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Penetration, Development, and Reproduction of *Heterodera schachtii* on *Fagopyrum esculentum*, *Phacelia tanacetifolia*, *Raphanus sativus*, *Sinapis alba*, and *Brassica oleracea*[1]

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Abstract: The penetration, development, and reproduction of a California population of the sugarbeet cyst nematode, *Heterodera schachtii*, was observed on cultivars of cabbage (*Brassica oleracea*), phacelia (*Phacelia tanacetifolia*), buckwheat (*Fagopyrum esculentum*), oilseed radish (*Raphanus sativus*), and white mustard (*Sinapis alba*). With the exception of the nonhost, phacelia, all were readily penetrated by second-stage juveniles of *H. schachtii*. After 38 days at 25 C, no cysts were observed on phacelia cv. Angelia or on the oilseed radish cv. Nemex and Pegletta. Cyst production was low (<2.5 cysts/plant) on the buckwheat cv. Tardo and Prego and most of the oilseed radish cultivars. Cyst production was intermediate (5–14 cysts/plant) on most of the white mustard cultivars, and high on cabbage (20–110 cysts/plant). In microplot studies conducted over 133 days (approx. 450 degree-days, base 8 C), the reproductive index for *H. schachtii* was greater than 1.0 for cultivars of phacelia, oilseed radish, and white mustard as well as in fallow treatments, indicating the need for further research on the use of these crops under field conditions.

Key words: buckwheat, *Fagopyrum esculentum*, *Heterodera schachtii*, oilseed radish, *Phacelia tanacetifolia*, *Raphanus sativus*, reproduction, *Sinapis alba*, sugarbeet cyst nematode, trap crop, white mustard.

The sugarbeet cyst nematode, *Heterodera schachtii* Schmidt, is an economically damaging pest in many sugarbeet growing regions of the world. Management is complicated by the longevity of cysts and eggs, a wide range of weed hosts (1), and the lack of safe and economical nematicides. Sugarbeet cyst nematode management involves disruption of hatching, host finding, penetration, development, and reproduction.

A promising approach is the use of trap crops, plants that allow penetration yet are poor hosts for the nematode. Various plants with potential as trap crops have been shown to stimulate hatch, including sugarbeet (*Beta vulgaris*), oilseed radish (*Raphanus sativus* var. *oleifera*), white mustard (*Sinapis alba*), and buckwheat (*Fagopyrum esculentum*) (5,14,16,17). Nematode-resistant cruciferous crops, particularly oilseed radish, may be useful as crop rotations that reduce *H. schachtii* populations. Cultivars of oilseed radish, white mustard, and buckwheat that stimulate hatch and depress *H. schachtii* reproduction have been developed in Europe (1). The research presented here was conducted to assess the usefulness of these cultivars for *H. schachtii* management in California sugarbeet and cole crop production.

Materials and Methods

Experiment 1. Penetration: Treatments consisted of the following plants: oilseed radish, *Raphanus sativus* var. *oleifera* cv. Adagio, Nemex, Pegletta, Renova, Siletina, Siletta Nova, and Ultimo; white mustard, *Sinapis alba* cv. Albatross, Emergo, Maxi, Martigena, Metex, and Serval; buckwheat, *Fagopyrum esculentum* (Moench) cv. Prego and Tardo; phacelia, *Phacelia tanacetifolia* (Benth.) cv. Angelia; and cabbage, *Brassica oleracea* var. *capitata* cv. Copenhagen Market. All cultivars were from P. H. Petersen Saatzucht, Lundsgaard, Germany, with the exception of Martigena and Renova (KWS Kleinwanzlebener Saatzucht AG, Einbeck, Germany), and Copenhagen Market

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(Northrup King, Co., Minneapolis, MN). The *H. schachtii* population originated in Half Moon Bay, California, and inoculum for experiments was cultured on Copenhagen Market cabbage in greenhouses.

Seeds were germinated at 25 C on moist filter paper in petri dishes. Germinated seeds were transplanted into 10-dram snap-cap vials (Baxter Diagnostics, Hayward, CA) containing 37 cm^3 of autoclaved white silica sand (No. 60 silica sand, Corona Industrial Sand Co., Corona, CA). Vials contained one plant/vial and were inoculated by pipette as a soil drench with approximately 930 J2 (25 J2/cm^3 sand) of *H. schachtii* collected from cysts by Baermann extraction. Inoculated vials were held in an incubator at 25 C and 24 hours light from two F40CW fluorescent lamps. After 5 days, roots were rinsed free of sand, and entire root systems were stained with acid fuchsin (2). Whole root systems were pressed between glass plates (7.5 × 5.0 cm^2), and nematode number and growth stage were determined at 40× magnification using an inverted compound microscope. Growth stages were categorized as J2 (early J2) or swollen (late J2, J3). The experiment was conducted twice. There were five replicates per treatment in the first trial and six replicates per treatment in the second trial.

The data were highly variable and lacked normality and homogeniety of variance, so nonparametric statistics were used. Means were assigned Wilcoxon ranked sum scores, which were subjected to a chi-square approximation of the Kruskal–Wallis test using SAS statistical procedures and software (13). Treatment rank scores were compared using Dunn's method for significant differences ($P \leq 0.05$) between treatments (6). Treatments that had values of zero for all replicates of an observed parameter were not included in the statistical analyses. Although statistically significant differences could not be determined for treatments with consistent zeroes, practical biological significance was inferred and considered as an important indicator of cultivar host status.

Experiment 2. Development within roots: Seventeen cultivars of white mustard, oilseed radish, buckwheat, phacelia, or cabbage were planted and inoculated with *H. schachtii* J2 as previously described. The bottoms of snap-cap vials (Baxter Diagnostic 20 dram [3.7 cm × 6.2 cm]) were perforated once with a 3.0-mm hole, and a 2.5-cm-d circular nylon mesh was placed in the bottom of each vial to prevent sand loss. Vials were filled with 60 cm^3 of silica sand for a final weight of approximately 83.5 g of sand per vial. Vials containing one seedling were inoculated with 4.5 ml of nematode suspension containing 290 *H. schachtii* J2/ml for a final concentration of approximately 22 J2/cm^3 sand. Following inoculation, each vial was irrigated until the entire sand column was wetted. All vials were put into open plastic boxes and held in a growth chamber at 25 C and 24 hours light. Vials were irrigated daily with half-strength Hoagland's solution except every fifth day, when they were leached with distilled water. Thirty-eight days after inoculation, roots were gently rinsed free of sand. Dislodged cysts were collected on a 0.147-mm sieve and counted. Roots were stained and examined as described for the penetration experiment to quantify *H. schachtii* J2, swollen (late J2, J3, and J4), and adult growth stages. A second trial was conducted similar to the first except that the seedlings were allowed to establish for 9 days prior to inoculation, and the inoculum level was reduced to approximately eight nematodes/cm^3 sand. These changes were included to mitigate poor plant health observed in the first development trial. Data were analyzed and significance was determined ($P \leq 0.05$) as described for the penetration experiment.

Experiment 3. Reproductive potential: Three 4-week-old Copenhagen Market cabbage seedlings were transplanted into microplots infested with cysts and J2 from *H. schachtii* greenhouse cultures. Microplots consisted of 208-liter plastic drums with open tops and perforated bottoms that were buried to ground level and filled with river sand. Microplots were ir-

rigated daily for 0.5 hours using two low-volume emitters per plot (Roberts Co., San Marcos, CA; 0.30 liter/minute) to supply 75 ppm N from a 20-20-20 NPK solution until 15 days before removal of cabbage tops. After 71 days, cabbage foliage was removed and discarded. Soil samples were taken to determine the nematode population used as the initial population (Pi) for subsequent experimentation. Four cores were collected per plot to a depth of 30 cm with a 2.5-cm Oakfield tube. Subsamples of 150 cm^3 of moist soil were processed by sieving through nested 250-, 38-, and 25-μm-pore sieves using three volumes of tap water (ca. 1,500 cm^3 total). Cysts retained on the 250-μm-mesh sieve were returned to the soil subsample for subsequent processing. The J2 and eggs retained on the 38- and 25-μm-mesh sieves were combined and processed by sugar flotation and centrifugation (10). The J2 extracted from the sand were counted on a Hawksley slide using a stereomicroscope. After processing for J2 and eggs, soil subsamples were dried at room temperature, and cysts were recovered by sieving and decanting. Collected cysts were dried in funnels on Whatman No. 4 filter paper and later floated in a 9:1 ethanol:glycerine mixture to remove debris (3). Cysts were ground for 30 seconds using a Tri-R tissue homogenizer (Tri-R Corp., Rockville Center, NY), and the released eggs, J1, and J2 were extracted on a 25-μm-pore sieve and counted. The initial population was considered to be the sum of J2 from soil and J1 + J2 + eggs from ground cysts.

Seven days after removal of cabbage tops, each microplot was planted with 21-day-old transplants of phacelia cv. Angelia, cabbage cv. Copenhagen Market, white mustard cv. Emergo, Martigena, or Serval, or oilseed radish cv. Pegletta, Renova, or Nemex. All plots received seven plants except Copenhagen Market cabbage treatments, which received five plants per plot, and fallow control plots, which received no plants. The experiment was a completely randomized design consisting of five replicates of nine treatments for a total of 45 microplots. Bird depredation was prevented by covering each plot with a single layer of cheesecloth that was removed 73 days after transplanting. From transplanting to 62 days posttransplant, microplots were irrigated twice per day for 15 minutes with a solution of 25 ppm N (from 15-30-15 NPK). From 62–104 days, irrigation was 15 minutes/day with 50 ppm N (from 15-30-15 NPK). From 104 days until termination of the experiment, irrigation was with 25 ppm N (from 15-30-15 NPK) every other day for 15 minutes. The final population of each plot (Pf at day 133 posttransplant) was determined as described for determination of initial population (Pi). Because the data were not normal and variances were not homogeneous, data were logarithmically transformed (log [(Pf/Pi) + 1]) prior to one-way analysis of covariance using SAS software (13). Significance was determined ($P \leq 0.05$) using Duncan's multiple-range test. Additionally, to help discern treatment effects, means for treatments were normalized to the fallow value by subtracting the fallow treatment mean from other treatment means.

Results

Experiment 1. Penetration: The number of J2 per plant in trial one ranged from 0 for phacelia cv. Angelia to 175.8 for the oilseed radish cv. Siletta Nova (Table 1). There were no differences ($P \leq 0.05$) between the control treatment (cabbage cv. Copenhagen Market) and other treatments (Table 1). In trial two, the number of J2 per plant ranged from 2.8 for phacelia to 154.3 for oilseed radish cv. Nemex (Table 1). Cabbage had more J2 per plant than did phacelia (Table 1).

Swollen nematodes per plant in trial one ranged from 0 for phacelia, white mustard cv. Martigena, and buckwheat cv. Prego, to 38.6 for cabbage (Table 1). Cabbage had more swollen nematodes than did the buckwheat cv. Tardo, oilseed radish cv. Nemex, and white mustard cv. Serval (Table 1). In trial two, the number of swollen

TABLE 1. J2 (early J2), swollen (late J2 and J3), and total *H. schachtii* per plant in roots of tested cultivars held for 5 days at 25 C after inoculation with 25 J2/cm^3 sand.

Genus	Cultivar	J2/plant		Swollen/plant		Total/plant	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Brassica	Copenhagen Market	78.8 abc	113.8 bcd	38.6 b	22.7 abc	117.4 abc	136.5 bcd
Phacelia	Angelia	0	2.8 a	0	0	0	2.8 a
Fagopyrum	Tardo	13.6 a	86.3 abcd	0.2 a	0.5 ab	13.8 a	86.8 abcd
	Prego	52.4 ab	98.2 abcd	0	0.3 a	52.4 ab	98.5 abcd
Sinapis	Albatross	—	—	—	—	—	—
	Emergo	122.2 abc	77.2 abcd	3.8 ab	34.3 abc	126.0 abc	111.5 abcd
	Martigena	111.6 abc	66.7 abcd	0 ‡	38.8 abc	111.6 abc	105.5 abcd
	Maxi	107.3 abc	40.3 abc	2.3 ab	24.8 abc	109.6 abc	65.2 abc
	Metex	74.8 abc	22.8 ab	6.6 ab	8.2 abc	81.4 abc	31.0 ab
	Serval	111.0 abc	43.2 abc	0.4 a	22.0 abc	111.4 abc	65.2 abc
Raphanus	Adagio	162.8 bc	90.3 abcd	7.6 ab	52.0 c	170.4 bc	142.3 bcd
	Nemex	172.8 c	154.3 d	0.8 a	49.8 c	173.6 bc	204.2 d
	Pegletta	168.4 bc	118.3 cd	4.0 ab	56.3 abc	172.4 bc	174.7 cd
	Renova	172.8 abc	142.2 bcd	7.2 ab	18.0 abc	140.0 abc	160.2 bcd
	Siletina	120.2 abc	60.3 abcd	4.0 ab	42.2 bc	124.2 abc	102.5 abcd
	Siletta Nova	175.8 bc	96.2 abcd	10.0 ab	36.5 abc	185.8 c	132.6 abcd
	Ultimo	112.2 abc	78.0 abcd	5.8 ab	31.8 abc	117.8 abc	109.8 abcd

Means in a column followed by different letters are significantly different ($P \leq 0.05$), as determined by Dunn's (6) method for multiple comparisons of Wilcoxon's rank sums.

Treatments with consistent zero values were not included in statistical analysis.

nematodes per plant ranged from 0 for phacelia to 56.3 for oilseed radish cv. Pegletta (Table 1). Numbers on cabbage were not different from any other treatment (Table 1). Phacelia supported no swollen stages in either trial.

Total nematodes per plant in trial one ranged from 0 for phacelia to 185.8 for oilseed radish cv. Siletta Nova (Table 1). Numbers on cabbage were not different from any other treatment (Table 1). In trial two, total nematodes per plant ranged from 2.8 for phacelia to 204.2 for oilseed radish cv. Nemex (Table 1). Cabbage had a greater total number of nematodes per plant than did phacelia (Table 1).

Consistent zero values for the phacelia cv. Angelia did not allow statistical comparison to other treatment values except for J2 and total nematodes in trial two. However, the almost total lack of penetration is biologically significant and establishes phacelia as a nonhost to *H. schachtii*, and thus, an unsuitable trap crop. Additionally, all replicates of the white mustard cv. Albatross died in both trials, so no comparisons could be made to other treatments.

Experiment 2. Development within roots: The number of J2 per plant in trial one ranged from 0 for phacelia cv. Angelia to 52.6 for cabbage cv. Copenhagen Market (Table 2). Numbers for cabbage were not different ($P \leq 0.05$) than those for other treatments (Table 2). In trial two, J2 ranged from 0 for phacelia to 229.8 for cabbage (Table 2). Cabbage had more J2 than did the oilseed radish cv. Adagio, Nemex, Siletina, Siletta Nova, and Ultimo (Table 2).

Swollen nematodes per plant in trial one ranged from 0 for phacelia to 35.2 for cabbage (Table 2). Numbers on cabbage were not different from those for other treatments (Table 2). In trial two, the number of swollen nematodes per plant ranged from 0 for phacelia to 784.8 for cabbage (Table 2). Cabbage had more swollen nematodes per plant than did oilseed radish cv. Siletina and Ultimo and buckwheat cv. Tardo and Prego (Table 2).

The number of cysts per plant in trial one ranged from 0 for phacelia, buckwheat cv. Tardo, and oilseed radish cv. Ultimo, Pegletta, and Nemex to 24.8 for white mustard cv. Albatross (Table 2).

TABLE 2. J2 (early J2), swollen (late J2 and J3), and cysts of *H. schachtii* per plant in roots of tested cultivars held for 38 days at 25 C after inoculation with 22 J2/cm^3 sand (trial 1) or 8 J2/cm^3 sand (trial 2).

Genus	Cultivar	J2/plant		Swollen/plant		Cysts/plant	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Brassica	Copenhagen Market	52.6 a	229.8 d	35.2 ab	784.8 c	23.2 b	109.6 c
Phacelia	Angelia	0	0	0	0	0	0
Fagopyrum	Tardo	8.0 a	25.8 abcd	0.6 a	4.0 a	0	0.8 a
	Prego	19.8 a	20.4 abcd	0.6 a	9.4 ab	0.8 ab	2.2 ab
Sinapis	Albatross	23.6 a	147.2 cd	13.2 ab	369.6 bc	24.8 c	93.4 bc
	Emergo	6.2 a	17.5 abcd	2.4 ab	20.0 abc	5.6 abc	9.3 abc
	Martigena	19.2 a	11.0 abcd	3.0 ab	7.2 abc	5.0 abc	6.4 abc
	Maxi	16.0 a	10.4 abcd	3.2 ab	18.4 abc	13.8 abc	5.6 abc
	Metex	18.4 a	43.0 bcd	1.6 ab	25.4 abc	13.6 bc	7.0 abc
	Serval	34.8 a	14.4 abcd	8.2 ab	32.0 abc	14.6 abc	2.0 a
Raphanus	Adagio	16.8 a	3.2 ab	8.6 b	9.0 abc	0.4 ab	0
	Nemex	5.8 a	3.4 ab	1.4 ab	6.2 abc	0	0
	Pegletta	14.2 a	4.4 abcd	4.6 ab	6.8 abc	0	0
	Renova	9.8 a	12.2 abcd	4.4 ab	7.0 abc	0.2 a	2.4 a
	Siletina	13.6 a	4.8 ab	8.8 ab	3.0 a	3.8 abc	9.6 abc
	Siletta Nova	8.6 a	3.8 abc	3.6 ab	43.8 abc	2.4 abc	22.3 abc
	Ultimo	7.2 a	1.6 a	3.0 ab	3.4 a	0	0.4 a

Means in a column followed by different letters are significantly different ($P \leq 0.05$), as determined by Dunn's (6) method for multiple comparisons of Wilcoxon's rank scores.
Treatments with consistent zero values were not included in statistical analysis.

Cabbage had more cysts per plant than Renova (Table 2). In trial two, cysts per plant ranged from 0 for phacelia and oilseed radish cv. Adagio, Pegletta, and Nemex to 109.6 for cabbage (Table 2). Cabbage had more cysts per plant than oilseed radish cv. Ultimo and Renova, buckwheat cv. Tardo and Prego, and white mustard cv. Serval (Table 2). In both trials, there were fewer cysts per plant on the oilseed radish cv. Renova than on cabbage. Phacelia and oilseed radish cv. Pegletta and Nemex had no cysts in either trial.

In general, the oilseed radish cv. supported little cyst development. White mustard cv. were intermediate. Cabbage and the susceptible white mustard cv. Albatross supported large numbers of cysts. Also, comparison of penetration values from Experiment 1 with cyst values from Experiment 2 (Fig. 1) suggests that a substantially higher percentage of nematodes are capable of entering the roots than are recovered as cysts after 38 days. Mortality or egress from the root may account for the disparity between the number of nematodes counted and the amount inoculated.

Experiment 3. Reproductive potential: The ratio of Pf/Pi in the microplot experiment increased in all treatments and ranged from 2.54 for fallow to 7.54 for Serval (Fig. 2). There was higher ($P \leq 0.05$) reproduction on Serval than on the oilseed radish cv. Nemex and Pegletta, white mustard cv. Martigena, phacelia, fallow, or cabbage. Cabbage treatments, however, were severely stunted and unlikely to support much nematode reproduction. Only oilseed radish cv. Nemex and white mustard cv. Martigena had a normalized Pf/Pi < 1.0.

The reproductive index was generally higher in microplots with lower initial nematode populations, resulting in a curvilinear relationship between Pi and Pf/Pi (Fig. 3). Plotting log (Pf/Pi) against log (Pi) by cultivar yielded no cultivar-specific response (1).

DISCUSSION

An effective trap crop must allow nematode penetration but block development into reproductive adults. In our laboratory

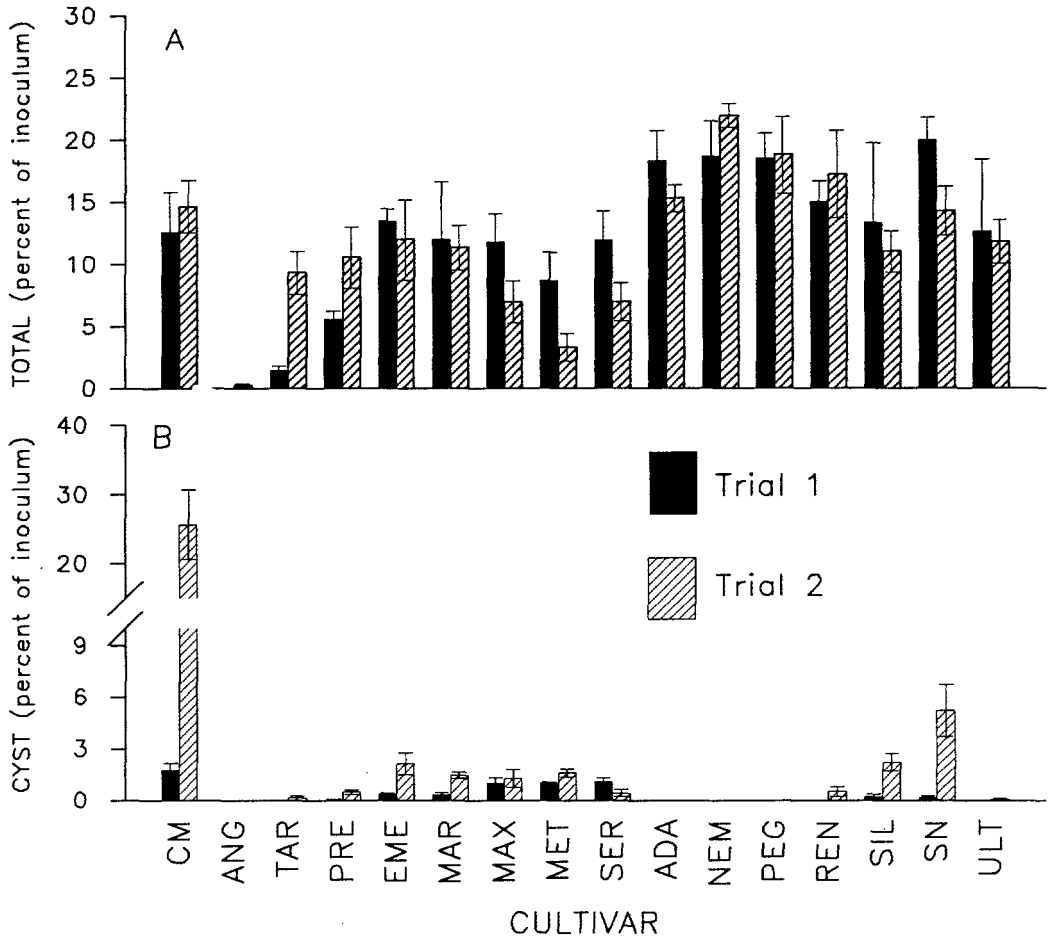

FIG. 1. *Heterodera schachtii* as a percentage of inoculum in cultivars of cabbage, buckwheat, phacelia, white mustard, and oilseed radish. A) Total nematodes 5 days after inoculation with 25 J2/cm^3 of sand from Experiment 1. B) Percentage of cysts 38 days after inoculation with 22 J2/cm^3 sand (trial 1) or 8 J2/cm^3 sand (trial 2) from Experiment 2. Error bars represent standard errors. (Cabbage cv. CM = Copenhagen Market; Phacelia cv. ANG = Angelia; Buckwheat cvs. TAR = Tardo, PRE = Prego; White mustard cvs. EME = Emergo, MAR = Martigena, MAX = Maxi, MET = Metex, SER = Serval; Oilseed radish cvs. ADA = Adagio, NEM = Nemex, PEG = Pegletta, REN = Renova, SIL = Siletina, SN = Siletta Nova, ULT = Ultimo).

experiments, all candidate cultivars except the non-host cv. Angelia (*Phacelia tanacetifolia*) were readily penetrated by J2, and most supported less cyst development than the susceptible cabbage cultivar. These findings suggest that many of the candidate cultivars could be used as trap crops for a California population of *H. schachtii*.

The distribution of growth stages, both as average number per plant (Table 2) and as a percentage of the inoculum (Fig. 1), suggests that nematode development was suppressed. In experiment 2, trial 2, cabbage and susceptible white mustard cv. Albatross contained nematode numbers in excess of the inoculum level (Table 2), indicating the occurrence of a second nematode generation. Varieties with little or no cyst development contained mostly J2 or swollen stages, indicating retardation of development.

The inhibition of nematode development did not appear to be related to degree-day accumulation or to a lack of host penetration, and may be related to the inability of the resistant cv. to supply essen-

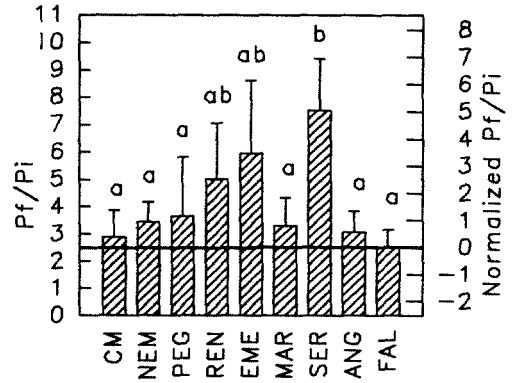

FIG. 2. Reproductive index (Pf/Pi) from field microplot experiment for cultivars of cabbage (CM = Copenhagen Market), oilseed radish (NEM = Nemex, PEG = Pegletta, REN = Renova), white mustard (EME = Emergo, MAR = Martigena, SER = Serval), phacelia (ANG = Angelia), or fallow (FAL = fallow). Left axis is actual value, right axis is Pf/Pi normalized to fallow by subtracting fallow Pf/Pi. Letters above bars indicate significant differences ($P \leq 0.05$) determined by Duncan's multiple-range test for data transformed by log [(Pf/Pi) + 1]. Error bars represent standard error.

tial nutrients for proper nematode development (1). Degree-day accumulation for the development experiment (approximately 650 DD), was sufficient for development and reproduction on a host (4), but reproduction was greatly suppressed in many of the cultivars tested. The penetration experiment indicated that penetration was high and was not a cause of low cyst numbers. For example, the oilseed radishes Nemex and Pegletta were readily penetrated, yet they supported no cyst development over the duration of the experiment. Grundler et al. (9) found that differentiation of *H. schachtii* into males or females was related to the ability of the host plant to supply essential amino acids. Golinowski et al. (7) found dysfunctional syncytia in the resistant cultivar Maxi. Early retardation of *H. schachtii* development, especially apparent in the buckwheat cv. Tardo and Prego (Table 2), may indicate a similar mechanism.

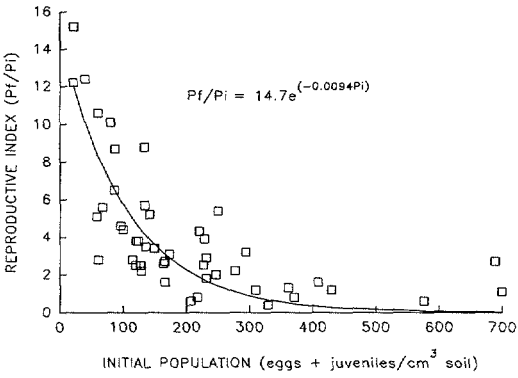

FIG. 3. Reproductive index (Pf/Pi) plotted against initial population (Pi) from field microplot experiment.

We believe that the cultivars with potential for California may best suppress sugarbeet cyst nematode when the initial nematode population is high. The negative effect of high initial populations on reproductive rate has been previously observed (11), and the curvilinear relationship of Pf/Pi to Pi (Fig. 3) from the microplot experiment was consistent with this phenomenon. In the development experiment, the percentage of *H. schachtii* recovered was higher in the trial inoculated with 8 nematodes/cm^3 sand than in the trial inoculated with 22 nematodes/cm^3 sand. Also, the lower inoculum level resulted in a second generation on the susceptible cabbage and white mustard cv. Albatross, while the high inoculum level did not. Perhaps there is competition for entrance or resources when the nematode population is high.

Although the laboratory experiments were encouraging for the control of cyst nematodes, microplot experiments produced equivocal results. Non-fallow treatments did not reduce *H. schachtii* numbers any better than did the fallow treatment. However, excepting the susceptible white mustard cv. Serval, non-fallow treatments were not significantly worse. The increase in nematode populations in fallow treatments was intriguing and unexpected. Unpublished research by our lab indicates that cabbage roots are able to survive at least 4 weeks after their tops have been removed. It is likely that immature nematodes continued to develop into cysts on decapitated cabbage roots. Since the sampling procedure for initial population was biased against immature females, Pi was

probably underestimated, resulting in Pf/Pi > 1.

Genetic variation in both the host and the nematode may complicate adoption of these crops into California agriculture. Penetration and development were highly variable among replicates within treatments, possibly caused by heterozygosity within the cultivars (11). This may explain the substantial but incomplete suppression of cyst development that occurred in some replicates but not in others for the buckwheat cv. Tardo and Prego, and oilseed radish cv. Adagio, Renova, and Ultimo.

Genetic variation in nematode populations may lead to *H. schachtii* pathotypes capable of reproducing on the cultivars tested here (5,8,12,15). In our laboratory development trials, none of the "resistant" white mustards had significantly fewer cysts than susceptible controls, and Siletina, a cultivar previously shown to be severely susceptible (1), had no more cysts than cultivars previously shown to be resistant. Hence, some of the cultivars may not be as effective in California as they are in Germany, perhaps due to genetic as well as environmental differences.

To conclude, there is evidence that the cv. tested may aid in management of sugarbeet cyst nematode in California. In general, oilseed radish cultivars showed greater potential than white mustard cultivars, but further experimentation to optimize planting and removal dates will be necessary for proper management of the crops to reduce cyst nematode populations.

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