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Resistance to Root-knot Nematodes in Cucumber and Horned Cucumber

TODD C. WEHNER,[1] S. ALAN WALTERS,[1] AND KENNETH R. BARKER[2]

Abstract: Two experiments were conducted in the greenhouse. In one experiment, cucumber (*Cucumis sativus*) and horned cucumber (*C. metuliferus*) cultigens were evaluated for resistance to four root-knot nematode species (*Meloidogyne arenaria, M. hapla, M. incognita,* and *M. javanica*), and, in a second experiment, a standard (12-week) test was compared with a rapid (6-week) test. In the first experiment, horned cucumber cultigens varied in response to the *Meloidogyne* species. 'Sumter' cucumber was more susceptible than the horned cucumber to *Meloidogyne incognita, M. javanica,* and *M. arenaria.* All cultigens were more resistant to *M. hapla* than to the other root-knot nematode species. In the second experiment, best results were obtained when the test was run for 12 weeks rather than 6 weeks after planting (or 10 and 4 weeks after inoculation, respectively). All cultigens were more resistant to *M. arenaria* than to either *M. incognita* or *M. javanica.*

Key words: African horned cucumber, cucumber, *Cucumis metuliferus, Cucumis sativus, Meloidogyne arenaria, Meloidogyne hapla, Meloidogyne incognita, Meloidogyne javanica,* nematode resistance, root-knot nematode.

Cucumber (*Cucumis sativus* L.) is the second most important vegetable crop in North Carolina, and root knot (caused by *Meloidogyne* spp.) is the most important cucumber disease. Annually, root-knot nematodes destroy approximately 12% of the crop in the state (6). Four species of root-knot nematodes can potentially attack cucumber in North Carolina: *Meloidogyne incognita* (Kofoid & White) Chitwood, *M. arenaria* (Neal) Chitwood, *M. hapla* Chitwood, and *M. javanica* (Treub) Chitwood; but *M. hapla* is not important on cucumber in the state. Cucumber cultivars resistant to these species would be valuable for growers.

The African horned cucumber (*Cucumis metuliferus* Naud.) is resistant but not immune to *M. arenaria, M. javanica,* and *M. incognita* (3). As a result, interspecific hybridization to transfer root-knot nematode resistance to the cultivated cucumber has been a goal of many researchers. So far, attempts to hybridize the two species have been unsuccessful (4).

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[1] Professor and graduate student, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695-7609.

[2] Professor, Department of Plant Pathology, North Carolina State University, Raleigh, NC 27695-7616.

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Screening methods have been standardized (2,7) for the accurate testing of cultigens (used to refer to breeding lines, cultivars, and plant introduction accessions collectively) for resistance to root-knot nematodes. This research involved two greenhouse experiments, one conducted in 1987 and one in 1988. The objective of the first experiment was to determine whether there were differences among *C. metuliferus* cultigens for resistance to four root-knot nematode species. The objective of the second experiment was to determine whether a 6-week test for rapid screening in a breeding program would predict the results of the standard 12-week test in determining the resistance of *Cucumis* cultigens to root-knot nematodes.

MATERIALS AND METHODS

Nematode species experiment: During the spring of 1987, five accessions of *C. metuliferus* and 'Sumter' cucumber (*C. sativus*) were evaluated for resistance to four species of root-knot nematodes (*M. incognita* race 1, *M. javanica, M. arenaria* race 1, and *M. hapla*). The experiment was a factorial treatment arrangement in a randomized complete block design with four replications. Each treatment combination consisted of one *Cucumis* cultigen and one nematode species in a 100-mm diameter

(1,450 cm^3 volume) pot. Each pot contained a 1:1 mix of steam-sterilized sand and field soil (loamy sand: 80% sand, 15% silt, and 5% clay). Five seeds were planted directly into each pot. Pots were irrigated twice daily using drip irrigation with fertilizer injection. At the three-leaf stage, plants were thinned to one per pot. Greenhouse temperature was 24–32 C day and 21–24 C night.

Each plant was inoculated 2 weeks after planting with 5,000 nematode eggs (5). Plants were evaluated for root-knot nematode galling 8 weeks after inoculation (10 weeks after planting) by rating the percentage (0 to 100%) of the root system galled (1). The number of egg masses per root system was also counted. Finally, roots were cut into segments 10 to 20 mm long and treated with 1% NaOCl (5) to extract the eggs from the root system. Gall index, egg number, and egg mass number were analyzed with the GLM procedure of SAS (SAS Institute, Cary, NC). Cultigen means for gall index, egg number, and egg mass number were compared using Fisher's LSD at $P = 0.05$.

Six-week vs. 12-week experiment: In spring 1988, an experiment was conducted to determine whether a rapid (6-week) test was as good as the standard (12-week) test for evaluating resistance to root-knot nematode. Resistance of four *C. sativus* and two *C. metuliferus* cultigens to *M. incognita* race 1, *M. incognita* race 3, *M. arenaria* race 1, *M. arenaria* race 2, and *M. javanica* was determined with the two test methods.

The experiment was a factorial treatment arrangement in a randomized complete block design with three replications. The treatment combination consisted of one plant, one method, and one root-knot nematode species or race per pot. Each pot contained a 1:1 mix of steam-sterilized sand and field soil (loamy sand: 80% sand, 15% silt, and 5% clay). Five seeds were sown into 100-mm diameter, 1,450 cm^3 pots, which were irrigated twice daily by drip irrigation with fertilizer injection.

At the two-leaf stage, one plant was taken out of each pot and transplanted into larger (150-mm diameter, 1700 cm^3) pots. At the three-leaf stage, the remaining plants were thinned to one per small pot. The plants in the small pots were used for the 6-week test; those in large pots for the 12-week test. Each treatment combination was inoculated 2 weeks after planting with 5,000 nematode eggs (5). Greenhouse temperature was 24–32 C day and 21–24 C night.

Each treatment combination was evaluated 6 or 12 weeks after planting (corresponding to 4 and 10 weeks after inoculation), depending on test method. Plants were evaluated by rating the roots for percentage galled by root-knot nematodes (1). Gall index data were analyzed with the GLM procedure of SAS. Means for cultigen and method were separated using Fisher's LSD at $P = 0.05$.

Results and Discussion

Nematode species experiment: For our purposes, the percentage of the root system galled can be used to classify resistance: 0–10% = highly resistant; 11–20% = moderately resistant; 21–40% = slightly resistant; and > 40% = susceptible. By these criteria, all *Cucumis* cultigens evaluated had some resistance to *M. hapla* (Table 1). 'Sumter' cucumber was susceptible to all *Meloidogyne* spp., except for *M. hapla.* The cultigens of *C. metuliferus* were susceptible to both *M. incognita* race 1 and *M. javanica.* Gall indices among *C. metuliferus* cultigens differed in response to two root-knot nematodes, *M. arenaria* race 1 and *M. incognita* race 1. Galling from *M. arenaria* race 1 and *M. javanica* was lower ($P < 0.05$) on all *C. metuliferus* cultigens than on *C. sativus* cv. Sumter. Over all treatment combinations, gall index and egg number were highly correlated ($r = 0.79$).

Numbers of eggs and egg masses of *M. incognita* race 1, *M. arenaria* race 1, and *M. javanica* were greater ($P \leq 0.05$) on 'Sumter' cucumber than on the *C. metuliferus* cultigens. For *M. incognita* race 1, PI 482452 had fewer ($P \leq 0.05$) eggs than the other *C. metuliferus* cultigens, indicating a higher level of resistance. No significant differ-

TABLE 1. Gall index (GI)†, number of eggs, and number of egg masses (EM) on six cultigens of *Cucumis* spp. tested with four species of root-knot nematodes (*Meloidogyne* spp.).

Cultigen	Species	*M. hapla*			*M. arenaria*			*M. incognita*			*M. javanica*		
		GI	Eggs	EM	GI	Eggs	EM	GI	Eggs	EM	GI	Eggs	EM
PI 482452	*C. metuliferus*	6	220	0	36	700	0	50	2,550	1	46	3,605	1
PI 482454	*C. metuliferus*	6	5	0	40	1,785	0	60	22,290	2	60	6,440	2
PI 482450	*C. metuliferus*	6	220	0	60	2,747	1	66	21,547	1	41	2,167	0
PI 482461	*C. metuliferus*	16	305	0	56	1,015	1	80	26,390	2	46	4,820	1
PI 482448	*C. metuliferus*	20	165	0	50	3,420	1	86	22,400	3	66	7,250	1
Sumter	*C. sativus*	30	255	0	96	69,200	5	96	63,000	4	96	75,000	5
LSD ($P = 0.05$) for row and column comparisons:					22	12,639	1						

Data are means of four replications of one plant each. *Meloidogyne arenaria* and *M. incognita* were race 1. Plants were inoculated 2 weeks after planting and evaluated 8 weeks later.

† Gall index = percentage of the root system galled (1).

ences ($P \leq 0.05$) occurred among the *Cucumis* cultigens for number of eggs or egg masses of *M. hapla,* indicating that all were resistant. Based on gall indices, number of eggs, and number of egg masses, PI 482452 was the most resistant cultigen to the root-knot nematodes tested. Although counts of eggs are preferable to galling indices for obtaining an indication of nematode reproduction (i.e., resistance), the galling indices may be advantageous when large numbers of cultigens must be assessed and time or labor is limited.

Six-week vs. 12-week experiment: The 6-week test did not allow time for extensive nematode gall development on susceptible plants. In some cases, it also did not allow for differentiation between *C. metuliferus* and *C. sativus* cultigens (Table 2). In the 12-week test, more of the differences between the two species were significant ($P \leq 0.05$).

Cucumis spp. were more resistant to races

TABLE 2. Gall index† for six cultigens of *Cucumis* spp. tested with five species of root-knot nematodes (*Meloidogyne* spp.) and two methods.

Cultigen	Species	Gall indices				
		Mi1	Mi3	Mj	Ma1	Ma2
	Six-week test					
PI 482452	*C. metuliferus*	21	29	19	14	10
PI 482448	*C. metuliferus*	18	28	18	17	12
Wisconsin SMR 18	*C. sativus*	31	53	24	17	11
Poinsett 76	*C. sativus*	32	54	36	19	12
Marketmore 76	*C. sativus*	40	57	40	25	16
Sumter	*C. sativus*	25	52	32	20	11
	Twelve-week test					
PI 482452	*C. metuliferus*	24	16	10	10	10
PI 482448	*C. metuliferus*	26	16	24	13	9
Wisconsin SMR 18	*C. sativus*	95	89	93	15	14
Poinsett 76	*C. sativus*	95	95	95	24	18
Marketmore 76	*C. sativus*	96	95	97	26	17
Sumter	*C. sativus*	98	99	98	44	26
Mean over cultigens and tests		50	57	49	20	14
LSD ($P = 0.05$) for row-column comparisons:				10		

Data are means of three replications of one plant each. The 6-week test used small (100-mm diameter) pots for 6 weeks (planting to evaluation), and the 12-week test used large (150-mm diameter) pots for 12 weeks (planting to evaluation).

† Gall index = percentage of the root system galled (1). Mi1 = *M. incognita* race 1, Mi3 = *M. incognita* race 3, Mj = *M. javanica,* Ma1 = *M. arenaria* race 1, and Ma2 = *M. arenaria* race 2.

of *M. arenaria* than to either *M. incognita* or *M. javanica.* Across all cultivars in both 6-week and 12-week tests, mean gall indices were lower for *M. arenaria* races 1 and 2 than for *M. incognita* races 1 and 3 or *M. javanica.* We concluded that the 12-week test was worth the extra time, because the 6-week test failed to detect important differences. The 6-week test (4 weeks after inoculation) does not allow sufficient time for root-knot nematode reproduction.

Two check lines that are often used in screening for resistance to foliar diseases in cucumbers are Wisconsin SMR 18 and Sumter. In the 12-week test, Wisconsin SMR 18 was moderately resistant (15% galling) to *M. arenaria,* whereas Sumter (35% galling) was only slightly resistant to *M. arenaria* (figures averaged across races 1 and 2). Sumter cucumber was highly susceptible to *M. arenaria* race 1 in the nematode species test but was moderately resistant to the same root-knot nematode race in the 6-week vs. 12-week experiment. This may have occurred because different populations were used in the two experiments.

Accessions of *C. metuliferus* were not highly resistant to the root-knot nematode species, *M. arenaria, M. incognita,* and *M. javanica.* However, there was some resistance in some accessions, agreeing with the findings of Dalmasso et al. (3). Specific races of *M. incognita* and *M. arenaria* were not described by Dalmasso et al. (3), only that three populations of each were tested. Our studies have provided additional information on *M. hapla* and on specific races of *M. arenaria* and *M. incognita.* Additional research is needed, particularly to evaluate the *Cucumis* germplasm collection for nematode resistance by the 12-week test method.

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