Susceptibility of plant selections to Heterodera schachtii and a race of H. trifolii parasitic on Sugarbeet in The Netherlands[1]

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Abstract: Similar host ranges were found for *Heterodera schachtii* and a race of *H. trifolii* parasitic on sugarbeet in The Netherlands. Twenty-nine of 41 plant accessions evaluated were susceptible to *H. trifolii*. Five breeding lines of the interspecific hybrid *Beta vulgaris-B. procumbens* which are resistant to *H. schachtii* were highly susceptible to *H. trifolii*. An accession of *B. maritima* with partial resistance to *H. schachtii* was resistant to *H. trifolii*. *Key words:* clover cyst nematode, sugarbeet nematode, Chenopodiaceae, Cruciferae, susceptibility.

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Until recently, the sugarbeet nematode, *Heterodera schachtii* Schm., 1871, was the only species of the genus known to attack sugarbeet, *Beta vulgaris* L. In 1975 a race of the clover cyst nematode, *H. trifolii* Goffart, was found to be widely distributed in southeastern Netherlands. Subsequent investigations revealed that this race caused severe sugarbeet crop losses and that legumes and a number of Dutch plant cultivars within the families Chenopodiacea and Cruciferae were hosts (6). The majority of agriculturally important plant species susceptible to *H. schachtii* are members of these families.

In 1981 sugarbeets were grown on more than 526,000 ha in 13 states of the USA. Although almost all of the beet growing areas are infested with *H. schachtii*, the race of *H. trifolii* that attacks sugarbeet has not been reported in the USA. Because of the severe damage to sugarbeet caused by this race of *H. trifolii*, investigations were undertaken in The Netherlands to obtain information on the susceptibilities of U.S. sugarbeet cultivars, cruciferous crops frequently grown in rotation with sugarbeet, interspecific hybrids of *Beta vulgaris* and *B. procumbens* resistant to *H. schachtii*, tomato, pea, and bean.

MATERIALS AND METHODS

Evaluation of host susceptibility: Forty plant cultivars or breeding lines (Table 1), selected mostly from the Cruciferae and Chenopodiaceae, were evaluated for susceptibility to the race of *H. trifolii* parasitic on sugarbeet.

Except for the *Beta* species and cultivars of bean and pea, seed were individually

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Table 1. Response of selected crop, ornamental, and weed plants to *Heterodera trifolii* and *H. schachtii*.

Plant species	Common name	Cultivar or breeding line	Number tested	*H. trifolii* infection index*	Host susceptibility† for *H. schachtii*
Beta corolliflora Zoss	Wild beet	WB 8	18	4.0	S
B. lomatogona Fisch & Meyers	Wild beet	WB 222	16	4.0	S
B. macrocarpa Guss.	Wild beet	WB 25	11	4.0	S
B. maritima L.	Wild beet	WB 151	20	4.0	S
B. patellaris Moq.	Wild beet	WB 74	9	0	R
B. patula Ait.	Wild beet	WB 95	13	4.0	S
B. procumbens Chrys. Sm.	Wild beet	WB 100	6	0	R
B. webbiana Moq.	Wild beet	WB 130	2	0	R
B. vulgaris L.	Table beet	Detroit Dark Red	20	4.0	S
B. vulgaris L.	Swiss chard	Fordhook Giant	7	4.0	S
B. vulgaris L.	Sugarbeet	Monohil	25	4.0	S
B. vulgaris-procumbens	Interspecific hybrid	SV 2	27	4.0	R
B. vulgaris-procumbens	Interspecific hybrid	SV 3	18	4.0	R
B. vulgaris-procumbens	Interspecific hybrid	N 146	6	4.0	R
B. vulgaris-procumbens	Interspecific hybrid	N 486	9	4.0	R
B. vulgaris-procumbens	Interspecific hybrid	YU 1	15	4.0	R
Brassica oleracea var. gemmifera L.	Brussels sprouts	Jade Cross E. strain	20	4.0	S
B. oleracea var. capitata L.	Cabbage	Copenhagen Market	20	4.0	S
B. oleracea var. botrytis L.	Cauliflower	Early Snowball	20	4.0	S
B. oleracea var. gongylodes L.	Kohlrabi	Early White Vienna	20	4.0	S
B. rapa L.	Turnip purple top	Strap Leaved	17	4.0	S
B. rapa L.	Turnip purple top	White Globe	17	4.0	S
Dianthus heddewigii L.	Pinks	Fringed Gaiety	20	4.0	S
Iberis umbellata L.	Globe Candytuft	Fairy Mixed Colors	20	0	S
Lycopersicon esculentum Mill.	Tomato	Ace	20	1.0	S
L. esculentum Mill.	Tomato	Improved Pearson	20	0.8	S
L. peruvianum (L.) Mill.	Wild tomato	PI 128657 (Peru)	20	0	S
L. peruvianum (L.) Mill.	Wild tomato	PI 270435 (Mexico)	20	0	S
L. pimpinellifolium (L.) Mill.	Current tomato	PI 79532 (Peru)	11	0.6	R
L. pimpinellifolium (L.) Mill.	Current tomato	PI 270453 (Mexico)	17	0.2	R
Phaseolus lunatus L.	Lima bean	King of the Garden	4	0	R
P. vulgaris L.	Garden bean	Spartan Arrow Stringless	18	0	R
P. vulgaris L.	Garden bean	Sungold (bush type)	28	0	R
Pisum sativum L.	Garden pea	Early Perfection	8	4.0	R
Rheum rhabarbarum L.	Rhubarb	Pie Plant Victoria	20	4.0	S
Raphanus sativus L.	Radish	Early Scarlet Globe	20	4.0	S
Spinacia oleracea L.	Spinach	Bloomsdale or Savory Leaved	17	3.2	S
Stellaria media (L.) Vill.	Common chickweed		20	3.5	S

Table 1. (Continued)

Plant species	*Common name*	Cultivar or breeding line	Number tested	*H. trifolii* infection index*	Host susceptibility† for *H. schachtii*
Tropaeolum majus L.	Garden nasturtium	Jewel Mixed Colors	13	0	S
Vigna unguiculata (L.)	Black Eye peas	California Black Eye	4	0	R

*Infection index: 0 = no female nematodes; 1 = lightly infected; 2 = moderately infected; 3 = severely infected; 4 = heavily infected.

†Susceptibility to *H. schachtii* reported by Steele (11) or observed in unreported tests by Steele. R = resistant; S = susceptible.

sown directly into individual rectangular PVC tubes 1.5 × 2.0 × 12.0 cm long filled with fine silver sand (13). Seed of *Beta* species were germinated in sand. Ten days after germination single seedlings were transplanted into individual plastic containers which were inoculated with 300 second-stage infective *H. trifolii* L2 juveniles. The inoculum was introduced adjacent to the seedling 1.5 cm below the soil surface. The inoculated plants were grown in an environmental chamber maintained at 24 C with an 8 h photoperiod at about 50,000 Lux. Bean and pea cultivars and sugarbeet cv. Monohil were sown directly in aluminum foil cylinders 6.5 × 17.5 cm long filled with steam-sterilized sandy loam soil. Ten days after the seedlings emerged, 30 *H. trifolii* cysts containing eggs and juveniles were added to the soil in each cylinder and the plants then placed on greenhouse benches. Twenty-eight days after inoculation, plants were harvested and the roots washed gently to remove sand and soil and examined for adult female *H. trifolii.*

Effect of temperature on host susceptibility: The infectivities of *H. schachtii* and *H. trifolii* were compared on 19 plant accessions (Table 2) grown at 24 and 28 C. Twenty seeds of each accession were sown directly into rectangular plastic tubes filled with fine silver sand. Ten days after germination, 500 newly hatched *H. schachtii* or *H. trifolii* second-stage infective juveniles were added to each tube as described previously. Inoculated plants were in environmental chambers at constant temperatures maintained at 24 or 28 C and examined for nematode development 27 and 22 days after inoculation, respectively. Up to 100 visible adult females firmly attached to the root surfaces were counted per root system but not beyond. Subsequent to these tests, SV-1, SV-2, SV-3, N-146, YU-1, and N-486 (cultivars resistant to *H. schachtii*) were again tested to verify resistance of these lines to U.S. populations of *H. schachtii.* Ten-day old seedlings were transplanted to individual aluminum foil cylinders and inoculated with the eggs and juveniles of 30 cysts. After 33 days in a greenhouse, the roots of each plant were washed and examined for adult females of *H. schachtii.*

RESULTS

Evaluation of host suitability: The numbers of selections are listed in Table 1 in the column head "Numbers tested." Of the 40 selections tested, 29 were susceptible to *H. trifolii;* no adult females were observed on any of the plants of 11 accessions. Six *Beta* spp, two *Brassica* spp, *Rheum rhubarbarum* (rhubarb), *Raphanus sativus* (radish), *Spinacia oleracea* (spinach), Stellaria media (common chickweed), and *Dianthus heddewigii* (pinks) were efficient hosts for *H. schachtii* and *H. trifolii* races parasitic on sugarbeet. The wild beet species *Beta patellaris, B. procumbens,* and *B. webbiana* were immune to the *H. trifolii* race. However, all plants of the five accessions of *B. vulgaris-procumbens,* which are resistant to *H. schachtii,* were highly susceptible to the sugarbeet race of *H. trifolii.*

None of three bean cultivars, *Phaseolus* spp, was a host for the sugarbeet race of *H. trifolii,* but garden pea, *Pisum sativum* cv. Early Perfection, was highly susceptible to the nematode.

Table 2. Effects of temperature on *Heterodera schachtii* and *H. trifolii* development to the adult female stage in plants inoculated with 500 larvae/plant

Species	Cultivar or Accession	*H. schachtii*							
		24 C*				28 C†			
		No. plants tested	No. plants infected	No. ♀/plant‡ range	No. ♀/plant‡ x̄	No. plants tested	No. plants infected	No ♀/plant‡ range	No ♀/plant‡ x̄
Beta vulgaris L.	Monohil	20	20	>100	>100	20	20	>100	>100
B. vulgaris L.	USH 10	20	20	> 50	> 50	20	20	>100	>100
B. vulgaris-procumbens	SV-1	9	4	1–3	0.8	10	1	1	> .1
B. maritima L.	SVP-BMH	20	20	>100	>100	20	20	>100	>100
B. maritima L.	SVP-BMF	20	20	4–81	25.1	20	19	1–98	16.5
B. patellaris Moq.	SVP-WB49	20	0	0	0	20	0	0	0
B. procumbens Chrys. Sm.	SVP-WB21	20	0	0	0	11	1	1	> .1
Brassica napus L.	Yet Neuf	11	11	33–105	77.8	15	16	9–144	58.1
Lycopersicon esculentum Mill.	Pearson Al	11	11	5–15	10.3	11	11	3–25	10.6
L. esculentum Mill.	Tomout	10	0	0	0	12	12	4–25	12.8
L. peruvianum (L.) Mill.	PI 128657	...	...	...	...	9	6	1–3	0.9
L. pimpinellifolium (L.) Mill.	PI 79532	10	0	0	0	10	4	1	0.4
Raphanus sativus L.	Silentina	...	...	...	...	9	8	3–86	28.2
R. sativus L.	SVP-Rs636	9	8	...	...	10	10	16–51	34.8
R. sativus L.	SVP-Rs604.03	...	...	1–19	8.8	10	9	1–29	6.4
Sinapsis alba L.	Hohenheimer	...	...	...	...	9	9	1–55	22.3
S. alba L.	SVP-Sa601.05	11	9	1–18	3.0	8	1	1	0.1
Spinacia oleracea L.	Round Seed	...	...	...	...	4	4	10–16	12.8
S. oleracea L.	Sharp Seed	20	20	>100	>100	10	10	27–69	47.9

*Plants examined 27 days after inoculation.
†Plants examined 22 days after inoculation.
‡Numbers above 100 were not counted.

Table 2. (Continued)

Species	Cultivar or Accession	*H. trifolii* 24 C* No. plants tested	No. plants infected	No. ♀/plant‡ range	x̄	28 C† No. plants tested	No. plants infected	No ♀/plant‡ range	x̄
Beta vulgaris L.	Monohil	20	20	>100	>100	20	20	>100	>100
B. vulgaris L.	USH 10	20	20	> 50	> 50	20	20	>100	>100
B. vulgaris-procumbens	SV-1	9	9	3–>50	>24.8	10	0	0	0
B. maritima L.	SVP-BMH	20	20	>100	>100	20	20	>100	>100
B. maritima L.	SVP-BMF	20	7	1–5	0.8	19	13	1–5	1.3
B. patellaris Moq.	SVP-WB49	20	0	0	0	20	0	0	0
B. procumbens Chrys. Sm.	SVP-WB21	20	0	0	0	20	0	0	0
Brassica napus L.	Yet Neuf	10	10	>50	>50	10	10	18–78	47.8
Lycopersicon esculentum Mill.	Pearson Al	9	9	4–14	8.7	11	11	1–9	5.6
L. esculentum Mill.	Tomout	10	1	1	0.1	12	12	7–20	11.4
L. peruvianum (L.) Mill.	PI 128657	...	...	...	...	11	4	1	0.4
L. pimpinellifolium (L.) Mill.	PI 79532	10	0	0	0	10	6	1–3	1.3
Raphanus sativus L.	Silentina	...	...	...	...	8	8	1–72	34.8
R. sativus L.	SVP-Rs636	7	7	...	...	8	8	7–56	19.8
R. sativus L.	SVP-Rs604.03	...	...	18–41	25.1	10	5	1–4	1.2
Sinapsis alba L.	Hohenheimer	...	...	...	...	11	10	17–67	43.0
S. alba L.	SVP-Sa601.05	10	0	0	0	11	3	1–5	0.8
Spinacia oleracea L.	Round Seed	...	...	...	...	8	8	1–10	3.9
S. oleracea L.	Sharp Seed	13	13	4–26	16.5	10	10	2–34	8.8

*Plants examined 27 days after inoculation.
†Plants examined 22 days after inoculation.
‡Numbers above 100 were not counted.

Effect of temperature on host susceptibility: Sugarbeet cultivars Monohil and USH-10 and *Beta maritima* cv. SVP-BMH were highly susceptible both to Dutch populations of *H. schachtii* and to *H. trifolii,* but *B. procumbens* and *B. patellaris* were immune to both nematode species grown at 24 or 28 C (Table 2). All plants of *B. maritima* cv. SVP-BMH were parasitized by more than 100 adult female nematodes. In contrast, roots of the resistant accession of *B. maritima* cv. SVP-BMF averaged significantly fewer females of *H. schachtii* than did cv. SVP-BMH. The mean number of *H. trifolii* found on cv. SVP-BMF was significantly lower than the number of *H. schachtii* per plant. *Beta vulgaris-B. procumbens* SV-1 resistant to *H. schachtii* from Salinas, California, was also highly resistant to the Dutch population of *H. schachtii* (Table 2). However, at 24 C plants of this accession showed varying degrees of susceptibility to the *H. trifolii* race. No females of this species developed on plants grown at 28 C (Table 2).

Oil seed rape, *Brassica napus,* was susceptible to both nematode species. Oil radish, *Raphanus sativus* cvs. Siletina and SVP-Rs636, showed a variable but moderate degree of susceptibility to *H. schachtii* and the race of *H. trifolii.* The oil radish selection SVP-Rs604.03 and white mustard, *Sinapsis alba* cv. SVP-Sa601.05, were resistant but the response was variable to both nematodes, whereas white mustard cv. Hohenheimer showed a response to *H. trifolii* that varied from resistant (less than 10 females per plant) to susceptible (more than 10 females per plant).

Spinacea oleracea 'Sharp Seed' was a good host for *H. schachtii* at 24 C but a less suitable host at 28 C and for *H. trifolii* at both temperatures. The *Lycopersicon* spp were not uniform in their reactions to *H. schachtii* and *H. trifolii;* although slightly greater numbers of *H. schachtii* than *H. trifolii* developed on 'Pearson Al,' the nearly total resistance of 'Tomout' and *L. pimpinellifolium* to both nematode species at 24 C was broken by growing these plants at 28 C (Table 2).

Reevaluation of *B. vulgaris-B. procumbens* hybrids for resistance to *H. schachtii* revealed that no adult females were present on the roots of SV-1, SV-2, SV-3, YU-1 or N-486, while all plants of sugarbeet cv. US H10 were heavily infected. Of 16 plants of accession N-146 evaluated, 9 had no adult female *H. schachtii* and infections of 7 plants ranged from 1 to > 100.

DISCUSSION

Although the wild beet species *Beta patellaris, B. procumbens,* and *B. webbiana* were immune to the *H. trifolii* race, the five *B. vulgaris-procumbens* hybrids resistant to *H. schachtii* were highly susceptible to *H. trifolii.* The accessions SV-1 (Table 2) and SV-2 (Table 1) are progenies of a parent homozygous for the dominant gene or genes conferring resistance to *H. schachtii* crossed with a nematode resistant plant which is either homozygous or heterozygous for this character. The accession SV-3 (Table 1) is the progeny of a cross between resistant homozygous and resistant heterozygous plants, whereas YU-1 is the S3 progeny of a single homozygous resistant plant. The accessions N-146 and N-486 were heterozygous for the gene or genes conferring resistance to *H. schachtii.* The sugarbeet cultivar Monohil (*B. vulgaris* L.) is extensively grown in Europe. The findings of the present test indicate that the gene or genes in either the homozygous or heterozygous combination conferring resistance to *H. schachtii* do not provide resistance to *H. trifolii.* Since *B. procumbens* is immune to *H. trifolii,* the genes conferring resistance to this nematode either were not transferred in the interspecific hybridization of this species and *B. vulgaris* or, if transferred, are not now contributing resistance in these accessions. This indicates that cultivars developed from these lines would be of little use in areas of The Netherlands heavily infested with this *H. trifolii* race unless other control measures are implemented. The results also suggest that sugarbeet and certain cruciferous crops produced in the U.S. may be highly vulnerable to this *H. trifolii* race if the nematode were to gain entry into this country. However, a selection of *B. maritima* which had partial resistance to *H. schachtii* is highly resistant to *H. trifolii* (4). Since *B. maritima* crosses readily with *B. vulgaris,* its resistance to *H. trifolii* may be transferred to sugarbeet.

Raski and Hart (9) failed to infect sugarbeet, *Beta vulgaris,* with a race of *H. trifolii* in California. Holtzmann and Aragaki (5) found a single female on one of three plants of red table beet, *B. vulgaris,* inoculated with *H. trifolii,* but high populations of *H. schachtii* were obtained on swiss chard, *B. vulgaris* cv. Cicla, and Savoy spinach, *Spinacea oleracea.*

Lycopersicon esculentum (tomato) is a marginal host for both nematode species. However, *L. peruvianum* (wild tomato) is a marginal host for *H. schachtii* (12) but is immune to *H. trifolii,* while *L. pimpinellifolium* is immune to *H. schachtii* (12) but is a host for *H. trifolii. Tropaeolum majus* (garden nasturtium) is susceptible to *H. schachtii* but is immune to *H. trifolii.* Mulvey (7) reported that the oak-leaved goosefoot, *Chenopodium glaucum,* is a common host of *H. schachtii* and *H. trifolii* in Canada. These observations are additional evidence that the same gene or genes do not necessarily confer resistance to both nematode species.

Apparently there are a number of races of *H. trifolii.* Mulvey (7) reported that certain cultivars of pea and bean were lightly parasitized by this species, while others were severely parasitized. Franklin (2) found that *P. sativum* was a nonhost but *P. vulgaris* was parasitized to a limited extent. Raski and Hart (9) observed that although only two females developed in garden pea, bush bean (*P. vulgaris* cv. Golden Wax) was heavily attacked by *H. trifolii.* Winslow (14) reported that pea is not a host of *H. trifolii,* but Hastings and Bosher (3) reported a species of *Heterodera* attacked pea in British Columbia, and Singh and Norton (10) found that six isolates of *H. trifolii* only lightly attacked two cultivars of pea and four cultivars of bean. Maas and Heijbroek (6) observed that this race of *H. trifolii* parasitized 13 of 14 bean cultivars, but of 15 pea cultivars examined, only Early Perfection was a host. In the study reported herein, none of three bean cultivars were susceptible to *H. trifolii* and Early Perfection garden pea was highly susceptible to the nematode.

Maas and Heijbroek (6) also found only light infections of the race of *H. trifolii* which attacks beets in The Netherlands on the white clovers 'Barbian,' 'Blanca,' and 'Tamar.' Only two females were found on the red clover, *T. pratense* cv. Robina, and none on 'Rotra.' This is not surprising, since several investigators have reported a wide variability in the susceptibility of *T. repens* and *T. pratense* to races of *H. trifolii* (1,2,5,7,8,9,10). These reports show that plant susceptibility to *H. trifolii* is influenced by varietal differences within common host plant species as well as differences between geographic isolates of the nematode. Although the race of *H. trifolii* evaluated in this study closely approximates the host range of *H. schachtii,* its hosts also include certain legumes which the latter species does not attack. Additional research may reveal varietal differences in susceptibility, or new races of *H. trifolii* parasitic on sugarbeet that show distinctive variations in host susceptibility may be discovered.

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