ratio decreased

with age at transplanting in controls and nematode-infected plants. Regardless of age, the S/R ratio of the nematode-infected seedlings was higher than that of the controls (Table 1).

Final juvenile population density decreased relative to the initial density (P_i) when seeds were sown into nematode-infested soil. With transplanted seedlings, a limited amount of reproduction was observed (Table 1).

Growthroom: Neither addition of nematodes at seeding nor inoculation of 2-week-old seedlings resulted in significant differences in weight of top, as compared to controls (Table 2). However, top weight of 4- and 6-week-old seedlings was significantly reduced by nematodes, as was root weight in all seedlings regardless of age at inoculation.

Top and root weights of controls and seedlings inoculated at transplanting differed significantly from those inoculated at seeding. However, there were no age-related differences between the seedlings except top weight at 2 versus 6 weeks of age.

The S/R ratio decreased with age in both control and nematode treatments; those of plants inoculated with nematodes, regardless of age at inoculation, were significantly higher than the controls (Table 2).

Final juvenile density increased more than 8 times the P_i when seeds were sown at inoculation. With 2-, 4-, and 6-week-old seedlings, the P_f values were significantly greater and averaged 39 times the P_i (Table 2).

DISCUSSION

Sowing seed in nematode-infested soil resulted in very little growth, whereas much less damage occurred when seeds were sown in nematode-free soil followed immediately by inoculation with nematodes. In the latter case, only root weight was significantly lower. Presumably, the root system was able to develop and acquire some tolerance during the time required for the nematodes to reach the roots from points of inoculation. These results confirm Griffin's observation (5) that *H. schachtii* was highly pathogenic when germinated sugar beet seed was sown into nematode-infested soil. The results also agree with Abawi and Mai's (1) report that

Table 1. Top and root weight and shoot/root ratio of sugar beet (*Beta vulgaris* L. cv. Monogerm C.S.F. 1971) seedlings of different age transplanted or seeded into Vineland fine sandy loam infested with 15,500 *Heterodera schachtii* juveniles/600-g pot, and final density (P_f) of the juveniles in the soil after 11 weeks in the greenhouse.

| Age of seedling at first root exposure to <i>H. schachtii</i> (wk) | Oven-dry weight (g) | | | | | | Shoot/root ratio | | P_f soil No. juveniles/pot (1000's) |
|--|----------------------|-------------------|---------|----------------------|-------------------|---------|----------------------|-------------------|---------------------------------------|
| | Tops | | | Roots | | | Non-infected control | Nematode-infected | |
| | Non-infected control | Nematode-infected | % Diff. | Non-infected control | Nematode-infected | % Diff. | | | |
| 0 | 1.97 a† | 0.04 a*‡ | 98 | .92 a | .01 a* | 99 | 2.14 | 4.00* | 13 a |
| 2 | 3.10 b | 2.10 b* | 32 | 2.11 b | .62 b* | 71 | 1.47 | 3.39* | 46 ab |
| 4 | 4.18 c | 2.92 c* | 30 | 3.47 c | 1.10 c* | 68 | 1.20 | 2.65* | 88 c |
| 6 | 4.09 c | 2.82 c* | 31 | 3.55 c | 1.45 d* | 59 | 1.15 | 1.94* | 74 bc |

†Numbers followed by the same letter within a column are not significantly different ($P = 0.05$) according to Duncan's new multiple-range test.

‡Difference at $P = 0.05$ between weights of noninfected control and those infected with nematodes are marked with an asterisk.

Table 2. Top and root weight and shoot/root ratio of sugar beet (*Beta vulgaris* L. cv. Monogerm C.S.F. 1971) seedlings of different age grown in Beverly fine sandy loam, and final density of *Heterodera schachtii* juveniles in soil after 11 weeks in the growthroom after inoculation with 7,400 juveniles/600-g pot.

| Age of seedling at inoculation (wk) | Oven-dry weight (g) | | | | | | Shoot/root ratio | | P_f soil No. juveniles/pot (1000's) |
|-------------------------------------|------------------------|---------------------|---------|------------------------|---------------------|---------|------------------------|---------------------|---------------------------------------|
| | Tops | | | Roots | | | Non-inoculated control | Nematode-inoculated | |
| | Non-inoculated control | Nematode-inoculated | % Diff. | Non-inoculated control | Nematode-inoculated | % Diff. | | | |
| 0 | 3.01 a† | 2.63 a | 13 | 2.68 a | 1.51 a* | 44 | 1.12 | 1.74* | 58 a |
| 2 | 3.96 b | 3.84 b | 3 | 4.69 b | 2.91 b* | 38 | .84 | 1.32* | 244 b |
| 4 | 4.29 bc | 3.50 b*‡ | 18 | 4.87 b | 3.14 b* | 36 | .88 | 1.11* | 297 b |
| 6 | 4.45 c | 3.80 b* | 15 | 5.55 b | 3.45 b* | 38 | .80 | 1.10* | 277 b |

†Numbers followed by the same letter within a column are not significantly different ($P = 0.05$) according to Duncan's new multiple-range test.

‡Difference at $P = 0.05$ between weights of noninoculated control and those inoculated with nematodes are marked with an asterisk.

yields of direct-seeded cabbage were smaller than those of cabbage transplanted into heavily infested fields.

Apart from the extreme sensitivity of germinating seed in nematode-infested soil, little evidence was found to suggest an increase in tolerance with age beyond the first 2 weeks. With 2-, 4-, and 6-week-old seedlings, damage to both tops and roots did not change with age and averaged, respectively, 31% and 66% in the greenhouse and 12% and 37% in the growthroom. These results are at odds with those of Griffin (5) who observed a direct relationship between plant age and damage by *H. schachtii* when germinated seed and sugar beet seedlings of different age were transplanted into soil containing much lower juvenile population densities than in the greenhouse study described above. The short duration of age effect on the tolerance of plants was also observed with *Pratylenchus penetrans* on apple (8) and alfalfa (12).

Sugar beet seedlings transplanted into nematode-infested soil suffered much more damage than nontransplanted seedlings inoculated with nematodes. It is possible that the damaged root systems form new roots resulting in a higher proportion of young root tips in transplanted seedlings. *Heterodera schachtii* juveniles are known to penetrate roots just behind the growing tip or where lateral roots emerge (14).

It seems unlikely that the difference in P_1 in the two experiments (25.9 vs. 12.3/g of soil) played a major role in the difference in damage observed. Both densities resulted in considerably less damage than in microplot experiments (11) where P_1 's of 6.2 and 14.4/g of soil caused respective losses in top weight of 46% and 79%. Significant sugar beet yield losses were reported at densities varying from 1 to 20 eggs/ml of soil (2,4,6,7,9,11), depending on environmental conditions (5,17).

The method of inoculation probably also affected the actual P_1 . In this greenhouse study and in microplots (11) and naturally infested field soil, the nematodes were evenly distributed throughout the soil. Therefore, most of the nematodes were too far removed from the germinating seeds or the small transplants to have an immediate effect. In contrast, when nematodes were

added to the soil in the growthroom study, they were concentrated near the germinated seed or transplanted root system. However, some mortality may have occurred, as was found with *Pratylenchus penetrans* when 46% died after they were injected into coarse sand (Seinhorst and Olthof, unpublished).

In both experiments, the S/R ratio tended to decrease with age in both controls and nematode-infected plants. Similarly, the presence of nematodes caused a significant change in the S/R ratio, regardless of age at which seeds or seedlings first became exposed to nematodes or inoculation. The S/R ratios were generally higher in the transplanted seedlings than in the nontransplanted seedlings, owing perhaps to loss of roots during transplanting. An increase in the S/R ratio with nematodes indicates that roots are damaged disproportionately more than the tops. Griffin (5) also noted that reduction in top growth was less than those for root growth in similar experiments. This phenomenon suggests that sugar beet seedlings are able to lose a certain amount of roots without showing a reduction in top growth, as was also shown for corn (15).

Final density of juveniles in the soil in both experiments depended on the weight of the root and averaged about 85,000 juveniles produced per gram of dry root in the growthroom and 69,000 in the greenhouse; this agrees with Griffin (6). The transplanting damage in the greenhouse, which could not be overcome in time, may explain both the smaller roots and hence the lower reproduction.

These experiments have confirmed that growth of sugar beets is severely restricted when seeds are sown in nematode-infested soil. The results indicate that an increase in tolerance of sugar beets to attack by *H. schachtii* does not occur beyond the first 2 weeks of growth, and that transplanting damage lowers the tolerance of seedlings to nematode attack.

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