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Response of Cut Flowers and Bedding Plants to Root-knot Nematodes

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Five separate experiments were conducted to test the susceptibility of different cut flowers and bedding plants to root-knot nematodes, *Meloidogyne incognita* (Kofoid & White) Chitwood race 2, *M. javanica* (Treub) Chitwood, and *M. arenaria* (Neal) Chitwood. The first set of experiments involving two separate tests was conducted in Oct. 2007. The first two tests consisted of seven cultivars of cut flowers and bedding plants grown under greenhouse conditions to test their susceptibility to root-knot nematodes, *Meloidogyne incognita* race 2 and *M. javanica*. Cultivars examined included 'Thumbelina' and 'Envy' zinnia (*Zinnia elegans* L.); 'Petite' and 'Jaguar' marigold (*Tagetes patula* L.), and 'Snowdrift' marigold (*T. erecta* L.); 'Dwarf Jewel Blend' nasturtium (*Tropaeolum minus* L.); and 'Potomac Pink' snapdragon (*Antirrhinum majus* L.). In a separate experiment, 'Potomac Pink' snapdragon plants were tested to determine their response to *M. arenaria* and varying concentrations of *M. incognita* race 2 inoculum. The last two tests were conducted in Dec. 2007 and involved *M. incognita* race 2 and *M. javanica.* The cultivars tested included 'Butterfly Blend' delphinium (*Delphinium grandiflorum* L.); 'Silver Princess' Shasta daisy (*Chrysanthemum maximum* Raymond); 'Blue Bedder' salvia (*Salvia splendens* Ker-Gawl); 'Chabaud Giant' carnation (*Dianthus caryophyllus* L.); 'Dwarf Magic Carpet' and 'Potomac Pink' snapdragons. Based on the numbers of nematodes recovered from the root systems and the soil, nasturtium and the two cultivars of snapdragon were susceptible to the root-knot nematodes evaluated while marigold, zinnia, salvia, and carnation were poor hosts ($P \leq 0.05$). Shasta daisy was moderately susceptible. 'Potomac Pink' snapdragon was also equally susceptible to both *M. incognita* and *M. arenaria.*

Cut flowers and bedding plants are widely grown in Florida. Florida was the second highest producer of floriculture with a wholesale value of $800 million in 2006 (USDA, 2007). Many cut flowers and bedding plants such as snapdragon (*Antirrhinum majus*), lisianthus [*Eustoma grandiflorum* (L.) Cass.], sunflower (*Helianthus annuus* L.), and gladiolus (*Gladiolus communis* L.) have been shown to be susceptible to root-knot nematodes (*Meloidogyne* spp.) (Overman, 1969, 1985; Rich and Dunn, 1982; Schochow et al., 2004; Wang and McSorley, 2005). Interpretation of results can be difficult because several species and races of root-knot nematodes are common (Taylor and Sasser, 1978), and may occur in Florida. The different races of root-knot nematodes may attack different plant species; for example, cotton (*Gossypium hirsutum* L.) is susceptible to *Meloidogyne incognita* race 3 but not to *M. incognita* races 1 and 2 (Taylor and Sasser, 1978). Responses of several bedding plants have been tested against *M. incognita* race 1, *M. javanica*, and *M. arenaria* race 1 (McSorley and Frederick, 1994), and against *M. incognita* race 3 (Walker et al., 1994). Most studies in Florida have involved *M. incognita* race 1, and salvia (*Salvia splendens*) cv. Bonfire and vinca [*Catharanthus roseus* (L.) G.Don] cv. Little Bright Eyes were demonstrated to have potential resistance to *M. incognita* race 1 and *M. javanica* (McSorley and Frederick, 2001). However, information on resistance of various flower cultivars against other root-knot nematode species and races is limited. Because methyl bromide, a broad-spectrum soil fumigant, is being phased out (Schneider et al., 2003), use of resistant varieties in managing root-knot nematode in floriculture is an alternative to consider.

The objectives of this study were to evaluate the response of some cut flowers and bedding plants to two species of root-knot nematodes, *M. incognita* race 2 and *M. javanica,* and to determine the response of snapdragon plants to *M. arenaria* and to different concentrations of *M. inocgnita* race 2.

Materials and Methods

Five separate experiments were conducted. The first set of experiments was begun in Oct. 2007 to examine different flower cultivars for their responses to *M. incognita* race 2 and *M. javanica* in separate experiments with each nematode. Additional experiments with *M. incognita* race 2 and *M. javanica* were begun in Dec. 2007. A separate test on snapdragon was also conducted beginning in October to examine the response of snapdragon to *M. arenaria* and various inoculum concentrations of *M. incognita* race 2. All experiments were carried out in a greenhouse on the University of Florida campus in Gainesville, FL.

October flower tests. Seven flower cultivars were examined against *M. incognita* race 2 and *M. javanica*, in separate experiments. The cultivars included: 'Thumbelina' zinnia (*Zinnia elegans,* Ferry-Morse Seed, Fulton, KY); 'Envy' zinnia (W. Atlee Burpee & Co., Warminster, PA).; 'Petite' marigold (*Tagetes patula*, Ferry-Morse Seed, Fulton, KY); 'Jaguar' (*T. patula*) and 'Snowdrift' marigold (*T. erecta*) (W. Atlee Burpee & Co., Warm-

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inster, PA); 'Dwarf Jewel Blend' nasturtium (*Tropaeolum minus*, Botanical Interests, Inc., Broomfield, CO); and 'Potomac Pink' snapdragon (Speedling Inc., Sun City, FL). Flowers were raised from seeds except for snapdragon, for which seedlings (2–3 cm tall) were used. Seeds were sown in 3 cm × 3 cm styrofoam trays in a 1:2 mixture of Stagreen Flower and Vegetable Planting Mix (United Industries Corp., St. Louis, MO) and Gardener Plus All Purpose Potting Soil (Green Leaf Products, Inc., Haines City, FL). Seedlings were kept in a growth chamber until 1 week before transplanting. Seedlings were transplanted 31 d after sowing into 4-inch (10 cm) diameter plastic pots filled with a 2:1 mixture of play sand (Scrugs Company, Valdosta, GA) and Stagreen Flower and Vegetable Planting Mix. The transplanted plants were inoculated with 250 second-stage juveniles (J2) per pot of *M. incognita* race 2 or *M. javanica* in water suspension with a syringe at 1- to 2-cm depth around the base of the plant.

Snapdragon nematode concentrations test. Seedlings of 'Potomac Pink' snapdragon were transplanted into 4-inch-diameter plastic pots with the same growing medium and conditions as the previous test. Plants were inoculated in Oct. 2007 with 250 J2 of *M. arenaria*, or with 250, 500, or 1000 J2 of *M. incognita* race 2.

December flower tests. Flowers examined in these experiments included: 'Butterfly Blend' delphinium (*Delphinium grandiflorum,* Botanical Interests, Inc., Broomfield, CO); 'Silver Princess' Shasta daisy (*Chrysanthemum maximum,* W. Atlee Burpee & Co., Warminster, PA); 'Blue Bedder' salvia (*Salvia splendens* Ker-Gawl*,* Ferry-Morse Seed, Fulton, KY); 'Chabaud Giant' carnation (*Dianthus caryophyllus,* Ferry-Morse Seed, Fulton, KY); two cultivars of snapdragon, 'Potomac Pink' seedlings (Speedling Inc., Sun City, FL), and 'Dwarf Magic Carpet' (Ferry-Morse Seed, Fulton, KY). Seedlings were raised as described for the October flower test. Seedlings were transplanted 68 d after sowing into 4-inch-diameter plastic pots with the same ratio of sand and potting mix described for the October tests. Plants were inoculated with 250 J2 of *M. incognita* race 2 or *M. javanica* 7 d after transplanting. Nematode suspension was delivered using a syringe into three holes of 1- to 2-cm depth around the base of the plants.

Nematode inocula, experiment maintenance, and data collection. Nematode inocula for all the experiments were obtained from nematode cultures maintained in the greenhouse. Cultures had been originally obtained from various field sites in Florida. *Meloidogyne incognita* had been maintained on pepper (*Capsicum annuum* L.), *M. javanica* on tobacco (*Nicotiana tabacum* L.), and *M. arenaria* on tomato (*Lycopersicon esculentum* Mill.). Inoculum for the various nematodes was obtained by extracting nematode eggs from roots of culture plants in 0.75% NaOCl (Hussey and Barker, 1973) and incubating on Baerman trays for 10 d (Rodriguez-Kabana and Pope, 1981). Each treatment (flower cultivars in most tests, nematode inoculum levels in the concentrations test) was replicated four times and pots were arranged in a randomized complete-block design on raised benches in the greenhouse. Plants were watered daily and fertilized with 1.23 g per pot of $19N–6P_2O_5–12K_2O$ (Osmocote, Scotts-Sierra Horticultural Products Company, Marysville, OH) 15 d after transplanting.

Both the October and December experiments were terminated beginning at 103 d after inoculation within a period of 10 d. Root gall index was rated on a scale of 0 to 5, where 0 = no galls, 1 = 1–2 galls, 2 = 3–10 galls, 3 = 11–30 galls, 4 = 31–100 galls, and 5 = more than 100 galls per root system (Taylor and Sasser, 1978). Eggs of nematodes were extracted from each root system in 0.75% NaOCl (Hussey and Barker, 1973) and incubated on Baermann trays for 8 d to obtain hatched J2. Numbers of the J2 were counted using an inverted microscope. A soil sample from each pot was also collected, and nematodes were extracted from a 100-cm^3 subsample using a sieving and centrifugation procedure (Jenkins, 1964).

Numbers of J2 and root gall index were analyzed by analysis of variance (ANOVA) using SAS software (SAS Institute, Cary, NC) for each experiment. When ANOVA results were significant, means were separated by Waller-Duncan (k = 100) *t*-test at $P \leq 0.05$. Nematode J2 count data were $\log_{10}$-transformed prior to ANOVA but untransformed means are reported in all tables.

Results and Discussion

October flower tests. Snapdragon and nasturtium showed significant galling by *M. incognita* race 2 (Table 1). All marigold and zinnia cultivars were free of galls. Nasturtium was more susceptible to *M. incognita* race 2 compared to other flower species based on the number of J2 recovered from the roots and soil. Snapdragon showed a numerically high number of J2 obtained from the roots, but it was not significantly different from the marigold and zinnia cultivars because the majority of the J2 obtained from snapdragon roots was from one replicate. All cultivars of marigold and zinnia were less susceptible. No nematodes were recovered from 'Envy' zinnia roots but it was not significantly different from all marigold cultivars and 'Thumbelina' zinnia.

Root galling by *M. javanica* was higher on snapdragon compared to the other flower species (Table 1). However, numbers of nematodes recovered from root systems and from soil were significantly higher in both snapdragon and nasturtium compared to other flower species. Low levels of J2 numbers were obtained from all marigold and zinnia cultivars.

The low level of nematodes recovered from all cultivars of marigold and zinnia suggests that these cultivars are poor hosts of *M. incognita* race 2 and *M. javanica*. Many marigold cultivars were reported to be poor hosts to root-knot nematodes and are often used as rotational or cover crops to manage root-knot nematodes (Krueger et al., 2007; Ploeg, 2002). Zinnia ('Scarlet') was reported to be a poor host to *M. incognita* race 1 and *M. arenaria* race 1 but was infected by *M. javanica* (McSorley and Frederick, 1994). Cultivars of zinnia in the present study were poor hosts of both *M. incognita* and *M. javanica,* suggesting the existence of differences in susceptibility within this species. Yassin and Ismail (1994) reported that planting zinnia (cultivars not specified) around tomato plants reduced population build-up of *M. incognita* and *Rotylenchulus reniformis* Linford & Oliveira. Nasturtium was a good host of both *M. incognita* race 2 and *M. javanica* . Crow (2005) reported that nasturtium was one of the ornamental plants most heavily infested by root-knot nematodes. 'Potomac Pink' snapdragon was also a good host to *M. javanica*. Previous studies have shown that 'Potomac Pink' snapdragon was a good host to *M. incognita* race 1 (Wang et al., 2005).

Snapdragon nematode concentrations test. The responses of snapdragon treated with 250 and 500 nematode juveniles were not different from each other, but a high number of nematodes were recovered in the plants treated with 1000 *M. incognita* race 2 (Table 2). However, snapdragon plants treated with only 250 J2 of *M. arenaria* produced numbers of J2 extracted per root system that were not different from plants treated with 500 or 1000 *M. incognita* race 2. Plants treated with 1000 *M. incognita* showed

Table 1. Susceptibility of cut flowers and bedding plants to *Meloidogyne incognita* race 2 and *M. javanica* in October flower tests.

Plant	Cultivar	Gall index[z]	J2[y] per root system	J2 per 100 cm soil
		M. incognita race 2		
Snapdragon	Potomac Pink	2.00 a[x]	2022.0 b	4.0 b
Nasturtium	Dwarf Jewel Blend	1.50 a	1067.0 a	108.0 a
Marigold	Snow Drift	0.00 b	11.0 bc	0.2 b
Marigold	Petite	0.00 b	3.0 bc	0.0 b
Marigold	Jaguar	0.00 b	1.0 c	0.0 b
Zinnia	Thumbelina	0.00 b	1.0 c	0.0 b
Zinnia	Envy	0.00 b	0.0 c	0.0 b
		M. javanica		
Snapdragon	Potomac Pink	3.25 a	1425.5 a	8.5 a
Nasturtium	Dwarf Jewel Blend	0.75 b	318.3 a	12.0 a
Marigold	Snow Drift	0.00 c	0.8 bc	0.0 b
Marigold	Petite	0.00 c	1.5 bc	0.0 b
Marigold	Jaguar	0.00 c	0.3 c	0.0 b
Zinnia	Thumbelinia	0.25 bc	1.0 bc	1.0 ab
Zinnia	Envy	0.25 bc	74.0 b	2.0 ab

[z]Gall index rated on 0 (0 galls) to 5 (>100 galls per root system) scale. See text for complete scale.
[y]Second-stage juveniles.
[x]Means in a column followed by same letters are not different ($P \leq 0.05$) according to Waller-Duncan k-ratio (k=100) *t*-test. Analysis is based on $\log_{10}(x+1)$ values for nematode (J2) count. Non-transformed data are presented here.

Table 2. Response of 'Potomac Pink' snapdragon to different inoculation concentrations of *Meloidogyne incognita* race 2 and *M. arenaria*.

Nematode	Concn	Gall index[y]	J2[z] per root system	J2 per 100 cm soil
M. incognita R2	250	2.00 b[x]	2,022 b	3.00 b
M. incognita R2	500	3.25 ab	634 ab	14.00 b
M. incognita R2	1000	4.74 a	11,932 a	367.50 a
M. arenaria	250	3.50 a	6,702 a	8.00 b

[z]Second-stage juveniles.
[y]Gall index rated on 0 (0 galls) to 5 (>100 galls per root system) scale. See text for complete scale.
[x]Means in a column followed by same letters are not different ($P \leq 0.05$) according to Waller-Duncan k-ratio (k=100) *t*-test. Analysis is based on $\log_{10}(x+1)$ values for nematode count. Non-transformed data are presented here.

the highest numbers of J2 obtained from the soil. However, there was no difference in the numbers of J2 obtained from soil of plants treated with *M. arenaria* and *M. incognita,* which were inoculated with the same concentration (250 J2). Results suggest that 'Potomac Pink' snapdragon is equally and highly susceptible to both *M. arenaria* and *M. incognita* race 2. The highest gall rating was obtained in plants treated with 1000 J2 of *M. incognita* race 2, which was not significantly different from *M. arenaria*.

December flower tests. Root galling by *M. incognita* race 2 was highest on 'Potomac Pink' snapdragon compared to other flower species (Table 3). Delphinium, salvia, and carnation showed little or no galling by *M. incognita*. The numbers of J2 obtained from the root system and soil were also highest in 'Potomac Pink' compared to other flower species. Almost negligible numbers of J2 were recovered from the roots of salvia and carnation compared to other cultivars.

A similar trend in the susceptibility of these cultivars was obtained with *M. javanica*. 'Potomac Pink' snapdragon showed high root galling by *M. javanica* (Table 3). Salvia showed no galling, while delphinium and carnation showed relatively low galling. The numbers of J2 recovered from roots and soil were also highest in 'Potomac Pink'. Carnation had the lowest number of J2 recovered from roots. No nematodes were obtained from the soil of salvia and carnation.

Previous studies had shown differences in the response of salvia cultivars to root-knot nematodes. 'Bonfire' salvia was found to be a poor host to *M. incognita* race 1 and *M. javanica* (McSorley and Frederick, 2001; 1994). 'Blue Bedder' salvia in this study showed low galling and few numbers of J2 of both *M. incognita* race 2 and *M. javanica*.

Conclusions

The results from this study showed that 'Potomac Pink' and 'Dwarf Magic Carpet' snapdragon and nasturtium were highly susceptible to both *M. incognita* and *M. javanica*. Shasta daisy was moderately susceptible to these nematodes. In contrast, the marigold, zinnia, salvia, and carnation cultivars were poor hosts and were fairly resistant to these nematodes. Delphinium was somewhat intermediate in its response, but would be a much better choice for commercial planting than the highly susceptible snapdragon. Among commonly-grown cut flower crops in Florida, larkspur (*Consolida ajacis* [L.] Schur) and lisianthus appear to have some resistance to root-knot nematodes (Wang and McSorley, 2005). Damage to lisianthus by root-knot nematodes is reported from California (Schochow et al., 2004), and root galling is occasionally observed in the field in Florida. However, recent tests of some lisianthus cultivars grown in Florida revealed they were fairly resistant to *M. incognita* race 1 (Wang and McSorley, 2005).

The data presented here extend our knowledge of nematode resistance in flowers such as marigold, zinnia, salvia, and carnation to other nematode species and races, especially *M. javanica* and *M. incognita* race 2. It is very difficult for homeowners, growers, and even nematologists to distinguish differences among *M. javanica* and races 1 and 2 of *M. incognita* in the field. Attempting to match a specific resistant flower cultivar to a specific species

Table 3. Susceptibility of cut flowers and bedding plants to *Meloidogyne incognita* and *M. javanica* for the December flower test.

Host	Cultivar	Gall index[z]	J2[y] per root system	J2 per 100 cm soil
		M. incognita race 2		
Snapdragon	Potomac Pink	4.75 a[x]	5,750.0 a	8.50 a
Snapdragon	Dwarf Magic Carpet	3.25 b	1,374.0 b	2.00 b
Shasta Daisy	Silver Princess	3.25 b	491.0 bc	1.25 b
Delphinium	Butterfly Blend	0.25 c	25.0 cd	0.75 b
Salvia	Blue Bedder	0.00 c	2.0 d	0.00 b
Carnation	Chabaud Giant	0.00 c	1.0 d	0.00 b
		M. javanica		
Snapdragon	Potomac Pink	4.50 a	3,866.3 a	33.25 a
Snapdragon	Dwarf Magic Carpet	2.50 bc	1,085.5 b	5.50 b
Shasta Daisy	Silver Princess	3.50 ab	519.8 bc	5.00 b
Delphinium	Butterfly Blend	1.50 cd	169.5 bc	2.00 bc
Salvia	Blue Bedder	0.00 d	4.5 cd	0.00 c
Carnation	Chabaud Giant	0.25 d	2.0 d	0.00 c

[z]Gall index rated on 0 (0 galls) to 5 (>100 galls per root system) scale. See text for complete scale.

[y]Second-stage juveniles.

[x]Means in a column followed by same letters are not different ($P \leq 0.05$) according to Waller-Duncan k-ratio (k=100) *t*-test. Analysis is based on $\log_{10}(x+1)$ values for nematode (J2) count. Non-transformed data are presented here.

or race of root-knot nematode would be problematic. Therefore a more practical and effective course of action would be to choose a flower cultivar known to be resistant to several different types of root-knot nematodes.

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