Supplement to Journal of Nematology 28(4S):639–642. 1996.

Screening of Carnation Cultivars for Resistance to *Meloidogyne incognita*

M. R. Cho,[1] J. Y. Kim,[1] C. Song,[2] J. Y. Ko,[1] S. Y. Na,[1] and M. S. Yiem[1]

Abstract: A total of 33 carnation cultivars cultured in Korea were screened for resistance to the southern root-knot nematode, *Meloidogyne incognita.* Carnations were tested by either inoculating with 5,000 eggs or by transplanting into a mixture of bedding medium and soil infested with an average of 435 second-stage juveniles/300 cm^3 soil. Cultivars, Desio, Castelaro, Kappa, Rara, Izu Pink, Target, and Antalia were highly resistant to *M. incognita.* Twelve cultivars were moderately resistant, and the remaining 14 cultivars were susceptible. These results were similar to those obtained when the cultivars were subjected to field populations of the condition on a carnation farm.

Key words: carnation, *Dianthus caryophyllus,* Korea, *Meloidogyne incognita,* resistance, root-knot nematode.

Carnation, *Dianthus caryophyllus* L., is one of the most important cut-flower crops in Korea. The cultivation area was 113 ha in 1993 and has been increasing gradually with expanding market demand (1). Carnations are cultured mainly under greenhouse conditions in the southern part of Korea.

Yield loss of carnation caused by root-knot nematodes was estimated at 10% to 20% worldwide (13). Southern root-knot nematode *Meloidogyne incognita* (Kofoid & White) Chitwood is reported as one of the biological agents that limit carnation production (10,13). Soil fumigants that have been used effectively in the past to control root-knot nematodes are no longer available (8). The increasing environmental and cost limitations of chemical control methods have contributed to the renewed interest in plant resistance in integrated pest management strategies (8,9). Fawzy et al. (5) reported that among 12 carnation cultivars tested, Scania and Imperial White Sim were resistant to *M. incognita.* Although resistant cultivars are available for many crops such as bean, citrus, cotton, tomato, tobacco, rose, cowpea, potato, soybean, alfalfa, apricot, and grape (2,8–11), studies on the resistance of carnation cultivars to root-knot nematodes is limited.

Received for publication 30 July 1996.

[1] Researchers, National Horticultural Research Institute, Suwon, 441-440, Korea.

[2] Researcher, Korea Research Institute of Chemical Technology, Taejun, 305-606, Korea.

Meloidogyne incognita was found to cause serious problems with carnations cultivated in several greenhouses in Kumi, an area in the mid-southern part of Korea. Carnation farms in Korea usually plant several cultivars in one greenhouse to meet seasonal market demands. One farm had severe root-knot damage on some cultivars, while other cultivars were growing well under the same greenhouse. The objective of this study was to screen carnation cultivars for resistance to the southern root-knot nematode *M. incognita.*

Materials and Methods

Soil nematode density and root-knot nematode galling of carnation cultivars from a greenhouse at Kumi was determined on 13 January and 12 April 1994. Soil samples were collected 15 cm deep with a 50-cm^3 auger at six or more locations along a row of each cultivar planted. Roots with severe galls were collected for nematode species identification. In the January survey, root systems of six cultivars were removed from the field and transported to the laboratory for estimation of the amount of root galling.

Soil samples were processed by the modified decanting-Baermann funnel method. The number of second-stage juveniles (J2) were counted under a stereomicroscope after 48 hours. Roots collected from the farm were washed in running tap water, and galling percentages were recorded. Observation of perineal patterns con-

firmed identification of the nematode as *M. incognita* (4, 7, 12). Eggs of *M. incognita* were extracted from the roots in 0.5% sodium hypochlorite solution and caught on a sieve with 25-μm-pore opening (6). Five thousand eggs were inoculated around roots of tomato seedlings (*Lycopersicon esculentum* Mill). cv. Youngkwang) planted in pots using Baroker (Seoul Agricultural Supply Company, Seoul, Korea) medium, which consisted of organic matter 85%, vermiculite 8%, zeolite 5%, and fertilizers 2%, with pH 5.5–6.0. The infected tomato plants were grown in the greenhouse for later use as a source of nematode inoculum.

Carnation cultivars used in this study were collected from carnation farms or selected from the carnation germplasm collection in the National Horticultural Research Institute, Suwon, Korea. Cuttings of each carnation cultivar were maintained at 4 °C for 24 hours for better rooting and blooming. The cuttings were then planted in vermiculite for rooting. Rooted cuttings were transplanted into 15-cm-diam. plastic pots containing Baroker medium on 12 May 1994. Pots were inoculated with 5,000 eggs on the same date they were transplanted. Treatments were replicated seven times. Plants were grown under a rain-sheltered shaded greenhouse. After 12 weeks, roots were washed free from debris and the number of galls per root was counted.

Rooted carnation cultivars also were used for a resistance screening test in *M. incognita*-infected soil. Soil collected from the carnation farm was transported in plastic bags to the laboratory and was mixed with Baroker medium in a 1:2 ratio providing an infestation level of *M. incognita* at 435 J2/300 cm^3 soil. The infested soil mixture was placed in a plastic container, 45 × 90 × 12 cm, and rooted carnations were transplanted in rows in the infested soil mixture on 8 June 1994. Each cultivar had five replicates. The carnations were grown under a rain-sheltered greenhouse. Four weeks after transplanting, roots of each carnation cultivar were carefully removed from the soil and washed in running tap water and the number of galls per entire root system was counted.

Results and Discussion

Root-knot nematode damage on carnation: The numbers of *M. incognita* J2 were different among the soil samples from different carnation cultivars under greenhouse conditions (Tables 1,2). In the first survey in January 1994, the cultivars (Kappa and Target) had no root galls, and no J2 were extracted from soil; however, four cultivars (Echo, Roland, Pink Roland, and Scarlet Elegance) had root systems that ranged from 5% to 100% galled and with 8 to 400 J2/300 cm^3 soil (Table 1). In the second survey in April 1994, there were great differences in number of J2 in soil among the carnation cultivars (Table 2). Among the soil samples, J2 were not extracted from cultivars Kappa, Target, Echo, Rara, and Antalia. However, J2 numbers per 300 cm^3 soil ranged from 24 to 4,320 in the soil samples from cultivars Espana, Tasman, Roland, Pink Roland, Roland Korea, and Scarlet Elegance. Large differences were observed in the plant heights between nematode-damaged cultivars and undamaged cultivars along the rows in the greenhouse. The number of wilted and dead plants also was much higher in nematode-damaged cultivars. Survey results indicated apparent differences in resistance among the carnation cultivars planted in the same greenhouse.

Screening of carnation cultivars for resistance to M. incognita: The responses of the carnation cultivars to *M. incognita* are listed

Table 1. Survey on the *Meloidogyne incognita* density and root-galling in carnation by cultivars (Kumi, 13 January 1994).

Carnation cultivars	No. of second-stage juveniles/300 cm^3 soil	Total root system galled (%)
Kappa	0	0
Target	0	0
Echo	8	5
Roland	40	80
Pink Roland	96	80
Scarlet Elegance	400	100

Data are the average of five observations for each cultivar.

TABLE 2. Survey on the *Meloidogyne incognita* density around root system of carnation by cultivars (Kumi, 12 April 1994).

Carnation cultivars	No. of second-stage juveniles/300 cm^3 soil
Kappa	0
Target	0
Echo	0
Rara	0
Antalia	0
Espana	24
Tasman	24
Roland	240
Pink Roland	384
Roland Korea	2,304
Scarlet Elegance	4,320

Data are the average of five observations for each cultivar.

in Table 3. Among the 33 carnation cultivars tested in pots, eight cultivars (Kappa, Echo, Rara, Izu Pink, Target, Castelaro, Antalia, and Desio) were highly resistant to *Meloidogyne incognita,* with 0 to 1.5 galls/root system. Eleven cultivars had 3 to 25.4 galls/root system and were categorized as moderately resistant. The remaining 14 cultivars, with more than 42 galls, were categorized as susceptible.

The results of resistance screening in the infested soil mixture were similar to the results from the inoculation test (Table 3). However, gall numbers were much lower than found in the pot test. This might be due to the shorter period of growth, about 4 weeks, which might not be enough time

TABLE 3. Screening of carnation cultivars for resistance to *Meloidogyne incognita* in pots inoculated with 5,000 eggs/pot or in infested greenhouse soil mixture containing 435 second-stage juveniles/300 cm^3 soil.

Carnation cultivars	Pot experiment No. of galls/root[a]	Infested soil mixture No. of galls/root[b]
Kappa	0 a	0 a
Echo	0.3 a	0 a
Rara	0.6 a	0 a
Izu Pink	0.9 a	0 a
Target	1 a	0 a
Castelaro	1.1 a	0 a
Antalia	1.2 a	0 a
Desio	1.5 a	0 a
Rachel	3 a	0 a
Espana	3.3 a	0 a
Mercury	3.6 a	0 a
Red Corso	3.7 a	0 a
Rony	3.7 a	0 a
Carmit	6.0 a	0 a
Saturn	6.1 a	0 a
White Royalitee	11.1 a	0 a
Saturnus	11.9 a	1.7 a
Mars	20.7 ab	2 a
Imperial White Sim	25.4 ab	7 ab
Galil	42.1 abc	10 abc
Yellow Dusty	63.6 bcd	10 abc
Lena	66.3 bcd	14 bc
Virgo	86.4 cde	18.8 cd
Sarinah	103.3 de	25 de
Elegance Korea	104.2 de	28 ef
Roland	127.1 ef	30 ef
Darling	147.9 fg	33.3 fg
Red Lena	150.7 fg	40 gh
Beta	157.9 fg	45 hi
Scarlet Elegance	172.6 gh	46 hi
Tasman	178.6 gh	47.5 hi
Astra	190.7 gh	60 j
Shinkibo	212.9 h	64 j

Data in pot experiment are means of seven replicates; data in infested soil mixture are means of five replicates. Means within a column followed by the same letter are not different according to Duncan's multiple-range test ($P \leq 0.05$).

[a]Root galls were counted 12 weeks after inoculation.

[b]Root galls were counted 4 weeks after transplanting in the infested soil mixture.

for visible galls to form. In 16 cultivars, no galls were observed.

All the carnation cultivars considered resistant in the inoculation test showed similar results in the infested soil test with the exception of Echo. Echo had 18.8 galls in the infested soil test, whereas there was no galling in the inoculation test. The susceptible cultivars from the inoculation test also showed similar root gall numbers in the infested soil test with the exception of Galil and Sarinah, which formed no galls. Moderately resistant cultivars in the inoculation test showed less galling than the susceptible cultivar group. Through the two screening tests, it was evident that there were differences in resistance among the cultivars. Fawzy et al. (5) reported that Imperial White Sim was resistant to *M. incognita;* however, the cultivar was susceptible in this study. This susceptibility may be due to a difference in the race of the nematode. Most *M. incognita* populations in Korea are reported as race 2 (3).

The 33 carnation cultivars tested were categorized into three groups based on the two screening tests: Resistant cultivars; Kappa, Rara, Izu Pink, Target, Castelaro, Antalia, and Desio, moderately resistant cultivars; Rachel, Espana, Mercury, Red Corso, Echo, Rony, Carmit, Saturn, White Royalitee, Saturnus, Mars, Imperial White Sim, and susceptible cultivars; Galil, Yellow Dusty, Lena, Virgo, Sarinah, Elegance Korea, Roland, Darling, Red Lena, Beta, Scarlet Elegance, Tasman, Astra, and Shinkibo. This grouping based on the screening tests corresponded well with the differences in the J2 numbers in the soil and growth differences among the cultivars, which were observed in the carnation greenhouse (Tables, 1,2).

Results of this study indicate a difference among carnation cultivars with respect to resistance to the root-knot nematode, *M. incognita.* This could be used by carnation breeders for developing new cultivars with resistance to *M. incognita,* and by carnation farmers to choose cultivars with resistance to root-knot nematodes.

Literature Cited

1. Anonymous. 1994. Horticultural production in Korea. National Horticultural Research Institute, RDA, Korea.

2. Cho, M. R., S. K. Chung, and W. H. Kim. 1993. Selection of rose rootstocks resistant to Northern root-knot nematode, *Meloidogyne hapla.* Journal of Agricultural Science, RDA, Korea 23:100–105.

3. Choi, Y. E. 1981. The root-knot nematodes, *Meloidogyne* spp., in Korea. *In* Proceedings of the 3rd Research Planning Conference on Root-knot Nematodes, *Meloidogyne* spp., Region VI, 20–24 July 1981. Jakarta, Indonesia.

4. Eisenback, J. D., H. Hirschmann, J. N. Sasser, and A. C. Triantaphyllou. 1981. A guide to the four most common species of root-knot nematode (*Meloidogyne* spp.), with a pictorial key. Raleigh, NC: North Carolina State Graphics.

5. Fawzy, R. N., F. W. Riad, and L. R. Rizhallh. 1991. Screening of carnation resistance for root-knot nematode, *Meloidogyne incognita.* Annals of Agricultural Science 29:797–810

6. Hussey, R. S., and K. R. Barker. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. Plant Disease Reporter 57:1025–1028.

7. Jepson, S. B. 1983. Identification of *Meloidogyne:* A general assessment and a comparison of male morphology using light microscopy, with a key to 24 species. Revue de Nématologie 6:291–309.

8. Kaplan, D. T. 1982. Plant resistance to nematodes: Symposium introduction. Journal of Nematology 14:1–2.

9. Roberts, P. A. 1982. Plant resistance in nematode pest management. Journal of Nematology 14: 24–33.

10. Sasser, J. N., F. E. Hartman, and C. C. Carter. 1987. Summary of preliminary crop germplasm evaluation for resistance to root-knot nematode. Raleigh, NC: North Carolina State Graphics.

11. Sasser, J. N., and M. F. Kirby. 1979. Crop cultivars resistant to root-knot nematodes, *Meloidogyne species,* with information on seed sources. Raleigh, NC: North Carolina State Graphics.

12. Taylor, A. L. 1987. Identification and estimation of root-knot nematode species in mixed populations. Bulletin 12:1–73. Gainesville, FL: Florida Department of Agricultural and Consumer Services.

13. Taylor, A. L., and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (*Meloidogyne* species). Raleigh, NC: North Carolina State Graphics.