

RESEARCH NOTE - NOTA INVESTIGATIVA

HOST STATUS OF SEVERAL CUT FLOWER CROPS TO THE ROOT-KNOT NEMATODE, *MELOIDOGYNE INCOGNITA*

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ABSTRACT

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Many cut flower growers in Florida produce crops directly in the field, subjecting them to soil-borne diseases and root-knot nematode infection. Seven cultivars of cut flowers were tested for their susceptibility to two races of the southern root-knot nematode (*Meloidogyne incognita*) in a greenhouse. Cultivars evaluated were 'Potomac Royal' snapdragon (*Antirrhinum majus*), 'Madonna Blue' blue lace flower (*Didiscus caeruleus*), 'Green Mist' and 'Queen of Africa' white dill (*Ammi majus*), 'Qis White Cut' larkspur (*Consolida ajacis*), and 'Avila Rose Rim' and 'Echo Pink' lisianthus (*Eustoma grandiflorum*). Cultivars of lisianthus and larkspur tested were relatively poor hosts to *M. incognita* races 1 and 2 as compared to the known susceptible host, snapdragon ($P < 0.05$). Based on number of nematodes extracted per gram of root tissue, 'Madonna Blue' blue lace flower was more susceptible, 'Green Mist' white dill was equally susceptible, and 'Queen of Africa' white dill was less susceptible than snapdragon ($P < 0.05$). Numbers of nematodes per gram of root were not different for *M. incognita* races 1 and 2 ($P > 0.05$) on any plant cultivar. Despite differences in nematode susceptibility, numbers of flowers, and shoot and root weights of all cultivars tested except 'Madonna Blue' were not affected by nematode inoculation. *Meloidogyne incognita* race 1 reduced the number of flower buds and shoot weight of 'Madonna Blue' compared to the control, indicating that this blue lace flower cultivar is intolerant to this nematode.

Key words: *Ammi majus*, *Antirrhinum majus*, blue lace flower, *Consolida ajacis*, *Didiscus caeruleus*, *Eustoma grandiflorum*, larkspur, lisianthus, resistance, snapdragon, white dill.

RESUMEN

Wang, K.-H. y R. McSorley. 2005. Evaluación de la reproducción del nematodo del nudo radical *Meloidogyne incognita* en algunas variedades de flores de corte. *Nematopica* 35:45-52.

En Florida, muchos productores de flores de corte tienen sus cultivos directamente en el campo, exponiéndolos a enfermedades causadas por agentes del suelo y a infecciones por nematodos. En este trabajo, se evaluó la susceptibilidad de siete variedades de flores de corte a dos razas de *Meloidogyne incognita* en invernadero. Las variedades y especies evaluadas fueron 'Potomac Royal' de *Antirrhinum majus*, 'Madonna Blue' de *Didiscus caeruleus*, 'Green Mist' y 'Queen of Africa' de *Ammi majus*, 'Qis White Cut' de *Consolida ajacis*, y 'Avila Rose Rim' y 'Echo Pink' de *Eustoma grandiflorum*. La reproducción de las razas 1 y 2 de *M. incognita* en las variedades de *E. grandiflorum* y *C. ajacis* evaluadas fue relativamente baja en comparación con el testigo susceptible, 'Potomac Royal' ($P < 0.05$). Según la cantidad de nematodos por gramo de raíces, 'Madonna Blue' fue más susceptible que 'Potomac Royal', mientras que 'Green Mist' fue igualmente susceptible, y 'Queen of Africa' fue menos susceptible ($P < 0.05$). No hubo diferencias ($P > 0.05$) entre la cantidad de nematodos por gramo de raíces de *M. incognita* raza 1 y 2 en ninguna de las variedades. A pesar de las diferencias en susceptibilidad, la cantidad de flores y el peso de raíces y de la parte aérea no se vieron afectados por la inoculación con el nematodo en ninguna variedad, excepto 'Madonna Blue'. La raza 1 redujo la cantidad de botones

florales y el peso de la parte aérea de 'Madonna Blue', sugiriendo que esta variedad no es tolerante a este nematodo.

Palabras clave: *Ammi majus*, *Antirrhinum majus*, *Consolida ajacis*, *Didiscus caeruleus*, *Eustoma grandiflorum*, resistencia.

The United States is the third largest producer among the top three cut flower producing countries in the world after The Netherlands and Colombia (Anonymous, 2000). Total cut flower sales in the U.S. were \$421 million in 2003 (Jerardo, 2004). Traditional fresh cut flowers such as carnations (*Dianthus* spp.) have declined in popularity, whereas other species are becoming more popular (Hodges and Haydu, 2003). Snapdragon (*Antirrhinum majus* L.) (U.S. sales in 2003 of \$14.6 million), larkspur (*Consolida ajacis* (L.) Schur.) (U.S. sales in 2003 of \$11.2 million), and lisianthus (*Eustoma grandiflorum* (Raf.) Shinn.) (U.S. sales in 2003 of \$6.3 million) have recently become more important in the U.S. Their sales values were ranked among the top 13 cut flowers in 2003 (Jerardo, 2004).

In Florida, many of these flowers are grown directly in the field, subjecting them to plant-parasitic nematodes including a major pest on floral crops, root-knot nematodes (*Meloidogyne* spp.). Snapdragon has long been known to be susceptible to root-knot nematodes, and may show wilting or other damage symptoms (Goff, 1936; McSorley and Frederick, 1994; Tarjan, 1952). Relatively little is known about the susceptibility of other newly developed flower varieties to root-knot nematodes. The few cultivars of lisianthus that have been tested were poor hosts to *M. incognita* (Wang *et al.*, 2005), whereas tolerance of larkspur to *M. incognita* varied among cultivars (Wang *et al.*, 2005).

Susceptibility to nematodes is defined as the ability of the plant to support nematode development, or reproduction. Resis-

tance is the opposite of susceptibility, and therefore nematode resistance is characterized by a low nematode reproduction rate (Trudgill, 1985). However, evaluation of plant performance against nematode infection should not exclude an evaluation of nematode tolerance. Independent of nematode resistance and susceptibility, nematode tolerance is the ability of a plant to withstand nematode infection and provide normal yield and performance. Tolerance can be measured by plant growth (Trudgill, 1985). It is important to know both the resistance and tolerance of a plant to a specific nematode because this information can help the grower to manage the nematode pest accordingly. For example, a plant that is very susceptible to nematode infection might be tolerant to the nematode, thus posing no threat of yield loss to the grower.

Objectives of this study were to examine the host status of several cut flower cultivars commonly grown in South Florida to *M. incognita* (Kofoid & White) Chitwood races 1 and 2, and to evaluate the tolerance of these cut flowers to nematode infection under greenhouse conditions.

MATERIALS AND METHODS

Seven cultivars of cut flowers representing five genera were evaluated for susceptibility to *M. incognita* in a greenhouse trial on the University of Florida campus in Gainesville, FL. Approximately 1-cm-tall transplant seedlings in 1-cm² cell plugs were obtained from Sunshine State Carnations in Hobe Sound, FL, on 13 Jan. 2004. Cut flowers tested were 'Potomac Royal' snapdragon,

'Madonna Blue' blue lace flower (*Didiscus caeruleus* [R. Grah.] DC.), 'Green Mist' and 'Queen of Africa' white dill (*Ammi majus* L.), 'Qis White Cut' larkspur, and 'Avila Rose Rim' and 'Echo Pink' lisianthus. Snapdragon and lisianthus were included because they were known to be good and poor hosts of *M. incognita*, respectively (McSorley and Frederick, 1994; Wang *et al.*, 2005). Flower seedlings were transplanted into 7.5-cm-diam. plastic pots the day after they were received. Each pot contained 500 g dry weight of builders' sand and peat potting mix (4:1 ratio) to produce a medium with 97% sand, 0.5% silt, and 2.5% clay, with 3.0% organic matter content.

Nematode inocula for *M. incognita* races 1 and 2 were obtained from greenhouse cultures of 'California Wonder' pepper (*Capsicum annuum* L.) and 'NC95' tobacco (*Nicotiana tabacum* L.), respectively. Nematode eggs were extracted from root systems in 0.35% NaOCl (Hussey and Barker, 1973) and incubated on Baermann trays (Rodriguez-Kabana and Pope, 1981) for 7 days to obtain juveniles. Two weeks after transplanting, 1,500 *M. incognita* second-stage juveniles (J2) were inoculated into each pot dedicated to receive *M. incognita* race 1 or race 2 treatments. Nematodes were delivered in 6 mL of water by a syringe inserted to a depth of 1 cm in three holes around the stem of the plant. Uninoculated control plants received 6 mL of water. Thus, the experiment was a 7 × 3 (cut flowers × nematode inoculation) split-plot design arranged in a randomized complete block with 4 replications.

Flower transplants were maintained under greenhouse conditions with ambient temperatures of 13°C minimum and 30°C maximum. Plants were watered daily, and fertilized with Miracle-Gro fertilizer (Scotts Miracle-Gro Product, Inc., Marysville, OH) weekly with 50 mL/plant of a solution of 0.54 g/L of 15-30-15 (N: P₂O₅:

K₂O). Plant heights were measured at approximately 3-week intervals.

Experiments were terminated 13 weeks after nematode inoculation between 3 May and 6 May 2004. Shoot and root fresh weights, number of flower buds and blooms, and root gall indices were recorded. Plant height was measured. Root gall index for *M. incognita* was rated on a modified scale of 0 to 6 where 0 = no galls, 1 = 1 to 2 galls, 2 = 3 to 10 galls, 3 = 11 to 30 galls, 4 = 31 to 100 galls per root system, 5 = 25% to 50% of root system galled, and 6 = 51 to 75% of root system galled (Netscher and Sikora, 1990; Taylor and Sasser, 1978). Eggs of nematodes were extracted from root systems and incubated on Baermann trays for 7 days as described previously to obtain J2 from roots. Soil from each pot was placed in a plastic bag and mixed well. A 100 cm³ soil sample was then used to extract nematodes by sieving and centrifugal flotation (Jenkins, 1964). Numbers of *M. incognita* J2 were counted using an inverted microscope.

Root-knot galling index, and numbers of nematodes per root system, per g of root, and per 100 cm³ soil for the two nematode inoculated treatments were analyzed by 7 × 2 (cut flower × nematode race; uninoculated controls not included) split-plot analysis of variance (ANOVA), followed by one-way ANOVA for each nematode race. Means of these parameters were separated by Waller-Duncan *k*-ratio (*k* = 100) *t*-test at *P* ≤ 0.05. Nematode count data were log-transformed prior to ANOVA, but untransformed means are reported in all tables. Data analyses were performed using SAS software (SAS Institute, Cary, NC).

Data on plant measurement (root and shoot weights, number of flower buds, and blooms) were subjected to 7 × 3 (cut flower × nematode treatment) split-plot ANOVA to examine the cut flower and nematode treatment effects. We anticipated that plant

growth would be different among flowers with very different genetic makeup, therefore the ratio of plant heights between the inoculated and the uninoculated plants of each flower cultivar was used to standardize comparisons among cut flowers. Shoot and root weights, and number of flowers were adjusted similarly. Thus, a 7×2 split-plot ANOVA was performed to examine treatment effects of flower cultivar and nematode race on tolerance to the nematode. Since significant interactions were observed between cut flower cultivar and nematode treatment, these data were then analyzed by one-way ANOVA for each nematode treatment.

RESULTS AND DISCUSSION

Cultivar Susceptibility

Significant interactions ($P \leq 0.05$) between flower selection and nematode race were observed for root-gall index, and for *M. incognita* numbers in the soil as well as in the roots, based on 7×2 (cut flower cultivar \times nematode race) split-plot ANOVA. Therefore, these parameters were analyzed by one-way ANOVA for each race of *M. incognita*. Similar root-gall index results were observed between the two races of *M. incognita* (Table 1). 'Madonna Blue' blue lace, 'Green Mist' and 'Queen of Africa' white dill had similar ($P > 0.05$) root-gall indices as the known susceptible host of *M. incognita*, 'Potomac Royal' snapdragon, but higher root-gall indices than 'Qis White Cut' larkspur, and 'Avila Rose Rim' and 'Echo Pink' lisianthus ($P \leq 0.05$).

Consistent with the pattern of root-gall indices, numbers of *M. incognita* race 2 in the whole root system were significantly higher in snapdragon, blue lace flower, and the two cultivars of white dill than in larkspur and the two lisianthus cultivars (Table 1). The reproductive factor (Rf =

final population/initial population) of both cultivars of lisianthus tested ranged from 0.003 to 0.03 for the two races of *M. incognita*. A similar trend to root-gall index was also observed for the numbers of *M. incognita* race 1 in the root system, except that the 'Queen of Africa' white dill had lower numbers of *M. incognita* race 1 than blue lace flower. Due to plant growth differences among the cut flowers, plants with a larger root system might harbor more nematodes and appear more favorable for nematode reproduction. Therefore, nematode counts were adjusted to numbers per g of roots. After this adjustment, the susceptibility of blue lace flower was clearly greater than 'Queen of Africa' white dill, regardless of the nematode race (Table 1). The ranking of numbers of *M. incognita* race 2 in the soil was similar to the pattern of nematode numbers in roots, but numbers of *M. incognita* race 1 in the soil for snapdragon and 'Queen of Africa' white dill were not different from those in larkspur. Numbers of nematodes were not different ($P > 0.05$) between *M. incognita* races 1 and 2 in all of the cultivars tested.

Cultivar Tolerance

Although plant heights were measured, no differences were observed among the cut flower cultivars and nematode treatments (data not shown). Numbers of flowers and shoot and root weights of all cultivars tested except for 'Madonna Blue' were not affected by nematode inoculation, based on the 7×3 split-plot ANOVA (data not shown). *Meloidogyne incognita* race 1 reduced ($P \leq 0.05$) the number of flower buds and shoot weight of 'Madonna Blue' compared to the control (Table 2), indicating that the blue lace flower was intolerant to *M. incognita* race 1. On the other hand, *M. incognita* race 2 did not affect any of the plant growth parameters of 'Madonna Blue'.

Table 1. Susceptibility of seven cut flower cultivars to *Meloidogyne incognita* races 1 and 2.

Host	Cultivar	Gall index		Nematodes/root system		Nematodes/g root		Nematodes/100cm ³ soil	
		Mi1 ^a	Mi2	Mi1	Mi2	Mi1	Mi2	Mi1	Mi2
Snapdragon	Potomac Royal	5.25 a ^c	6.00 a	762 ab	1,197 a	56 b	79 ab	7 bc	28 ab
Blue lace	Madonna Blue	6.00 a	5.75 a	2,849 a	2,693 a	273 a	156 a	204 a	80 a
White dill	Green Mist	5.50 a	5.75 a	636 ab	1,234 a	78 b	95 a	47 a	60 a
White dill	Queen of Africa	5.00 a	5.75 a	326 b	622 a	18 c	30 b	10 b	24 ab
Larkspur	Qjs White Cut	2.25 b	2.25 b	46 c	35 b	4 d	3 c	8 b	12 bc
Lisianthus	Avila Rose Rim	1.50 b	2.00 b	10 d	49 b	1 d	5 c	1 cd	0 d
Lisianthus	Echo Pink	1.75 b	2.25 b	5 d	14 b	1 d	3 c	0 d	5 cd

^aMi1 = *Meloidogyne incognita* race 1; Mi2 = *Meloidogyne incognita* race 2.

^cMeans in a column followed by the same letters are not different according to Waller-Duncan *k*-ratio *t*-test ($P = 0.05$). Means are average of 4 replications.

Table 2. Numbers of flower buds, shoot and root weight of 'Madonna Blue' blue lace flower affected by *Meloidogyne incognita* races 1 (Mi1) and 2 (Mi2).

	Number of buds	Shoot weight (g)	Root weight (g)
Mi1	28 b ^c	59.94 b	9.35 a
Mi2	37 ab	73.57 ab	13.14 a
Uninoculated	53 a	87.42 a	17.06 a

^cMeans in a same column followed by the same letters are not different according to Waller-Duncan *k*-ratio *t*-test ($P > 0.05$). Means are average of 4 replications.

To standardize the evaluation of nematode tolerance among the cultivars, the ratio of plant growth in the inoculated plant to the uninoculated plant was used. Many of the cut flowers had higher numbers of flowers, or greater shoot and root weights in the *M. incognita* inoculated pot than in the uninoculated pot, as indicated by values > 1.0 (Table 3). Only the ratios of root weights differed among the cut flowers when inoculated with *M. incognita* race

1 (Table 3). Blue lace flower had the lowest ratio of root weight of inoculated to control plants among the cut flowers tested, but only 'Echo Pink' lisianthus had higher root weight ratio than the blue lace flower ($P \leq 0.05$).

Susceptibility of these cut flower cultivars to the two races of *M. incognita* was similar. Although it is commonly expected that $R_f > 1$ on a susceptible host, the relatively low temperatures throughout the

Table 3. Effects of *Meloidogyne incognita* race 1 and 2 inoculation on flower yield and shoot and root weight of seven cut flower selections.

Host	Cultivar	Ratio of inoculated to control plants ^c					
		Flower		Shoot weight		Root weight	
		Mi1	Mi2	Mi1	Mi2	Mi1	Mi2
Snapdragon	Potomac Royal	0.82 a ^c	0.87 a	1.08 a	1.04 a	1.22 ab	1.30 a
Didiscus	Madonna Blue	0.76 a	0.97 a	0.69 a	0.85 a	0.54 b	0.91 a
White Dill	Green Mist	1.23 a	1.40 a	1.07 a	1.14 a	0.97 ab	1.35 a
White Dill	Queen of Africa	1.01 a	0.69 a	1.03 a	0.93 a	1.18 ab	1.24 a
Larkspur	Qis White Cut	1.25 a	1.05 a	1.03 a	1.07 a	1.28 ab	1.04 a
Lisianthus	Avila Rose Rim	1.34 a	1.11 a	1.32 a	1.27 a	1.18 ab	1.43 a
Lisianthus	Echo Pink	1.87 a	1.47 a	1.72 a	1.50 a	1.79 a	1.14 a

^cNumber of flowers in nematode inoculated treatment/Number of flowers in control; similar ratios computed for shoot and root weight.

^cMeans in a column followed by the same letters are not different according to Waller-Duncan *k*-ratio *t*-test ($P = 0.05$). Means are average of 4 replications.

experiment might have resulted in a low Rf value even on the known susceptible host, snapdragon. Nematode Rf values should not be the sole evaluation criterion for nematode host status, especially in a greenhouse pot test with an artificial inoculation. Use of Rf values for this purpose is limited because Rf value is influenced by initial nematode population density (Seinhorst, 1970), temperature, length of time after inoculation, root penetration rate of the nematode inoculum, availability of plant roots for infection at inoculation, time period of conducive environments for nematode development, and other environmental factors (McSorley, 1998). Therefore, it is critical to compare nematode reproduction to a known susceptible host when evaluating for host status of plant species to a nematode, rather than relying on Rf value alone.

'Madonna Blue' blue lace flower and 'Green Mist' white dill were considered good hosts to both races of *M. incognita* because numbers of nematodes/g root were greater or not different than those on the snapdragon. In addition, the blue lace flower also had Rf > 1.0. Difference in nematode numbers/g root between the two white dill cultivars reemphasized that differences in susceptibility within a species exist. 'Madonna Blue' blue lace flower was also intolerant to *M. incognita* infection, especially to race 1 of this nematode. Blue lace flower also had the lowest ratios of root weight (inoculated/uninoculated) among the cut flowers tested, indicating the root system of blue lace flower was the most intolerant to *M. incognita* race 1. Therefore, 'Madonna Blue' should not be planted in a *M. incognita*-infested field.

Although snapdragon and white dill were relatively susceptible to *M. incognita* infection, the intense fertilization schedule in the greenhouse likely avoided the detection of any plant growth reduction by these

nematodes. It is not known if damage on snapdragon and white dill by *M. incognita* infection can also be avoided by adequate fertilization and irrigation in the field. Even if improving plant tolerance to nematode infection by fertilization prevents or reduces yield losses for a current cropping season, this practice might increase nematode population levels for the next season.

The low numbers of root-knot nematodes/g root of the two lisianthus cultivars tested and their corresponding low Rf values are consistent with the fact that they were poor hosts to the two races of *M. incognita*. This result is consistent with the performance of four other cultivars of lisianthus, 'Malibu Blue Blush,' 'Ventura Blue Rim,' 'Ventura Purple,' and 'Laguna Pink Rim,' previously found to be poor hosts of *M. incognita* (Wang *et al.*, 2005). This information provides growers a possible choice for a cut flower cultivar to be planted in a *M. incognita*-infested site, if no effective soil fumigant is available as an alternative to methyl bromide for nematode management. However, the evaluation of susceptibility of lisianthus and other cut flower cultivars to *M. incognita* under field conditions requires further study. The authors have observed occasional galling from *M. incognita* in the field, and 'Mariachi Lime Green' lisianthus was found to be susceptible and intolerant to *M. javanica* (Treub) Chitwood, *M. hapla* Chitwood, and *M. incognita* in California (Schochow *et al.*, 2004).

'Qis White Cut' larkspur is also a relatively poor host to *M. incognita*, similar to the host status of 'Qis Dark Spur' larkspur previously tested (Wang *et al.*, 2005). However, shoot weight of 'Qis White' larkspur was reduced by *M. incognita* race 1 infection (Wang *et al.*, 2005).

In conclusion, snapdragon, blue lace flower, and the two cultivars of white dill tested are susceptible to *M. incognita*, and

should be avoided in *M. incognita*-infested areas. Several lisianthus and larkspur cultivars reported here and in a previous study (Wang *et al.*, 2005) are poor hosts to *M. incognita* and could be selected as better choices than snapdragon, white dill, or blue lace flower for rotation of cut flower crops in a production nursery. This information offers an additional approach for *M. incognita* management, which is urgently needed in the ornamental industry, due to the phasing out of methyl bromide as a soil fumigant.

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