Journal of Nematology 30(2):226–231. 1998.

Reducing *Meloidogyne incognita* Injury to Cucumber in a Tomato-Cucumber Double-Cropping System[1]

P. D. Colyer,[2] T. L. Kirkpatrick,[3] P. R. Vernon,[2] J. D. Barham,[3] and R. J. Bateman[3]

Abstract: The effects of a root-knot nematode-resistant tomato cultivar and application of the nematicide ethoprop on root-knot nematode injury to cucumber were compared in a tomato-cucumber double-cropping system. A root-knot nematode-resistant tomato cultivar, Celebrity, and a susceptible cultivar, Heatwave, were grown in rotation with cucumber in 1995 and 1996. Celebrity suppressed populations of *Meloidogyne incognita* in the soil and resulted in a low root-gall rating on the subsequent cucumber crop. Nematode population densities were significantly lower at the termination of the cucumber crop in plots following Celebrity than in plots following Heatwave. Premium and marketable yields of cucumbers were higher in plots following Celebrity than in plots following Heatwave. Application of ethoprop through drip irrigation at 4.6 kg a.i./ha reduced root galling on the cucumber crop but had no effect on the nematode population density in the soil at crop termination. Ethoprop did not affect cucumber yield. These results indicate that planting a resistant tomato cultivar in a tomato-cucumber double-cropping system is more effective than applying ethoprop for managing *M. incognita*.
Key words: cucumber, cultural control, double crop, *Meloidogyne incognita*, nematode, root-knot nematode, tomato, trellising.

Host plant resistance is an effective, economical, and environmentally safe pest management practice. Although numerous vegetable cultivars are available with resistance to the root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, commercially acceptable cucumber (*Cucumis sativis* L.) cultivars with resistance to this nematode have not been developed (Fassuliotis, 1979; Walters et al., 1993). One strategy to reduce root-knot nematode damage to susceptible crops is through crop rotation with nonhost or resistant plants (Anonymous, 1968; Bridge, 1996). Certain crop rotation systems have been shown to decrease root-knot nematode damage in vegetable crops (Johnson, 1985). The length of time a resistant or nonhost crop must be grown influences the efficacy of controlling the root-knot nematode. Another common management strategy is the application of nematicides (Johnson, 1985). Unfortunately, the number of nematicides labeled for application to cucumbers is limited.

Trellising cucumbers can increase yield and fruit quality (Hanna et al., 1987; Konsler and Strider, 1973; Russo et al., 1991). A tomato (*Lycopersicon esculentum* Mill.)-cucumber double-cropping system, where the trellis infrastructure established for tomato is reused for a subsequent cucumber crop, is feasible and can partially offset the cost of erecting a trellis (Hanna et al., 1989; Hanna, 1993). Growing a susceptible tomato cultivar, however, can significantly increase the population density of *M. incognita* prior to planting cucumber. Several tomato cultivars with high levels of resistance to *M. incognita* have been released for commercial production. The objectives of this study were to evaluate the use of a *M. incognita*-resistant tomato cultivar in a tomato-cucumber double-cropping system in relation to root-knot nematode population density and cucumber yield. The effects of the resistant tomato cultivar were compared with the effects of applying a nematicide to cucumber.

Materials and Methods

Experiments were conducted at the Red River Research Station in Bossier City, Louisiana, in 1995 and 1996. The soil was Norwood very fine sandy loam (Typic Unidflu-

Received for publication 10 November 1997.
[1] Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript no. 97-84-0395.
[2] Professor and Research Associate, respectively, Louisiana Agricultural Experiment Station, Red River Research Station, P.O. Box 8550, Bossier City, LA 71113-8550.
[3] Professor, Research Assistant, and Agricultural Technician, respectively, Arkansas Agricultural Experiment Station, Southwest Research and Extension Center, Hope, AR 71801.
E-mail: pcolyer@agctr.lsu.edu
This research supported by Southern Regional Integrated Pest Management grant no. 95-43103-1545.

vent: fine-silty, mixed, calcareous, thermic). *Meloidogyne incognita*-susceptible 'Heatwave' tomato had been grown in the field during the spring of 1994 followed by a summer crop of cucumber. The experimental design was a 2 × 2 factorial arranged as a randomized complete block. Treatments were *M. incognita*-resistant (Celebrity) or susceptible (Heatwave) tomato followed by cucumber with or without application of ethoprop. Each treatment combination was replicated four times. Plots were single rows 7.3 m long and 1.45 m apart. Spacing between tomato plants was 46 cm, and the space between cucumber plants was 30 cm. All plots were established with drip irrigation and black plastic mulch.

Prior to planting tomato, 560 kg/ha of 8-24-24 (N, P_2O_5, K_2O) fertilizer was broadcast over the field. Metribuzin (0.55 kg a.i./ha) (1995) or trifluralin (1.12 kg a.i./ha) plus metribuzin (0.55 kg a.i./ha) (1996) were broadcast over the field prior to transplanting. Tomato plants were transplanted on 7 April 1995 and 11 April 1996. A trellis system was erected using iron rods and string to support the tomato plants. Drip irrigation was applied as needed to the tomato crop. Foliar disease and insect control were maintained by a weekly spray program based on site monitoring and Louisiana Cooperative Extension Service guidelines.

Immediately before planting cucumbers, tomato plants were killed with a foliar application of glyphosate (1.4 kg a.i./ha). One week after applying glyphosate, ethoprop (EC) was injected through the drip system at 4.6 kg a.i./ha. Cucumber cv. Dasher II was direct-seeded 2 days after applying ethoprop (11 July 1995 and 26 July 1996). Cucumber plants were trained to vine vertically using the dead tomato stems and trellis infrastructure for support. At the three-leaf stage, 9.0 kg/ha ammonium nitrate (34%) was injected through the drip irrigation system, with two additional applications of 9.0 kg/ha at 3-week intervals. Drip irrigation was applied as needed to the cucumber crop throughout the growing season to prevent water stress. Total amount of rainfall and irrigation water was 33 and 43 cm in 1995 and 1996, respectively. Plots were sprayed weekly with chlorothalonil (1.68 kg a.i./ha) to control foliar diseases and with endosulfan (0.84 kg a.i./ha) or permethrin (0.175 kg a.i./ha) to control insects. Cucumbers were harvested seven times between 1 and 22 September 1995, and 12 times between 9 September and 4 October 1996. Fruit were graded according to U.S. Department of Agriculture standards for U.S. Fancy, No. 1, No. 2, and culls (Anonymous, 1958). Premium yield was determined by combining the weight of fruit graded as U.S. Fancy and No. 1. Total yield was the sum of premium yield and No. 2 fruit.

Nematode population density was determined from each plot at termination of the tomato crop and following the final cucumber harvest. A composite of 20 soil cores was collected from the root zone of plants in each plot. Cores were collected to a depth of 20 cm with a 2.5-cm-diam. sampling tube. Second-stage juveniles (J2) were extracted from a 500-cm^3 subsample by wet-sieving and sugar flotation and counted with a dissecting microscope (Ayoub, 1980). All root fragments in the subsample were collected and shaken for 4 minutes in 0.05% NaOCl to free eggs from egg masses (Hussey and Barker, 1973). The J2 and eggs extracted from each plot were totaled and transformed to log (J2 + eggs + 1) for statistical analysis.

Severity of root galling was rated on 10 cucumber root systems/plot after the final harvest on a 0- to -5 scale: 0 = no galls, 1 = 1 to 2, 2 = 3 to 10, 3 = 11 to 30, 4 = 31 to 100, and 5 = more than 100 galls/root system.

Data were subjected to analysis of variance with PC/SAS software (SAS Institute, Cary, NC) appropriate for completely randomized design for the tomato data and a 2 × 2 factorial design for the cucumber data.

Results

Tomato yields are not reported in this paper. In 1995, injury from *Sclerotium rolfsii* was severe late in the tomato-growing season, with approximately 70% of the plants infected by the second harvest; consequently, yield data were extremely variable. In 1996, prolonged hot weather during the fruit-ripening period resulted in severe fruit cracking, particularly with the root-knot nematode-resistant cultivar Celebrity, resulting in loss of marketable yields from many of the plots.

In both years, root galling was less severe and the *M. incognita* population density at tomato harvest was lower on Celebrity than on Heatwave tomato (Table 1). The tomato root gall ratings and nematode population densities on both tomato cultivars were lower in 1995 than in 1996.

There was no significant interaction between the preceding tomato cultivar and nematicide application in either year for soil population density of *M. incognita* at cucumber harvest, cucumber root galling, or premium and marketable yield of cucumbers. Consequently, data are presented using only the two main factors, tomato cultivar and nematicide application.

The population density of *M. incognita* in the soil at cucumber harvest was lower following Celebrity than following Heatwave both years (Fig. 1). Ethoprop treatment did not influence *M. incognita* population density at termination of the cucumber crop. Both prior tomato cultivar and ethoprop application, however, had a significant effect on the root-gall rating of cucumber. Root gall severity was lower following the resistant tomato cultivar than following the susceptible cultivar both years. Application of ethoprop also suppressed root galling on cucumber both years (Fig. 2). This effect was greater in 1995 than in 1996. The average root-gall rating on cucumber across all treatments was higher in 1996 (3.3) than in 1995 (1.9). This increase was associated with a higher soil population density at the termination of the prior tomato crop in 1996 than in 1995. Cucumber plants following Heatwave tomato were visibly stunted and more chlorotic throughout the growing season than plants following Celebrity.

Cucumber following Celebrity tomato also produced more premium and marketable fruit than cucumber following Heatwave both years (Fig. 3). Nematicide application had no significant effect on the yield of premium and marketable fruit either year. The mean yield of marketable fruit, but not premium fruit, across all treatments was higher in 1995 than in 1996. Higher yields in 1995 were associated with a lower initial nematode population density in the soil following tomato than in 1996.

TABLE 1. Effect of tomato cultivar on tomato root-gall rating and numbers of *Meloidogyne incognita* second-stage juveniles (J2) and eggs per 500 cm^3 soil at tomato harvest.

Year	Tomato cultivar	Root-gall rating[a]	Log (J2 + eggs + 1)[b]
1995	Celebrity	0.8a	0.5a
	Heatwave	1.1b	1.9b
1996	Celebrity	0.5a	0.5a
	Heatwave	1.9b	3.3b

Means in columns for the same year followed by different letters are different at $P = 0.01$.

[a] Root-gall rating on 0- to -5 scale: 0 = no galls, 1 = 1 to 2, 2 = 3 to 10, 3 = 11 to 30, 4 = 31 to 100, and 5 = more than 100 galls/root system.

[b] Nematode counts were transformed for statistical analysis. Transformed means are presented.

Discussion

The effectiveness of cultivar resistance and nematicide application for nematode management in vegetable cropping systems has been demonstrated (Johnson, 1985). A concern in using *M. incognita*-resistant tomato cultivars is the possible ineffectiveness of the resistance at high soil temperatures (Overman, 1991). Soil temperatures in northwestern Louisiana during the April–June period generally exceed 27 °C, the temperature at which loss of the expression of resistance has been reported to occur (Dropkin, 1969). Expression of resistance, however, appears to be determined by temperature within the first few days after nematode infection. Few *M. incognita* juveniles developed in the resistant tomato cultivar Nematex when plants were inoculated and incubated at 27 °C for 2 days and then held at 32 °C (Dropkin, 1969). In our study, it appears that soils were sufficiently cool during the early growing season to circumvent infection and reproduction by the *M. incog-*

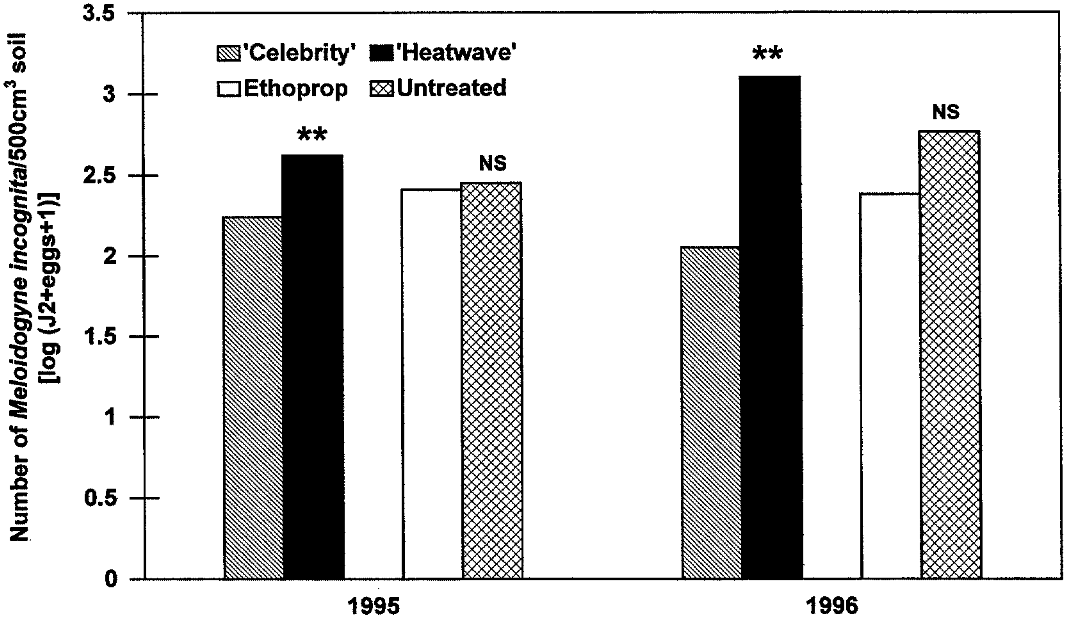

FIG. 1. *Meloidogyne incognita* soil population densities in ethoprop-treated and untreated plots of cucumber following resistant (Celebrity) or susceptible (Heatwave) cultivars of tomato. ** and NS indicate statistical significance ($P < 0.01$) or nonsignificance between bars in a pair.

nita population, as indicated by the low root-gall ratings on the resistant tomatoes both years. Average maximum soil temperatures for April 1995 and 1996 were 23.9 and 23.3 °C, respectively.

From an environmental-quality perspec-

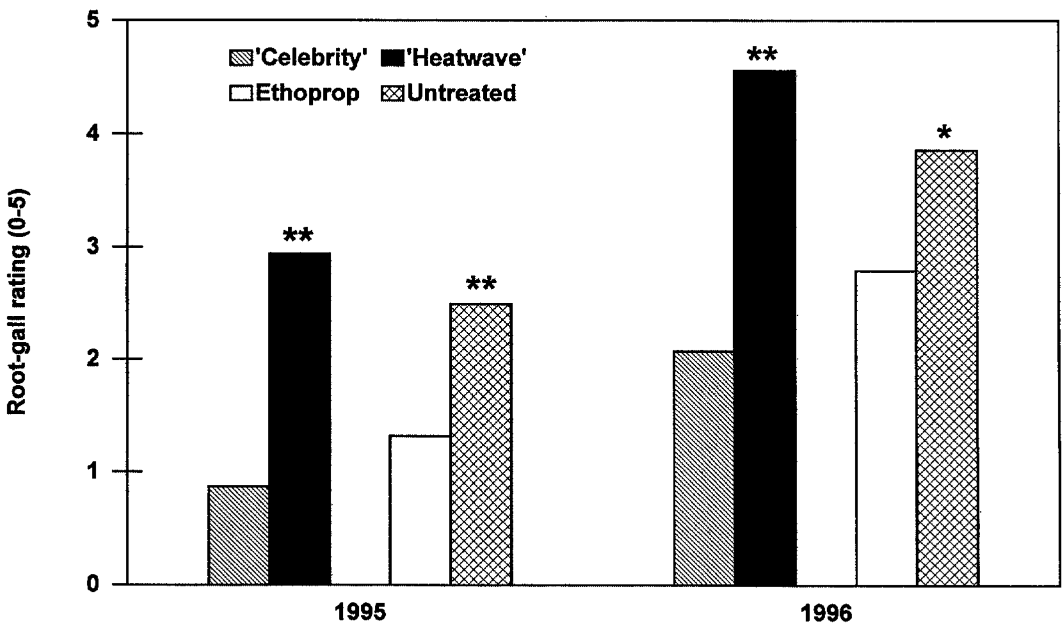

FIG. 2. Root-gall ratings of cucumber from ethoprop-treated and untreated plots of cucumber following resistant (Celebrity) or susceptible (Heatwave) cultivars of tomato. Statistical comparisons were made between bars in a pair.

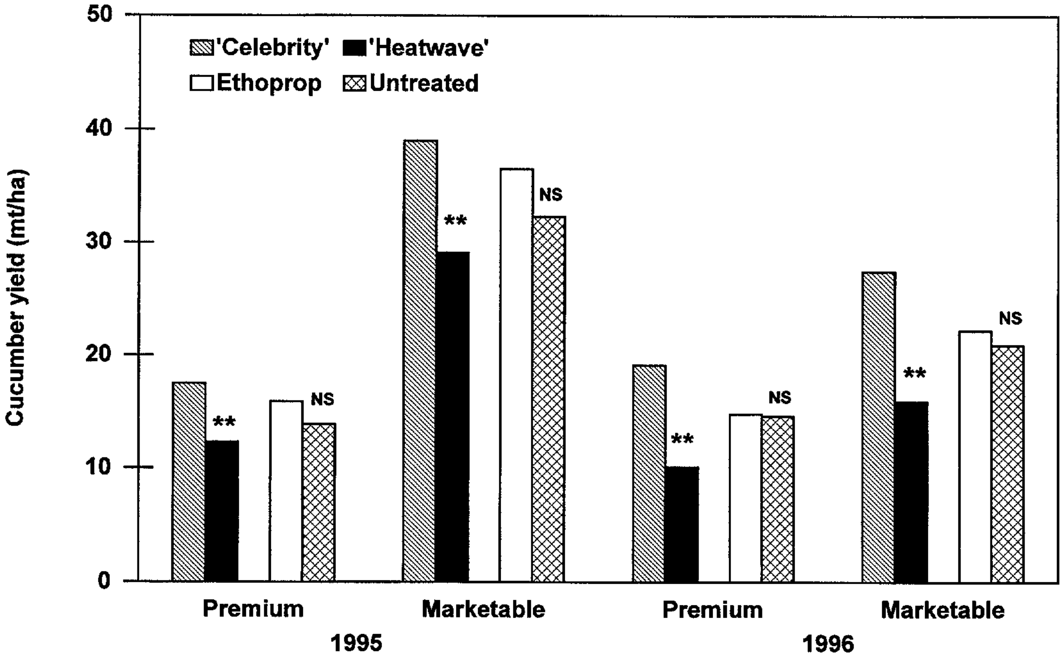

FIG. 3. Yield of cucumber from ethoprop-treated and untreated plots of cucumber following resistant (Celebrity) or susceptible (Heatwave) cultivars of tomato. ** and NS indicate statistical significance ($P < 0.01$) or nonsignificance between bars in a pair.

tive, it appears that growing a root-knot nematode-resistant tomato cultivar in a tomato-cucumber double-cropping system may be more desirable than routine use of nematicides for *M. incognita* management. However, the poor marketability of fruit from the resistant cultivar Celebrity in this study illustrates that extreme care must be taken in selection of nematode-resistant tomato cultivars that are adapted to the region in which they are to be grown. Resistance to environmental factors such as weather cracking, as well as *S. rolfsii* and other economically significant pathogens, also must be included in the nematode-resistant cultivars before their use for root-knot nematode management can be exploited.

LITERATURE CITED

Anonymous. 1958. United States standards for grades of cucumber. 46 FR 63203. Washington, D.C.: USDA Agricultural Marketing Service.

Anonymous. 1968. Reduction of nematode populations through land-management and cultural practices. Pages 94–105 *in* Control of plant-parasitic nematodes. Washington, D.C.: National Academy of Sciences.

Ayoub, S. M. 1980. Plant nematology: An agricultural training aid. Sacramento, CA: NemaAid Publications.

Bridge, J. 1996. Nematode management in sustainable and subsistence agriculture. Annual Review of Phytopathology 34:201–225.

Dropkin, V. H. 1969. The necrotic reaction of tomatoes and other hosts resistant to *Meloidogyne:* Reversal by temperature. Phytopathology 59:1632–1637.

Fassuliotis, G. 1979. Plant breeding for root-knot nematode resistance. Pp. 425–435 *in* F. Lamberti and C. E. Taylor, eds. Root-knot nematodes (*Meloidogyne* species): Systematics, biology, and control. New York: Academic Press.

Hanna, H. Y. 1993. Producing trellised cucumbers double-cropped with tomatoes. HortScience 28:96–98.

Hanna, H. Y., A. J. Adams, and R. J. Edling. 1989. Double-cropping cucumber and tomatoes to minimize the cost of staking cucumber. Proceedings Florida State Horticultural Society 102:326–328.

Hanna, H. Y., A. J. Adams, and R. N. Story. 1987. Increased yield in slicing cucumbers with vertical training of plants and reduced plant spacing. HortScience 22: 32–34.

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.

Johnson, A. W. 1985. Specific crop rotation effects combined with cultural practices and nematicides. Pp. 283–301 *in* J. N. Sasser and C. C. Carter, eds. An advanced treatise on *Meloidogyne*. Vol. I: Biology and control. Raleigh: North Carolina State University Graphics.

Konsler, T. R., and D. L. Strider. 1973. The response of cucumber to trellis vs. ground culture. HortScience 8:320–321.

Overman, A. J. 1991. Diseases caused by nematodes: Root-knot nematodes. Pp. 49–50 *in* J. B. Jones, J. P. Jones, R. E. Stall, and T. A. Zitter, eds. Compendium of tomato diseases. St. Paul, MN: American Phytopathological Society Press.

Russo, V. M., B. W. Roberts, and R. J. Shatzer. 1991. Feasibility of trellised cucumber production. HortScience 26:1156–1158.

Walters, S. A., T. C. Wehner, and K. R. Barker. 1993. Root-knot nematode resistance in cucumber and horned cucumber. HortScience 28:151–154.