Root-knot Nematode Resistance in Cucumber and Horned Cucumber

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Additional index words. Cucumis sativus, C. meliferus, disease resistance, cucurbit, Meloidogyne incognita, M. arenaria, M. hapla, M. javanica, vegetable breeding

Abstract. Cucumber (Cucumis sativus L.) and horned cucumber (C. meliferus Naud.) germplasm were evaluated for their resistance to root-knot nematodes (Meloidogyne spp.). All 24 C. meliferus cultivars evaluated were resistant to all root-knot nematodes tested- M. incognita (Kofoid and White) Chitwood race 3, M. arenaria (Neal) Chitwood race 2, and M. hapla Chitwood. All 884 C. sativus cultivars (cultivars, breeding lines, and plant introduction accessions) tested were resistant to M. hapla and few to M. incognita race 3. Only 50 of 884 C. sativus cultivars evaluated were somewhat resistant to M. arenaria race 2 and M. incognita race 3. A retest of the most resistant C. sativus cultivars revealed that LJ 90430 [an accession of C. sativus var. hardwickii (R.) Alef.] and ‘Mincu’ were the only cultivars that were moderately resistant to M. arenaria race 2. LJ 90430 was the only cultivar, besides the two retested C. meliferus cultivars, that was resistant to M. javanica. Threelb. Chitwood. All C. sativus cultivars retested, including LJ 90430, were highly susceptible to M. incognita races 1 and 3. The two C. meliferus cultivars retested were highly resistant to all root-knot nematodes tested- M. arenaria race 2, M. incognita races 1 and 3, and M. javanica.

Cucumber is one of the three most important horticultural crops in North Carolina (North Carolina County Agents’ Estimates, 1990). Root knot is the most economically important cucumber disease in North Carolina, causing an average annual yield loss of 11% (St. Armand and Wehner, 1991). Cucumber is considered to be one of the most susceptible major vegetable crops to root-knot nematodes (Fassuliotis, 1979). Root knot is predominantly caused by four Meloidogyne species: M. incognita, M. arenaria, M. javanica, and M. hapla (Fassuliotis, 1982). Cucumber cultivars resistant to one or more of these species would be useful to growers by providing disease control with reduced nematicide use. Meloidogyne hapla is not a problem on cucumbers grown in North Carolina, but field-grown cucumbers in Canada were significantly damaged by M. hapla (Zimmer and Walkof, 1968).

Much effort has been invested in identifying resistance to root-knot nematodes in many crop species, including cucumber (Fassuliotis, 1979). Forty-two cucumber cultivars were tested by Winstead and Sasser (1956). All were resistant to M. hapla and susceptible to M. incognita, M. incognita ‘acrita,’ M. javanica, and M. arenaria. The U.S. Dept. of Agriculture (USDA) germplasm collection (289 cucumber accessions in 1963) was evaluated by Fassuliotis and Rau (1963). All accessions were susceptible to M. incognita ‘acrita’ and were marked by profuse galling and nematode reproduction.

The African horned cucumber is highly resistant to root-knot nematodes. Norton and Granberry (1980) reported that C. meliferus was highly resistant to the root-knot nematodes M. incognita, M. arenaria, and M. javanica. Wehner et al. (1991) found that C. sativus ‘Sumter’ was more susceptible than C. meliferus to M. incognita, M. arenaria, and M. javanica. Other Cucumis species, including C. anguria L., C. ficifolius A. Rich., C. longipes Hook., and C. heptadactylus Naud., are resistant to Meloidogyne spp. (Fassuliotis, 1967).

Although there has been much progress in selecting and breeding for root-knot resistance in many other important horticultural crops, no progress has been made in cucumber, and attempts to produce viable interspecific hybrids between cucumber and several related resistant wild Cucumis spp. have failed (Fassuliotis, 1979). Successful gene exchange between C. sativus and related wild species is difficult using conventional hybridization techniques, since C. sativus has a different chromosome number than other related wild Cucumis spp.

Screening methods have been standardized for evaluating root-knot resistance, and several have been useful (Fassuliotis, 1979). Evidence of the existence of races for some Meloidogyne spp. demonstrated a need to reevaluate cultivar response to specific races (Taylor and Sasser, 1978).

The objective of this research was to evaluate the C. sativus and C. meliferus germplasm collection for resistance to three root-knot nematode species- M. incognita race 3, M. arenaria race 2, and M. hapla. The most resistant and susceptible cultivars from the initial screening [14 plant introduction (PI) accessions, 12 cultivars, and 6 breeding lines of C. sativus and 2 PI accessions of C. meliferus] were retested for resistance to 4 root-knot nematodes- M. incognita race 1, M. incognita race 3, M. arenaria race 2, and M. javanica.

Two greenhouse experiments were conducted: a germplasm evaluation and a retest of the most resistant or susceptible 34 cultivars. Evaluating the germplasm collection. A greenhouse experiment was conducted to evaluate 924 cultivars for resistance to three species of root-knot nematodes- M. incognita race 3, M. arenaria race 2, and M. hapla. Thirty-six breeding lines, 136 cultivars, and 728 PI accessions of C. sativus and 24 PI accessions of C. meliferus were tested. Old cultivars were obtained from the National Seed

Received for publication 21 Aug. 1991. Accepted for publication 29 Sept. 1992. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products named nor criticism of similar ones not mentioned. This paper is based on a portion of a thesis to be submitted by S.A.W. in partial fulfillment of the requirements for the MS. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

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Table 1. Origin and resistance of cultigens used in germplasm evaluation for root-knot nematode resistance in Cucumis spp.2

<table>
<thead>
<tr>
<th>Cultigen</th>
<th>Origin</th>
<th>Accessions</th>
<th>Turkey</th>
<th>P.R. China</th>
<th>Yugoslavia</th>
<th>Iran</th>
<th>India</th>
<th>Japan</th>
<th>Former USSR</th>
<th>Czechoslovakia</th>
<th>Netherlands</th>
<th>USA</th>
<th>Other</th>
<th>Breeding lines</th>
<th>Cultivars</th>
<th>Current</th>
<th>No data obtained</th>
<th>Accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. sativus</td>
<td>900</td>
<td>728</td>
<td>170</td>
<td>93</td>
<td>63</td>
<td>59</td>
<td>46</td>
<td>43</td>
<td>40</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td>36</td>
<td>136</td>
<td>17</td>
<td>31</td>
<td>15</td>
</tr>
</tbody>
</table>

2Cultivars and breeding lines were obtained from cucumber breeders and commercial seed companies; plant introduction accessions from the Regional Plant Introduction Station, Ames, Iowa; and old cultivars from the National Seed Storage Lab. (NSSL), Fort Collins, Colo. Cultigen resistance is based on data obtained from Meloidogyne incognita race 3 and M. arenaria race 2.

3Included is LJ 90430 (a breeding line of C. sativus var. hardwickii).
Storage Laboratory (NSSL), Fort Collins, Colo., new cultivars from seed companies, and breeding lines from state experiment stations. PI accession seeds were obtained from the North Central Plant Introduction Station, Ames, Iowa, originally collected from diverse locations around the world (Table 1).

In our tests, all C. sativus and C. metuliferus plants were grown from seed in 15cm-diameter (1.8 liter) clay pots on benches in a greenhouse. Five seeds of each cultivar were sown in pots containing 1 sand : 1 soil (v/v; 85% sand, 10% silt, 5% clay) steam-sterilized mixture. Plants were thinned to two per pot at the two-leaf stage and to one per pot at the three-leaf stage. Fertilizer (200 mg N/kg) was supplied twice daily by drip irrigation. Greenhouse temperatures averaged 35C day/27C night.

*Meloidogyne incognita* race 3, *M. arenaria* race 2, and *M. hapla* populations were maintained in the greenhouse on tomato (*Lycopersicon esculentum* L. 'Rutgers') for use as inoculum. Inoculum was prepared using Hussey and Barker's technique (1973) and was standardized to 200 eggs/ml of water, so that 25 ml of suspension would contain ~5000 eggs. A 25-ml suspension of eggs was poured on the soil around the base of each plant. After all plants had been inoculated, each pot was topped with 13 mm of moist potting medium to protect eggs from desiccation.

Root-knot nematode damage was determined on washed roots (Nijs and Hofman, 1983) 9 weeks after inoculation (11 weeks after planting) using the gall index system (0% to 100% of roots covered with galls) (Barker et al., 1986). The gall index system was a modification of that used by Taylor and Sasser (1978). Percentage of galled roots was used to determine resistance as follows: 0% = immune, 1% to 10% = highly resistant, 11% to 20% = moderately resistant, 21% to 40% = slightly resistant, and >40% = susceptible.

The experiment was a split-plot treatment arrangement in a randomized complete-block design with three replications for *M. incognita* race 3 and *M. arenaria* race 2 and one replicate for *M. hapla*. Whole plots were the three nematode species, and subplots were the 924 cultigens. Data were subjected to analysis of variance using SAS (SAS Inst., Cary, N.C.), and cultigen means were tested using Fisher's least significant difference (LSD).

Retesting the extreme cultigens. In the second experiment, we confirmed results from Expt. 1 using the most resistant or susceptible 34 *Cucumis* cultigens (14 accessions, 12 cultivars, and 6 breeding lines of *C. sativus* and 2 PI accessions of *C. metuliferus*) for resistance to four root-knot nematodes (*M. incognita* race 1, *M. incognita* race 3, *M. arenaria* race 2, and *M. javanica*).

The experiment was conducted in a greenhouse at ~35C day/24C night. The same procedures and cultural practices were followed as in Expt. 1.

Roots were rated 11 weeks after planting (9 weeks after inoculation) using the gall index system as described for Expt. 1, after which egg masses on roots were stained red with phloxine B (Hartman and Sasser, 1985). Egg

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### Table 2. Root-knot nematode resistance (percent galls) in selected *Cucumis* cultigens evaluated with three species of *Meloidogyne* in the germplasm evaluation experiment. Cultigens ranked in order by resistance.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Cultigen</th>
<th>Origin</th>
<th>Roots affected (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>Green Thumb²</td>
<td>Harris Seed</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>PI 482545¹</td>
<td>Zimbabwe</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>PI 482546¹</td>
<td>Zimbabwe</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>PI 482456¹</td>
<td>Zimbabwe</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>PI 482450¹</td>
<td>Zimbabwe</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>PI 482440¹</td>
<td>Zimbabwe</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>PI 482242²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>PI 482453²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>PI 482452²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>PI 482444²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>PI 482439²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>PI 482455²</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Southern Pickle</td>
<td>Arkansas AES³</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>PI 482446³</td>
<td>Zimbabwe</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>PI 292190³</td>
<td>South Africa</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>PI 482458³</td>
<td>Zimbabwe</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td>PI 482451³</td>
<td>Zimbabwe</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>PI 202681³</td>
<td>South Africa</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>PI 482460³</td>
<td>Zimbabwe</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>PI 482461³</td>
<td>Zimbabwe</td>
<td>4</td>
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<tr>
<td>21</td>
<td>PI 482459³</td>
<td>Zimbabwe</td>
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<tr>
<td>22</td>
<td>PI 482443³</td>
<td>Zimbabwe</td>
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<td>23</td>
<td>PI 482435³</td>
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<td>24</td>
<td>PI 482441³</td>
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<td>25</td>
<td>PI 482458³</td>
<td>Zimbabwe</td>
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</tr>
<tr>
<td>26</td>
<td>PI 482462³</td>
<td>Zimbabwe</td>
<td>6</td>
</tr>
</tbody>
</table>

**Moderately resistant**

27 L190430 USDA, La Jolla, Calif. 19 5 33 0

**Slightly resistant**

28 PI 261608⁴ Spain 29 42 16 1
29 PI 422186⁴ Czechoslovakia 32 35 29 0
30 PI 211975⁴ Iran 33 33 27 0
31 PI 368586⁴ Yugoslavia 33 33 33 1
32 PI 292012⁴ Israel 33 37 30 1
33 PI 432867⁴ P.R. China 34 35 33 1
34 PI 249550⁴ Iran 35 35 50 1
35 PI 167043⁴ Turkey 35 33 36 1
36 PI 436610⁴ P.R. China 35 43 30 1
37 Minuc⁵ Minnesota AES⁶ 36 34 37 1
42 Delcrown⁶ NSSL¹ 37 32 42 0
60 Gy 4⁶ N.C. State Univ. 39 45 32 0

**Susceptible**

90 M 41⁴ N.C. State Univ. 42 42 42 0
245 Producer⁴ NSSL 49 38 59 1
267 Samtur⁴ Clemson Univ. 50 48 52 1
276 Dharampur-P¹ Nepal 50 46 55 0
289 Double Yield⁴ NSSL 50 58 42 1
340 Poinsett⁴ Clemson Univ. 51 49 53 0
343 H-19⁴ Arkansas AES 51 36 67 0
374 Gy 14A³ N.C. State Univ. 52 37 68 0
395 M 21⁴ N.C. State Univ. 53 46 59 0
407 Sprint 440 Asgrov Seed 53 50 56 1
419 Slice⁵ Clemson Univ. 53 58 48 1
443 Wisconsin SMR 12 Wisconsin AES¹ 54 37 70 0
445 Samtur¹ Clemson Univ. 54 41 67 2
512 Dasher II Petoseed 55 51 59 2
515 Markmore 76 Cornell Univ. 55 55 55 0
615 Wisconsin SMR 18 Wisconsin AES 58 55 61 1
632 Calypso⁴ N.C. State Univ. 58 55 60 1
665 Poinsett 76 Cornell Univ. 58 51 65 1
709 Clinton⁴ N.C. State Univ. 59 53 65 1
845 Samtur⁴ Clemson Univ. 64 74 90 0
894 PI 137836⁴ Iran 68 73 62 1
895 PI 357859⁴ Yugoslavia 68 63 72 1
896 PI 178884⁴ Turkey 68 63 73 1
897 PI 368551⁴ Yugoslavia 68 72 64 0
898 PI 266667⁴ Germany 68 62 75 1
899 PI 308915⁴ Former USSR 69 82 57 ---
900 PI 179260⁴ Turkey 70 80 61 0
901 Early Cluster⁴ NSSL 70 67 73 0
902 PI 192940⁴ P.R. China 71 73 68 2

Continued on next page
masses were counted using Hadisoeganda and Sasser's method (1982). The egg index system used was a modification of that used by Sasser et al. (1984). Percentage of roots covered with egg masses was used to determine resistance as follows: 0% = immune, 1% to 10% = resistant, 11% to 50% = moderately resistant, and >50% = susceptible.

The experiment was a split-plot treatment arrangement in a randomized complete-block design with five replications. Whole plots were the four nematodes and subplots were the 34 cultigens. Gall index and egg mass data were analyzed using SAS's GLM and CORR procedures. Cultigen and nematode means were tested using Fisher's LSD.

### Evaluating the Germplasm Collection

All *Cucumis* cultigens evaluated were highly resistant to *M. hapla*, with little difference in root galling from the most resistant (*C. metuliferus*) to the least resistant (*C. sativus*) cultigens.

Selected cultigens evaluated, including the most root-knot resistant, the most susceptible, and current cultivars, are listed in Table 2. The complete data set will be entered into the Germplasm Resources Information Network (USDA, Washington, D.C.).

All *C. meliformis* accessions evaluated were found to be highly resistant (1% to 10% of roots galled) to all root-knot nematodes tested (Table 2). Those data confirm the work of others (Fassuliotis, 1967, 1970; Norton and Granberry, 1980; Wehner et al., 1991), who showed that *C. metuliferus* was resistant to the *Meloidogyne* spp. causing root knot. However, introducing resistance into *C. sativus* from *C. metuliferus* may be difficult due to cross incompatibilities.

Only four *C. sativus* cultigens (Southern Pickler, L90430, PI 249550, and PI 401733) were highly or moderately resistant to *M. arenaria* race 2, and 108 (e.g., SC 10, Delcrow, and Mincu) were slightly resistant to *M. arenaria* race 2. Most cultigens evaluated were susceptible (768 of 881). The most susceptible cultigen was PI 179260 (83% of roots galled). For *M. arenaria* race 2, data were not obtained for 19 cultigens due to seed germination or plant growth problems.

Seven *C. sativus* cultigens (Southern Pickler, PI 220169, PI 220169, PI 357865, PI 261608, PI 226510, PI 137848, and PI 432848) were highly or moderately resistant to *M. incognita* race 3. About 100 cultigens (e.g., Gy 4, LJ 90430, and Mincu) were slightly resistant to *M. incognita* race 3. Most cultigens evaluated (766 of 878) were susceptible to *M. incognita* race 3. 'Black Diamond' was the most susceptible (87% of roots galled). No data were obtained for 22 cultigens for *M. incognita* race 3 resistance.

Most *C. sativus* cultigens were susceptible to the root-knot nematodes tested, with a mean for *M. arenaria* race 2 and *M. incognita* race 3 of 48% and 8% of roots with galls. Some cultigens differed in resistance to the two nematodes, however. For example, PI 220169 had an average gall index of 68% for *M. arenaria* race 2 and 8% for *M. incognita* race 3. Considering both nematodes, no data were collected for 16 cultigens; of the 884 cultigens evaluated, 834...
were susceptible (94%). ‘Tiny Dill’ was the most susceptible cultivar overall (72% of roots galled). Only two cultivars were highly resistant ('Southern Pickler' and LJ 90430). 'Southern Pickler' was the most resistant cultivar overall (5% of roots galled by M. arenaria race 2, and 1% by M. incognita race 3). Forty-seven cultivars were slightly resistant to root knot.

Retesting the extreme cultigens. The two C. metuliferus cultivars reevaluated (PI 482452 and PI 482443) were highly resistant to all nematodes, with a mean of 5% and 6% of roots galled, respectively (Table 3). The C. sativus cultivar most resistant to all nematode species was LJ 90430, with 29% of its roots galled. [LJ 90430 is an accession of C. sativus var. hardwickii (R.) Alef.] LJ 90430 was highly resistant to all nematode species, including several important cultivars and breeding lines ('Poinsett', 'Sumter', Wisconsin SMR 18, and Gy 4). LJ 90430 was the only resistant C. sativus cultivar (8% of roots galled). Its high level of resistance was not significantly different from that of the C. metuliferus cultivars (Table 3).

Of 32 C. sativus cultivars evaluated, 31 were susceptible to M. javanica (Table 3), including several important cultivars and breeding lines ('Poinsett', 'Sumter', Wisconsin SMR 18, and Gy 4). LJ 90430 was the only resistant C. sativus cultivar (8% of roots galled). Its high level of resistance was not significantly different from that of the C. metuliferus cultivars (Table 3).

None of the C. sativus cultivars were susceptible to either of the M. incognita races tested, with at least 40% of roots galled and at least 50 egg masses. LJ 90430 was the only resistant C. sativus cultivar to M. incognita races 1 and 3, respectively, but the presence of large numbers of egg masses (1120 and 352 for M. incognita races 1 and 3, respectively) indicated no resistance to M. incognita.

In conclusion, all C. metuliferus cultivars were resistant to root-knot nematodes, and LJ 90430 was the most resistant C. sativus cultivar to those species of root-knot nematodes evaluated. The inheritance of the resistance in LJ 90430 remains to be determined.

**Literature Cited**


