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Use of a Resistant Pepper as a Rotational Crop to Manage Southern Root-knot Nematode

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Abstract. **A 3-year field study was conducted at Blackville, S.C., to evaluate the potential of using resistant pepper (*Capsicum annuum* L.) cultivars as a rotation crop for managing the southern root-knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood]. The experiment was a split-plot with main plots arranged in a randomized complete-block design. In 1993, the entire experimental site was infested with *M. incognita* by inoculating a planting of susceptible PA-136 cayenne pepper with eggs of *M. incognita* race 3. In 1994, the main plots were planted to either highly resistant 'Carolina Cayenne' or its susceptible sibling line PA-136. In 1995, 'Carolina Cayenne' and the susceptible bell cultivars California Wonder and Keystone Resistant Giant were grown as subplots in each of the original main plots. 'Carolina Cayenne' plants were unaffected by the previous crop. Previous cropping history, however, had a significant impact on the performance of the bell cultivars; the mean galling response was less ($P < 0.01$) and the yield was 2.8 times greater ($P < 0.01$) in the main plots previously cropped with 'Carolina Cayenne' than in those previously cropped with PA-136. These results suggest that resistant pepper cultivars have considerable merit as a rotation crop for managing *M. incognita* infestations in soils used for growing high-value vegetables.**

The southern root-knot nematode, *Meloidogyne incognita*, causes serious yield losses in pepper globally (Di Vito et al., 1985; Lamberti, 1979; Lindsey and Clayshulte, 1982; Sasser and Freckman, 1987; Thies et al., 1997; Thomas et al., 1995). The loss of many nematicides from the market due to environmental concerns and the prohibitive costs of reregistration has focused attention on the development of crop rotation schemes for managing plant parasitic nematodes in both vegetable and field crops (Hirunsalee et al., 1995; McSorley and Dickson, 1995; McSorley and Gallaher, 1992; Rodriguez-Kabana et al., 1992; Weaver et al., 1995). However, little information is available on the utilization of resistant vegetable cultivars as rotational crops for managing root-knot nematodes. In Florida, rotations of eggplant following resistant 'Mississippi Silver' cowpea or susceptible 'Clemson Spineless' okra were compared for managing *M. incognita* race 1 (McSorley and Dickson, 1995). Root galling of eggplant was less when grown following resistant cowpea than when grown following susceptible okra. In Louisiana, fruit yield and numbers were greater, and root galling and *M. incognita* population densities were less, when cucumber was grown after *M. incognita*–resistant 'Celebrity' than susceptible 'Heatwave' tomato (Hanna et al., 1994; Kirkpatrick and Colyer, 1997). This paper reports the results of a multiyear field study designed to evaluate the potential of using a *M. incognita*–resistant cayenne pepper cultivar as a rotation crop for managing *M. incognita* in a subsequent bell pepper crop.

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Materials and Methods

This multiyear field study was conducted at the Clemson Univ. Edisto Research and Education Center, Blackville, S.C. The pepper genotypes used in the study were 'Carolina Cayenne', PA-136, 'Keystone Resistant Giant', and 'California Wonder'. 'Carolina Cayenne' is a well-adapted cultivar that is highly resistant to *M. incognita* (Fery et al., 1986; Thies et al., 1997; Zamora and Bosland, 1994). PA-136 is a sibling line of 'Carolina Cayenne' that is highly susceptible to *M. incognita* (Dukes et al., 1997; Thies et al., 1997). Both 'Carolina Cayenne' and PA-136 were selected from a 'Carolina Hot' population that was heterogeneous for many traits, including resistance to *M. incognita* (Fery and Dukes, 1996). 'Keystone Resistant Giant' and 'California Wonder' are bell-type peppers; 'Keystone Resistant Giant' has an intermediate level of response to *M. incognita* (unpublished data) and 'California Wonder' is susceptible.

The entire experimental site was artificially infested with *M. incognita* race 3 in 1993 by inoculating a planting of susceptible PA-136 cayenne pepper with ≈7000 eggs per plant (Thies et al., 1997). A winter cover crop of root-knot susceptible hairy vetch (*Vicia villosa* Roth) was sown over the pepper plants in Dec. 1993 to maintain *M. incognita* populations over winter. The experiment was a split-plot with main plots arranged in a randomized complete-block design with nine replications. On 2 June 1994, main plots were planted to either the highly resistant 'Carolina Cayenne' or its susceptible sibling line, PA-136. Main plots were nine row beds established on 1-m centers with 46-cm in-row plant spacing and 15 plants per row. On 19 Oct. 1994, 10 cores of soil were collected in the root zones of pepper plants from each nine-row plot. Second-stage juveniles were extracted from 400 cm^3 soil using the sugar flotation method (Jenkins, 1964). In 1995, 'Carolina Cayenne' and the susceptible bell cultivars Keystone Resistant Giant and California Wonder were grown as subplots in each of the original main plots. Subplots were three row beds established on 1-m centers with 60-cm in-row plant spacing and 10 plants per row.

The seeds of all of the entries for the 1995 season were planted in the greenhouse on 7 and 11 Apr. in 25 × 51 × 4.5-cm-deep plastic flats containing Jiffy Mix (Jiffy Products of America, Batavia, Ill.) growing medium. Seedlings were transplanted into plastic growing trays containing 50 individual 5.5 × 5.5 × 7.0-cm-deep plastic cells (Growing Systems, Milwaukee, Wis.) filled with Jiffy Mix from 21 Apr. to 24 Apr. The plants were moved outdoors to harden on 10 May 1995. The herbicide trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine] was preplant incorporated in the field at 2.5 $kg \cdot ha^{-1}$ a.i. on 19 May 1995. The plants were transplanted in the field on 22 May 1995. Mature pepper fruit from the two bell-type cultivars were harvested weekly from 31 July to 31 Aug. 1995 from all plants in each plot. Mature red fruit were harvested from five plants of the cayenne cultivar on 22 Aug. and 31 Aug.; all mature red and green fruit were harvested from these plants on 6 Sept. Five plants were removed from each plot on 6 Sept. The root system of each plant was washed, scored for galling using a 1 to 5 scale (1 = 0% to 3% root system galled; 2 = 4% to 25%, 3 = 26% to 50%, 4 = 51% to 80%, and 5 = greater than 80% root system galled) (Thies et al., 1997), and *M. incognita* eggs were extracted from a 20-g subsample of roots using 1% NaOCl (Hussey and Barker, 1973). Data were subjected to analysis of variance using SAS System for Windows, Release 6.12 (SAS Institute, Cary, N.C.), and means were separated using Duncan's multiple range test.

Results and Discussion

The 1994 planting of 'Carolina Cayenne' effectively suppressed development of soil populations of *M. incognita*. Numbers of *M. incognita* second-stage juveniles present in soil samples collected on 19 Oct. 1994 from main plots where 'Carolina Cayenne' had been grown were only 3% ($P < 0.05$) of those of main plots where susceptible PA-136 had been grown (<1 second-stage juvenile per cm^3 soil and 83 second-stage juveniles per cm^3 soil, respectively) (Thies et al., 1997).

The performance of the 'Carolina Cayenne' plants in the 1995 season was unaffected by the previous crop. 'Carolina Cayenne' exhibited a highly resistant response to *M. incognita* when it was grown following its susceptible sibling line, PA-136, or when it was grown in the same plots for two consecutive years; i.e., roots of 'Carolina Cayenne' were not galled and reproduction of *M. incognita* was very limited (Table 1). Likewise, fruit yields and fruit numbers of 'Carolina Cayenne' were not different when grown after susceptible PA-136 or when grown in the same plots for two successive years. There was no significant interaction between the rotation crop treatment (1994) and the subsequent pepper cultivars grown in 1995 with regard to gall index, numbers of eggs per g fresh root, fruit yield, and fruit number.

Previous cropping history had a significant impact on the performance of the bell cultivars with respect to *M. incognita*. Although the response of the individual bell cultivars did not differ within crop rotation treatments (there was no interaction between crop rotation treatments and cultivars), the mean gall index of 'Keystone Resistant Giant' and 'California Wonder' (averaged over cultivars) was less ($P < 0.01$) when grown in rotation with resistant 'Carolina Cayenne' (gall index = 3.1) than when grown in rotation with susceptible PA-136 (gall index = 3.6) (Table 1). Likewise, mean fruit yield of the bell cultivars was 2.9 times greater ($P < 0.01$) and mean fruit numbers were 2.5 times greater ($P < 0.01$) when the bell cultivars were grown in rotation with 'Carolina Cayenne' than when grown in rotation with PA-136.

Cultivar differences between 'California Wonder' and 'Keystone Resistant Giant' were significant ($P < 0.05$) for root galling and *M. incognita* reproduction when averaged over the main plot rotation crop treatments ('Carolina Cayenne' and PA-136) (Table 1). 'California Wonder' plants exhibited a susceptible response to *M. incognita*; mean root gall ratings were 3.5 and *M. incognita* reproduction was 1.7 times greater than those for 'Keystone Resistant Giant'. 'Keystone Resistant Giant' plants exhibited an intermediate response to *M. incognita*; roots were moderately galled with mean root gall ratings of 3.1. Nematode reproduction was intermediate between that of resistant 'Carolina Cayenne' and susceptible 'California Wonder' plants.

The highly resistant 'Carolina Cayenne' was more effective in suppressing numbers of second stage juveniles in the soil after one growing season than was its susceptible sibling line PA-136. Our observations of reduced root galling and increased fruit yields of the two bell cultivars (averaged over cultivars), when grown in rotation with resistant 'Carolina Cayenne', parallel results of experiments in Louisiana where double-cropping of cucumbers following *M. incognita*–resistant 'Celebrity' tomato suppressed root galling and increased yield of cucumber (Hanna et al., 1994; Kirkpatrick and Colyer, 1997). Likewise, our results are comparable with results of vegetable rotation trials in Florida, where root galling of eggplant was less when grown in rotation with *M. incognita*–resistant cowpea than when grown in rotation with susceptible okra (McSorley and Dickson, 1995).

'Carolina Cayenne' exhibited an exceptionally high level of resistance when grown in rotation with either a resistant or a susceptible crop. Integration of a resistant cultivar, such as 'Carolina Cayenne', into vegetable crop rotation schemes should allow successful crop production in soils that are heavily infested with root-knot nematodes, while simultaneously suppressing nematode population densities in the soil to levels that allow production of a subsequent susceptible crop. Furthermore, host resistance is one of the most cost effective and environmentally compatible alternatives to using methyl bromide or other nematicides for managing plant parasitic nematodes. Resistant pepper cultivars such as 'Carolina Cayenne' should be considered highly useful as rotation crops in the development of strategies for managing southern root-knot nematode in susceptible vegetable crops.

Table 1. Gall index, numbers of *Meloidogyne incognita* eggs extracted from roots, fruit yield, and fruit number of three pepper cultivars grown in rotation with two cayenne pepper genotypes (PA-136 and 'Carolina Cayenne') differing in resistance to *M. incognita*.

Rotation crop/ pepper cultivar[z]	Gall index[y]	No. eggs/g fresh root	Fruit yield ($kg\cdot ha^{-1}$)	Fruit (no./ha)
PA-136 (S)[x]				
Carolina Cayenne	1.0[w]	254[w]	7,328[w]	521,288[w]
Keystone Resistant Giant[v]	3.4	11,174	2,534	13,296
California Wonder[v]	3.8	21,710	1,683	7,793
Carolina Cayenne (R)[u]				
Carolina Cayenne	1.0	738	6,407	610,691
Keystone Resistant Giant	2.8	10,859	4,571	21,859
California Wonder	3.3	15,822	7,611	29,879
Rotation crop mean (avg. over bell cultivars)				
PA-136	3.6**	9,140	2,108**	10,544**
Carolina Cayenne	3.1	11,046	6,091	25,869
Cultivar mean (avg. over rotation crops)				
Carolina Cayenne	1.0 a[t]	496 a	6,868[s]	565,990[s]
Keystone Resistant Giant	3.1 b	11,017 b	3,552 a	17,578 a
California Wonder	3.5 c	18,766 c	4,647 a	18,836 a

[z]Rotation crop (main plots) grown in 1994; pepper cultivars (subplots) grown in 1995.
[y]Gall index: 1 = 0% to 3% root system galled; 2 = 4% to 25%, 3 = 26% to 50%, 4 = 51% to 79%, and 5 = greater than 80% root system galled.
[x]S = susceptible to *M. incognita*.
[w]Rotation crop treatment × cultivar interaction F test was nonsignificant; therefore means were not separated.
[v]Susceptible bell cultivars.
[u]R = resistant to *M. incognita*.
[t]Mean separation within columns by Duncan's multiple range test ($P < 0.05$).
[s]Means for 'Carolina Cayenne' were not compared with those for bell pepper cultivars.
**Significantly different from values for 'Carolina Cayenne' by ANOVA ($P < 0.01$).

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