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Host Status of Selected Crops to *Meloidogyne chitwoodi*

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Abstract: Various crops were tested in greenhouse and field trials for their potential utility in the rotation sequence in the potato cropping system in *Meloidogyne chitwoodi*-infested soils of the Klamath Basin in northeastern California and southern Oregon. Two *Solanum* accessions from the International Potato Center in Peru were potential sources of resistance to *M. chitwoodi.* Cultivars of barley, oat, rye, wheat, and white lupine were maintenance hosts, supporting the nematode population at its current level without substantial increase or decline. Poor to nonhosts to race 1 of the nematode included cultivars of alfalfa, amaranth, oilseed radish, oilseed rape, and safflower. These crops have potential for inclusion in the cropping system but are subject to various constraints, including frost sensitivity and availability of markets. Sugarbeet, a new crop in the area, is a maintenance or better host of *M. chitwoodi.* Potato, tomato, and sunflower are excellent hosts.
Key words: alfalfa, amaranth, cereal, maintenance host, *Meloidogyne chitwoodi,* nematode, nonhost, oilseed radish, oilseed rape, poor host, potato, *Pratylenchus neglectus,* safflower, sugarbeet, sunflower, tomato.

The Columbia root-knot nematode, *Meloidogyne chitwoodi,* is a major pest of potato (*Solanum tuberosum*) in the northwestern United States, including the potato production regions of Colorado, Idaho, Utah, Washington, and the Klamath Basin of northern California and southern Oregon (22). The Klamath Basin is a high desert environment with a relatively short growing season (around 120 days) characterized by warm days and cool nights. Frost can occur on any night during the growing season. The season length is constrained by snow-cover and frozen soils during the winter.

The damage caused by *M. chitwoodi* in potatoes is a nematode-induced blemish of the tubers, which reduces their value and marketability. Field experiments show little evidence of yield reduction caused by the direct effect of the nematode population on crop growth (4,19). One strategy for the management of the Columbia root-knot nematode, and the reduction of its potential damage to potato crops, is the use of nonhost or resistant crops in the rotation. Season length and marketing constraints in the Klamath Basin have limited current rotation crops to alfalfa (*Medicago sativa*) and barley (*Hordeum vulgare*). Both crops are economically questionable for the cropping system, especially in short-term rotations, and are used primarily for agronomic benefits. Unfortunately, barley is a host of the Columbia root-knot nematode, and alfalfa, although a nonhost to the prevalent biotype (race 1), is a host to a second biotype (race 2) and to another root-knot nematode that occurs in the area, *M. hapla* (15,23). Both crops are hosts of the lesion nematode *Pratylenchus neglectus,* which often occurs with *M. chitwoodi* (5,7,13,25).

There have been several studies to determine the host status of crops grown in the *M. chitwoodi*-infested areas of Washington and Utah, and of potential alternate crops for those areas (6,8–12,14–18,20, 21,24). Recently, Brown et al. (1) identified sources of resistance to *M. chitwoodi* in wild *Solanum* species and successfully introduced the genes into potato breeding clones. The objectives of our studies were to determine the host status and susceptibility to nematode damage of candidate rotation crops for the Klamath Basin.

Materials and Methods

Greenhouse evaluations: Seeds of 49 cultivars representing 11 crop species were

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germinated and transplanted into 473-ml cups of sterilized sandy soil. Each cup was infested with an initial population (Pi) of 1,275 freshly hatched juveniles (J2) of *M. chitwoodi* race 1 from a greenhouse culture of a Klamath Basin population. The crop species included in the test were alfalfa, *Amaranthus* spp., barley, oat (*Avena sativa*), oilseed radish (*Raphanus sativus*), tomato (*Lycopersicon esculentum*), rye (*Secale cereale*), safflower (*Carthamus tinctorius*), sunflower (*Helianthus annuus*), wheat (*Triticum aestivum*), and white lupine (*Lupinus albus*). Each cultivar was replicated eight times, and the plants were irrigated with dilute Hoagland's nutrient solution via an automated drip system.

The experiment was terminated in two stages due to resource and equipment constraints. Four replications of each treatment were terminated after 68 days, and the remainder after 76 days. Tops were cut off the plants at soil level and weighed. Root systems were washed from the soil and rated for galling on a 0–100 scale (3). Each root system was also weighed, and a 20-g subsample was placed in a mist chamber. After 1 week, J2 of *M. chitwoodi* were collected and counted.

Final nematode population densities (Pf), root-gall indices, J2 per gram of root, and multiplication factors (R, where R = Pf/Pi) were subjected to analysis of variance blocked for the two termination dates. Based on the R values, we defined four categories of host. Excellent hosts supported substantial increases in the nematode population ($R > 10$), good hosts supported moderate increases in the nematode population ($10 > R > 1$), maintenance hosts supported the population without substantial increases or declines (R close to 1), and poor to nonhosts resulted in substantial population decreases ($R < 1$). For convenience of presentation and utility of the information, data were reanalyzed by crop species to distinguish differences among cultivars of a given crop. Means were separated by Duncan's multiple-range test.

In three additional greenhouse trials, *Solanum* accessions of the International Potato Center in Lima, Peru, provided by Dr. Parviz Jatala, were screened for resistance to *M. chitwoodi*. The accessions had tested resistant to one or more species of *Meloidogyne* through the International *Meloidogyne* Project (North Carolina State University, Raleigh, NC). Plants were grown in styrofoam cups and infested with 1,000 *M. chitwoodi* per cup. After 90 days, plant vigor and condition were visually rated. Root systems were washed from the soil and weighed, and a 20-g subsample of the root system was placed in a mist chamber. After 1 week, *M. chitwoodi* J2 were counted. Root-gall indices were not assessed due to the difficulty of detecting the very small galls caused by this nematode on potato roots.

Field evaluation: Candidate alternate short-growing-season crops that had proved to be nonhosts or poor hosts of *M. chitwoodi* in greenhouse trials, or related cultivars of crops adapted to Klamath Basin conditions, were tested for host status and agronomic characteristics in four field trials. The 1988 field test was a randomized complete block with three replications (3.7 m × 15.2 m plot sizes). The crops were irrigated (I) or nonirrigated (N) as appropriate to the plant species. Crops included in the test were lupine (cv. Sweetwhite) (I and N), oilseed rape (*Brassica campestris* cv. Cascade) (I and N), safflower (cv. Suntech Exp3033) (N), barley (cv. Briggs and Klages) (I), wheat (cv. Fieldwin) (I), pea (*Pisum arvense* cv. Austrian Winter) (I), a summer fallow (I and N), and a summer fallow followed by a fall cover crop (I). The experiment was established in a field site following potatoes, where the *M. chitwoodi* population was judged to be relatively uniform based on preliminary soil samples. Pi was measured across the experimental site, but not in individual plots. Pf was measured in each plot at the end of the growing season. In 1989, potatoes were grown in all plots, and Pf and tuber blemish ratings were assessed at harvest of the potato crop.

Population assessment for each plot at

each sampling period was based on two composite samples of 2.5-cm-d soil cores taken 30 cm deep. Soil samples were hand mixed, and nematodes were extracted from a 350-cm^3 subsample by two processes. A semiautomatic elutriator was used to separate the subsample into a root–organic matter fraction retained on a 40-mesh (367-μm-pore) sieve, and a fraction retained on a 400-mesh (38-μm-pore) sieve. The root–organic matter fraction was placed in a mist chamber for 5 days to allow egg hatch and emergence of motile endoparasitic stages. The latter fraction was subjected to sucrose-centrifugation in 1 M sucrose solution (2). Population levels of *M. chitwoodi* and *P. neglectus* in each sample were expressed per 1,000 cm^3 soil as the sum of the individuals detected in the sucrose-centrifugation and mist chamber fractions. Population levels per plot were calculated as the average of the two samples from each plot.

The 1989 field test was established in four randomized complete blocks (3.7 m × 15.2 m plot sizes). The crops tested were sunflower (cv. Sunwheat 102), safflower (cv. Suntech Exp3033), sugarbeet (cv. HH55), wheat (cv. Fieldwin), barley (cvs. Briggs and Klages), fallow with common rye, and fallow. Again, the experiment was established in a field site following potatoes, where the *M. chitwoodi* population was judged to be relatively uniform. In this experiment, Pi and Pf were measured in each plot.

Two field tests of wheat and barley cultivars were conducted in 1.5 m × 7.6 m plots; four replications of five cultivars in 1990 (barley cvs. Briggs, Crystal, and Steptoe, and wheat cvs. Fieldwin and G4299), and eight replications of eight cultivars in 1991 (barley cvs. Advance, B1202, Columbia, Gustoe, Klages, and Steptoe, and wheat cvs. Fieldwin and Yecora Rojo). The Pi and Pf of *M. chitwoodi* and *P. neglectus* were assessed in each plot. Seasonal nematode multiplication rates (Pf/Pi) were calculated for each crop or cultivar. Crop yields and percentage lodging of the cereals were determined.

Results

Greenhouse evaluations: Crop species and cultivars differed in their host status to *M. chitwoodi* (Table 1). Tomato cv. Columbian was an excellent host with a high *R* value and heavy galling. The three alfalfa cultivars tested were nonhosts, with gall ratings less than 1 and *R* values less than 0.1 over the 10-week period. Six cultivars of *Amaranthus* spp., representing *A. caudatus, A. hypochondriacus,* and *A. cruentus,* were nonhosts, and one cultivar was rated as a poor host (cv. UC275 of *A. retroflexus*). Two cultivars of barley were hosts and supported the nematode population (cvs. Steptoe and Wocus 71), while cv. Briggs was a very poor host. However, cv. Briggs was less vigorous than the other two barley varieties, with only about half the root development over the same growing period. Both oat cultivars tested were good hosts, supporting the *M. chitwoodi* population with high *R* values and exhibiting substantial galling. The common rye grown in the Klamath Basin was a maintenance host of the nematode and supported its reproduction with an *R* value close to 1.0, and very low indication of galling. Wheat cv. Nugaines was also a maintenance host (*R* close to 1.0) of the nematode, with intermediate root galling.

Of the four named and six unnamed cultivars of oilseed radish, one was a maintenance to moderate host based on *R* value and root galling (cv. 1), while the remainder were poor to nonhosts (Table 1). Four safflower cvs. were very poor to nonhosts, while differing considerably in vigor, as exhibited in root weights. Twelve cvs. of sunflower were good to excellent hosts of *M. chitwoodi,* with high levels of root galling. Six breeding lines of white lupine ranged from a nonhost (MN85.F4/854-1) through a poor host (MN85.F4/Blanca 101) to maintenance and better hosts, capable of sustaining and increasing the nematode population. However, differences in host status of white lupine were generally not significant due to the high degree of variability within each cultivar,

TABLE 1. Host status of selected crops, cultivars, and tomato to *Meloidogyne chitwoodi* in greenhouse evaluations 10 weeks after infestation with 1,275 second-stage juveniles (J2) per pot.

Species/cultivar	Root weight (g)	J2/pot	J2/g root	R†	Gall rating‡	Host status§
Lycopersicon esculentum						
Columbian	52.1	20,451	446.4	16.07	56.3	E
Medicago sativa						
Altra 55	19.4 a	91 a	14.1 a	0.07 a	0.4 a	P
Blazer	19.6 a	78 a	4.5 a	0.06 a	0.5 a	P
Pioneer	15.9 a	41 a	1.6 a	0.03 a	0.0 a	P
Amaranthus spp.						
A. retrofl. UC275	7.4 c	594 a	192.3 a	0.47 a	0.1 a	P
A. caudatus UC4	72.8 a	59 b	0.7 b	0.04 b	0.6 a	P
A. caudatus UC37	24.1 bc	46 b	2.6 b	0.04 b	0.0 a	P
A. caudatus UC54	29.5 b	36 b	1.3 b	0.03 b	0.1 a	P
A. hypocho. UC119	14.1 bc	29 b	3.4 b	0.02 b	0.1 a	P
A. cruentus UC87	31.8 b	7 b	0.2 b	0.01 b	0.0 a	P
A. cruentus UC192	22.5 b	5 b	0.3 b	0.01 b	0.0 a	P
Hordeum vulgare						
Steptoe	101.3 a	1,837 a	53.9 a	1.44 a	5.1 b	M
Wocus 71	107.2 a	1,662 a	17.0 a	1.31 a	16.4 a	M
Briggs	58.5 a	362 a	6.7 a	0.29 b	1.3 b	P
Avena sativa						
Ottawa	107.7 a	8,321 a	63.7 a	6.53 a	50.0 a	G
Cayuse	78.6 a	5,387 a	57.2 a	4.23 a	50.0 a	G
Secale cereale	80.6	1,357	17.4	1.07	1.5	M
Triticum aestivum						
Nugaines	90.6	1,618	31.4	1.27	17.0	M
Raphanus sativus						
1	14.6 a	3,287 a	729.9 a	2.58 a	3.5 a	M
4	19.5 a	261 a	35.4 b	0.20 b	0.1 a	P
Nemex	16.0 a	170 b	42.7 b	0.13 b	0.4 a	P
3	11.6 a	156 b	26.8 b	0.12 b	0.2 a	P
Siletta Nova	18.7 a	89 b	11.2 b	0.07 b	0.1 a	P
Siletena	15.7 a	66 b	15.7 b	0.05 b	0.0 a	P
Pegletta	30.5 a	57 b	1.1 b	0.05 b	0.1 a	P
6	15.7 a	53 b	16.9 b	0.04 b	0.6 a	P
2	18.6 a	6 b	0.4 b	0.00 b	0.0 a	P
5	23.4 a	5 b	0.1 b	0.00 b	0.0 a	P
Carthamus tinctorius						
UC1	10.3 b	26 a	8.8 a	0.02 a	0.0 a	P
Cargill CH51	27.7 a	9 a	1.6 a	0.01 a	0.1 a	P
UC26	8.1 b	0.3 a	0.02 a	0.00 a	0.0 a	P
Helianthus annuus						
Cargill 208	72.3 ab	25,790 a	323.7 bc	20.26 a	65.6 a	E
Cargill 209	52.8 cd	19,796 ab	445.4 bc	15.55 ab	50.0 abc	E
Interstate 7111	84.3 a	19,307 ab	244.2 bc	15.17 ab	56.3 ab	E
NK Sunbred 246	33.1 d	19,151 ab	693.7 a	15.04 ab	35.6 cd	E
Hybrid 894a	46.4 cd	17,084 ab	449.3 bc	13.42 ab	53.1 abc	E
Seed Tec 860107	35.5 d	16,413 ab	492.0 ab	12.89 b	38.8 cd	E
Hybrid 894b	64.6 bc	14,235 b	214.7 c	11.18 b	31.3 d	E
Seed Tec 317	45.6 cd	13,601 b	300.1 bc	10.68 b	43.8 bcd	E
Cargill 207	41.7 d	12,984 b	328.6 bc	10.20 b	40.6 bcd	E
Pioneer XF452	73.2 ab	12,542 b	211.4 c	9.85 b	37.5 cd	G
NK Sunbred 212	50.5 cd	1459 b	264.0 bc	9.00 b	37.5 cd	G
Pioneer XF4514	47.6 cd	10,301 b	198.9 c	8.09 b	43.8 bcd	G
Lupinus albus						
MN85.F4/ter FJZ	3.8 a	3,492 a	1,157.3 a	2.74 a	1.6 ab	G
MN85/BC.F4	1.8 a	2,701 a	1,094.6 a	2.12 a	0.2 b	G
MN85/ter FJZ	2.7 a	1,868 a	1,208.0 a	1.47 a	0.1 b	M
MN85.F4/85341.5	1.3 a	1,313 a	926.5 a	1.03 a	3.0 a	M
MN85.F4/Blanc101	1.7 a	738 a	412.1 a	0.58 a	0.4 b	P
MN85.F4/854-1	0.6 a	0 a	0.0 a	0.00 a	0.0 b	P

In each column, means followed by the same letter do not differ significantly ($P = 0.05$) within a crop species.

† R (multiplication rate) = (J2/pot)/(1,275 J2)

‡ Gall rating (0–100 scale): 0 = no galls; 100 = root extremely galled and reduced.

§ Host status categories: E = Excellent ($R > 10$); G = good ($10 > R > 1$); M = maintenance ($R +/- 1$); P = poor to nonhost ($1 > R > 0$).

TABLE 2. Root weight and final population densities (Pf) of *Meloidogyne chitwoodi* second-stage juveniles (J2) on *Solanum* accessions.

	Trial 1		Trial 2		Trial 3		
Accession #	Root weight (g)	J2/100 g	Root weight (g)	J2/100 g	Root weight (g)	J2/100 g	Relative Pf†
Tomato	56.0 b	6,327 a	60.6 a	2,591 a	44.1 bc	16,595 a	164.55
Russet Burbank	38.8 bc	131 b	9.6 cd	6 b	35.0 bcd	2,566 b	1.0
378898.12			3.9 d	3 b	7.0 ef	2,246 b	0.65
378875.24	54.4 b	0 b	17.1 b	10 b	58.2 ab	66 b	0.57
378908.38					4.5 f	0 b	0.0
378924.25	51.7 b	109 b			73.8 a	1,421 b	0.69
378908.23	79.7 a	0 b	9.6 cd	1 b	31.6 cde	135 b	0.07
378950.37	40.4 bc	63 b			11.2 def	5 b	0.24
378930.47	22.6 c	782 b			13.6 def	1,284 b	3.23
378875.20	21.8 c	40 b	16.6 b	0 b	31.7 cde	2,437 b	0.42
378875.46	49.1 b	0 b	11.9 bc	22 b	8.0 ef	892 b	1.36
378875.11	77.2 a	43 b	12.1 bc	11 b	7.7 ef	6,211 b	1.53
378950.65	20.2 c	2,274 b			19.6 cdef	5,068 b	9.64
378911.50	80.1 a	160 b			35.0 bcd	9,002 ab	2.36
378857.15	21.7 c	5 b	11.9 bc	18 b			1.63

Within a column, means followed by the same letter are not significantly different ($P = 0.05$).
† Pf standardized relative to the Pf on Russet Burbank in each trial.

perhaps indicating a lack of genetic homogeneity of these breeding lines.

Nematode population increase on *Solanum* accessions in three greenhouse trials is indicated in Table 2. Trial 1 was conducted in the spring, and Trial 3 in the fall, when greenhouse temperatures are not limiting to growth and reproduction of *M. chitwoodi*. Trial 2 was conducted in the late summer, when greenhouse temperatures are sometimes in excess of the favorable range for *M. chitwoodi*. The Pf were lower in Trial 2 than in Trials 1 and 3 across all accessions. A weighted average Pf for each accession was calculated relative to the Pf on cv. Russet Burbank in each trial. Accessions were omitted from trials when the propagative material was weak or diseased.

Field evaluations: In the 1988 field trial, population levels of *M. chitwoodi* were significantly higher ($P = 0.05$) following wheat (cv. Fieldwin) and fallow with Austrian winter peas than any other crop cultivar. The Pf were lowest following the fallow treatments (Fig. 1). At the end of the 1989 potato crop, the Pf of *M. chitwoodi* were higher in plots following Fieldwin wheat than in all other plots. The Pf were lower than in all other plots when potatoes followed the irrigated and nonirrigated fallow treatments. Tuber blemish ratings of the subsequent potato crop were variable and did not differ significantly among treatments; however, their mean values

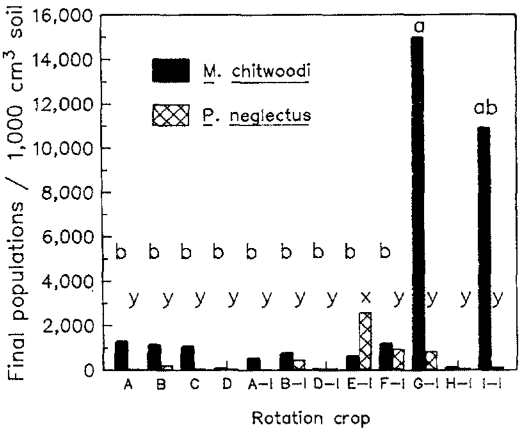

FIG. 1. Final population densities (Pf) of *Meloidogyne chitwoodi* and *Pratylenchus neglectus* in 1988 field screening trials for potential rotation crops, Klamath Basin, California. A = lupine cv. Sweetwhite, B = oilseed rape cv. Cascade, C = safflower cv. Suntech Exp3033, D = fallow, E = barley cv. Briggs, F = barley cv. Klages, G = wheat cv. Fieldwin, H = fallow plus cover crop, I = pea cv. Austrian winter, −I = irrigated. For each nematode species, final populations associated with the same letter do not differ significantly ($P = 0.05$).

were highest (16–30% range) following irrigated oilseed rape, wheat, Klages barley, and Austrian winter pea. Blemish ratings were lowest in plots following irrigated or nonirrigated fallow. The Pf of *P. neglectus* were higher following Briggs barley than the other treatments, and were generally higher in plots following cereals (Fig. 1). After the subsequent potato crop, Pf of *P. neglectus* were highest in the plots following Briggs barley, intermediate following Klages barley and Fieldwin wheat, and lower following all other crops.

In the 1989 field trial, the *M. chitwoodi* population had increased 12-fold at the end of the growing season under the excellent host, sunflower. It was held at or below the maintenance level (Pf/Pi = 1.0) by the nonhosts, poor hosts, and maintenance hosts included in the experiment (Fig. 2). Sugarbeet was a maintenance host of *M. chitwoodi.* All crops except wheat were good hosts of *P. neglectus,* with *R* values ranging from 2 to 12 (Fig. 2). Although the *R* values for *P. neglectus* were variable

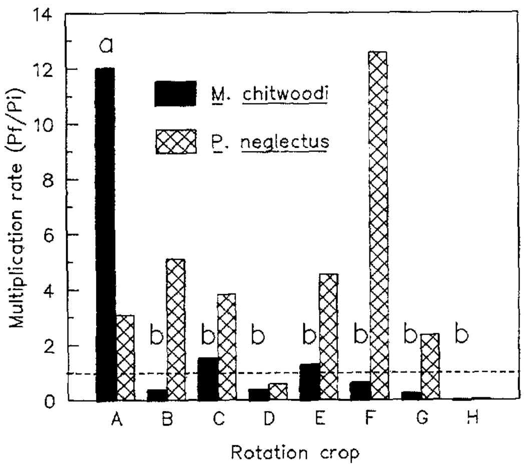

FIG. 2. Population changes (initial population/final population) of *Meloidogyne chitwoodi* and *Pratylenchus neglectus* in 1989 field screening trials for potential rotation crops, Klamath Basin, California. A = sunflower cv. Sunwheat 102, B = safflower cv. Suntech Exp3033, C = sugarbeet cv. HH55, D = wheat cv. Fieldwin, E = barley cv. Klages, F = barley cv. Briggs, G = fallow, H = fallow plus rye. For *M. chitwoodi,* multiplication rates associated with the same letter do not differ significantly ($P = 0.05$); differences among multiplication rates of *P. neglectus* were not significant.

within treatments and did not differ significantly between crops, the highest R was measured on Briggs barley, a cultivar not commonly used in the Klamath Basin.

In 1990 field trials, yields of wheat and barley did not differ significantly ($P = 0.05$), either between crop types or between varieties within crops (Table 3). However, the Crystal barley plots were almost 100% lodged, and G4299 wheat plots were 60% lodged. Similarly, multiplication rates for *M. chitwoodi* and *P. neglectus* did not differ either between crops or between varieties within crops (Table 4). In 1991, yields of wheat and barley averaged across cultivars did not differ, but there were yield differences between cultivars of barley, with cvs. Advance, Steptoe, and Gustoe yielding higher than the other cultivars, and between cultivars of wheat, with cv. Fieldwin the highest (Table 3). There were no differences in *R* of either *M. chitwoodi* or *P. neglectus* between the crop types (barley and wheat), nor of *M. chitwoodi* between varieties within either crop. The *R* of *P. neglectus* did not differ between the wheat varieties, but was higher on the high-yielding cvs. Steptoe and Advance than on the other barley varieties (Table 4).

DISCUSSION

Our greenhouse trials for alternate rotation crops for race 1 of *M. chitwoodi* from the Klamath Basin produced three groupings. Excellent hosts included potato, tomato, and sunflower. Maintenance hosts included barley, oat, wheat, rye, and white lupine. The *R* values for the cereals were somewhat lower than those reported for populations of race 1 of *M. chitwoodi* from the state of Washington, although except for wheat cv. Nugaines, most of the cultivars tested were different (12,14,16,17). Poor to nonhosts, in which there was substantial population decrease, included cultivars of amaranth, safflower, oilseed radish, and alfalfa. We are unaware of other studies of race 1 of *M. chitwoodi* with amaranth, safflower, or oilseed radish, but our results for alfalfa are in concurrence with

TABLE 3. Yields of barley and wheat cultivars in 1990 and 1991 in *Meloidogyne chitwoodi-* and *Pratylenchus neglectus*-infested field plots.

1990			1991		
Crop	Cultivar	Yield (kg/ha)	Crop	Cultivar	Yield (kg/ha)
Barley	Briggs	4446 a	Barley	Advance	5168 ab
Barley	Crystal	7128 a	Barley	B1202	4289 c
Barley	Steptoe	5248 a	Barley	Columbia	3680 d
Wheat	Fieldwin	4563 x	Barley	Gustoe	5743 a
Wheat	G4299	4750 x	Barley	Klages	3849 d
			Barley	Steptoe	5417 a
			Wheat	Fieldwin	4536 x
			Wheat	Yecora Rojo	4119 y

In each column, means followed by the same letter do not differ significantly within a crop species ($P = 0.05$).

those for Washington populations of race 1 (15,16,18).

We identified several potential rotation crops for the management of Columbia root-knot nematode in the potato cropping system of the Klamath Basin. All of the crops selected are grown in regions with short growing seasons and therefore may be adapted for the Klamath Basin. Barley is already used as a rotation crop in the area, and a poorer host than the common cultivars for the area (Steptoe, Gustoe, and Klages) could be readily incorporated into the system. Crystal barley was included in the trial because it is a new malting variety with market potential. It was a poor host for both nematodes, but its lodging may constitute a problem. Briggs and Steptoe barley appear to be poorer hosts for *M. chitwoodi* than Klages; however, Briggs is poorly adapted to the area. Wheat cultivar G4299 is a breeding line with resistance to *M. incognita*. It was a poor to maintenance host for *M. chitwoodi* in our trials. Our field data confirm that *P. neglectus* is a weak or non-pathogen of cereals (25) in that its multiplication rates were highest on the highest yielding varieties.

To be competitive in the diverse agriculture of California, potential rotation crops must have unique characteristics, or must not be grown elsewhere in the state. Both *Amaranthus* spp. and oilseed rape meet these criteria. The poor to nonhost status of several *Amaranthus* spp. and of oilseed rape cv. Cascade is therefore of interest. Several other cultivars of oilseed rape supported higher reproduction of the nematode in previous studies, but were effective in reducing population levels when incorporated into the soil as a green manure (14). Various *Amaranthus* spp. are grown as herbs and as specialty grains for the

TABLE 4. Multiplication rates (R) of *Meloidogyne chitwoodi* and *Pratylenchus neglectus* on wheat and barley cultivars in 1990 and 1991 field trials in the Klamath Basin, California.

1990				1991			
Crop	Cultivar	R_{mc}†	R_{pn}	Crop	Cultivar	R_{mc}	R_{pn}
Barley	Briggs	0.0 a	1.8 a	Barley	Advance	7.8 a	5.1 a
Barley	Crystal	0.8 a	0.8 a	Barley	B1202	6.8 a	2.1 b
Barley	Steptoe	0.0 a	2.0 a	Barley	Columbia	2.8 a	1.8 b
Wheat	Fieldwin	3.0 x	1.4 x	Barley	Gustoe	3.0 a	1.5 b
Whet	G4299	1.0 x	1.5 x	Barley	Klages	12.0 a	1.9 b
				Barley	Steptoe	1.6 a	5.9 a
				Wheat	Fieldwin	4.3 a	1.2 x
				Wheat	Yecora Rojo	5.0 x	2.6 x

In each column, means followed by the same letter do not differ significantly within a crop species ($P = 0.05$).
† R = Pf/Pi; mc = *Meloidogyne chitwoodi;* pn = *Pratylenchus neglectus.*

health-food market; however, most species of *Amaranthus* are frost sensitive, so the crop was excluded from our field trials. Oilseed rape could develop into a specialty crop, although currently available marketing contracts are not economically attractive. Several cultivars of oilseed radish were also poor to nonhosts of *M. chitwoodi* in our greenhouse trials, but their market potential is unknown and they were not included in field trials.

Our greenhouse trials with *Solanum* accessions from the International Potato Center in Lima, Peru, suggest two genotypes that may prove interesting to plant breeders as sources of resistance to *M. chitwoodi:* accession numbers 378908.23 and 378908.38. Evaluation of the first accession is based on three trials that indicated substantial plant vigor and root growth. That of the second accession is based on only one successful trial in which plant vigor and root growth were weak. The accessions were also screened against four races of *M. incognita* and two races of *M. arenaria, M. javanica,* and *M. hapla* by International *Meloidogyne* Project personnel at North Carolina State University. Accession 378908.23 was slightly galled, with evidence of egg mass production, by race 1 of *M. incognita,* race 2 of *M. arenaria,* and *M. hapla.* Accession 378908.38 showed no galling or egg mass production with any of the species or races; however, it grew poorly in the test, and several plants died. Accession 378950.37, which grew poorly in our test but appeared to be a potential source of resistance to *M. chitwoodi,* was moderately galled and exhibited egg mass production with *M. incognita* races 1 and 3, *M. arenaria* race 1, and *M. hapla* (J. N. Sasser, pers. comm.).

Unfortunately, we did not measure Pi of *M. chitwoodi* and *P. neglectus* on a per plot basis in 1988 field evaluation trials. That would have provided further data for our grouping of crops into poor, maintenance, and good hosts. We consider the maintenance host concept an important one in making cropping sequence decisions: maintenance hosts are poor choices as rotation crops, unless they are of high value, because the nematode population will not decline.

The 1988 field trials indicated that poor to maintenance hosts for *M. chitwoodi* include white lupine, oilseed rape (although blemish ratings on the subsequent potato crop were in conflict), and safflower. Our results with wheat were mixed. The high Pf for wheat in the 1988 field trial were at odds with our greenhouse study and 1989 field trial, but not with our 1991 field trial. We conclude that wheat generally supports population increase of *M. chitwoodi* in the field and should be considered more than a maintenance host. One-year fallow treatments are effective in reducing *M. chitwoodi* population levels, but may not be economically viable. The 1989 field trials confirm the poor to maintenance host status of safflower and barley, and suggest that sugarbeet is a maintenance host. Sugarbeet was included in the experiment without prior greenhouse screening due to industry interest in sugarbeet production in the area. Safflower shows promise for the Klamath Basin in *M. chitwoodi*-infested soils, but the frost intolerance of the crop at the flowering stage may present a problem. Sunflower, an excellent host of *M. chitwoodi,* is unsuitable as a rotation crop. Although our greenhouse trials suggest that rye is a maintenance host for *M. chitwoodi,* there was a substantial decrease in the population when it was used following a fallow period. This may reflect the effect of the fallow on the nematode population, or the fall-planted rye may be functioning as a trap crop for the nematode. The crops tested in the field were maintenance to good hosts of *P. neglectus,* with the possible exception of white lupine. Current indications are that it does not cause yield reductions in most of these primary crops. It will be important to understand the role of *P. neglectus* in the cropping system.

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