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Association of *Criconemella xenoplax* and *Fusarium* spp. with Root Necrosis and Growth of Peach

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Abstract: *Criconemella xenoplax*, *Fusarium solani*, and *F. oxysporum* caused necrosis of Nemaguard peach feeder roots in greenhouse tests. Root necrosis was more extensive in the presence of either fungus than wtih *C. xenoplax* alone. Shoot growth and plant height were less for plants inoculated with *F. oxysporum* or *F. solani* than for plants inoculated with the fungi plus *C. xenoplax*. Neither synergistic nor additive effects on root necrosis or plant growth occurred between *C. xenoplax* and the fungal pathogens.

Key words: *Criconemella xenoplax*, ring nematode, interaction, *Prunus persica*, *Fusarium solani*, *F. oxysporum*.

Criconemella xenoplax and *Fusarium* spp. have been isolated from soil and roots of peaches, respectively, in peach tree short life (PTSL) sites (7,8,11). In a recent survey of Georgia and South Carolina PTSL orchards, the seven most common nematode genera recovered were *Criconemella, Helicotylenchus, Meloidogyne, Paratrichodorus, Pratylenchus, Tylenchorhynchus,* and *Xiphinema,* with *Criconemella* spp. the most abundant and most frequently recovered under trees in PTSL sites (7). *Criconemella xenoplax* (Raski) Luc & Raski was the most abundant of the ring nematode species.

Feeding of *C. xenoplax* causes root malformation and discoloration, and reduces the number of functional peach feeder roots (5,10,11). *Fusarium* spp. are associated with problems of orchard establishment on land previously planted to peach in California (3). *Fusarium oxysporum* also has been associated with the sudden collapse of a peach orchard in Georgia (2). According to Nyczepir and Lewis (8), the incidence of *Fusarium* spp. was greater in the presence of *C. xenoplax* than in its absence in necrotic feeder roots of Nemaguard peach from PTSL orchards in South Carolina, but the interrelationship was not clearly defined. Our objective was to investigate the association of *C. xenoplax* with *Fusarium* spp. as it relates to feeder root necrosis of peach in the greenhouse.

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Materials and Methods

Seedlings (*Prunus persica* (L.) Batsch cv. Nemaguard) from virus-free seed were grown in flats for 5 months and transplanted individually into 15-cm-d plastic pots containing vermiculite and steam pasteurized sand (1:1). Seven days after transplanting pots were inoculated with 1) *C. xenoplax* (Cx), 2) *Fusarium oxysporum* (Fo) or *F. solani* (Fs), 3) Cx + Fo or Fs, 4) Fo or Fs 4 weeks after Cx inoculation (Cx + Fo[4] or Fs[4]), or 5) left noninoculated.

Criconemella xenoplax was isolated from a PTSL orchard in Byron, Georgia, and increased on Nemaguard peach grown in a sand : vermiculite medium. Nematodes were extracted from the medium using centrifugal-flotation (4). Each nematode-infested treatment received 20 ml aqueous suspension (5,000 ± 50 adults and juveniles per pot) which was poured onto the medium surface. Additional water was applied to wash the *C. xenoplax* into the medium. A 20-ml aliquot of nematode-free solution obtained from the extraction procedure was added in a similar manner to each pot not receiving *C. xenoplax.*

Fusarium oxysporum was obtained from necrotic peach tree feeder roots from a PTSL orchard in Bryon, Georgia. Inoculum for the experiment was produced by growing the fungus on Nash medium (6) under continuous light at 25 C for 11 days. A conidial suspension was obtained by flooding the culture with water and dislodging the spores with a bent glass rod. A total of 1.84×10^7 macroconidia suspended in 20 ml water was added to each treated pot as described for *C. xenoplax.* Treatments, replicated six times, were arranged in a randomized complete block design on

TABLE 1. Effect of *Criconemella xenoplax* (Cx) and/or *Fusarium oxysporum* (Fo) on feeder root necrosis, dry root and shoot weight, and plant height increase after 130 days and apical meristem activity of Nemaguard peach after 90 and 130 days in the greenhouse.

Treatment	R†	Root index‡	Dry root weight (g)	Dry shoot weight (g)	Height increase (cm)	Plants with active apical meristems (N)§	
						90 days	130 days
Cx	2.8	2.17 ± 0.31	10.27 ± 0.47	10.74 ± 1.36	58.35 ± 7.65	1 bc	0 a
Fo	0.0	3.80 ± 0.49	9.16 ± 0.86	8.82 ± 1.68	41.00 ± 9.93	0 c	0 a
Cx + Fo	4.0	2.00 ± 0.37	8.43 ± 0.48	11.66 ± 0.75	72.30 ± 5.05	6 a	0 a
Cx + Fo⁴‖	3.0	3.33 ± 0.49	8.74 ± 0.90	11.15 ± 0.90	65.77 ± 8.52	5 ab	1 a
Control	0.0	1.50 ± 0.34	9.88 ± 0.83	9.75 ± 1.67	50.48 ± 13.95	3 abc	0 a
Contrasts¶							
Control vs. Cx, Cx + Fo, and Cx + Fo⁴	—	*	NS	NS	NS	NS	NS
Control vs. Fo, Cx + Fo, and Cx + Fo⁴	—	*	NS	NS	NS	NS	NS
Cx vs. Cx + Fo and Cx + Fo⁴	—	NS	+	NS	NS	*	NS
Fo vs. Cx + Fo and Cx + Fo⁴	—	*	NS	*	*	*	NS

† R = final population divided by the initial (Pi); Pi = 5,000 Cx/pot.
‡ Root index: 0 = no root necrosis; 1 = less than 10%; 2 = 11–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100% necrotic.
§ Numbers within each column followed by the same letter were not statistically different ($P < 0.01$) according to Fisher's Exact Test.
‖ Cx + Fo⁴ = Fusarium added 4 weeks after inoculation with Cx.
¶ * = $P = 0.05$; + = $P = 0.10$; NS = no significant difference. Data are means ($\bar{x}$ ± SE) of six replicates.

a bench in an air-conditioned greenhouse (25 ± 5 C) in October 1984. Plants were watered daily and fertilized every 2 weeks, alternating solutions A and B and adding 50 ml/pot. *Solution A* consisted of 45 g $Ca(NO_3)_2$ and 15 g $MgSO_4$ in 19 liters water; *Solution B* contained 45 g $NaNO_3$ (Natural Chilean Nitrate), 12 g $Ca(H_2PO_4)_2$ (super phosphate), and 2 ml minor element solution (10 g $MgCl_2$, 10 g $CuCl_2$, 20 g $MnCl_2$, 30 g $ZnCl_2$, 1 liter water) in 19 liters water. The study was terminated after 130 days, and the following data were recorded: 1) Cx population density; 2) root necrosis index; 3) dry root and shoot weight; and 4) plant height (difference between initial and final height). Nematodes were extracted from 100 cm^3 soil per pot using a semi-automatic elutriator (1) combined with centrifugal-flotation (4). Each root system was submerged in 1% NaOCl for 4 minutes and rated for necrosis on a scale of 0–5: 0 = no necrosis; 1 = less than 10%; 2 = 10–25%; 3 = 26–50%; 4 = 51–75%; and 5 = 76–100% necrotic. A necrosis index was calculated using the modified formula of Powell et al. (9).

A second experiment identical to the first with the following exceptions was conducted: 1) *Fusarium solani* obtained from a Nemaguard seedling used for culturing *C. xenoplax* in the greenhouse was substituted for *F. oxysporum*; 2) 3-month-old peach seedlings were used; 3) treatments were replicated eight times; and 4) the test was terminated after 90 days.

All data were subjected to general linear model analysis (GLM) and linear comparisons. Fisher's Exact Test was used for analyzing apical meristem activity data. In the second experiment, data from the noninfested control plants were not analyzed because the plants accidentally became infested with nematodes. Data from other treatments in the second experiment were included since they substantiated trends observed in the first experiment.

RESULTS

Effect of Fo / Cx on peach: Feeder root necrosis was more extensive ($P = 0.05$) in the presence of Fo and (or) Cx compared with the control (Table 1). Root necrosis, based on treatment means and standard errors,

TABLE 2. Effect of *Criconemella xenoplax* (Cx) and/or *Fusarium solani* (Fs) on feeder root necrosis, dry root and shoot weight, plant height increase and apical meristem activity of Nemaguard peach after 90 days in the greenhouse.

Treatment	R†	Root index‡	Dry root weight (g)	Dry shoot weight (g)	Height increase (cm)	Plants with active apical meristems (N)§
Cx	3.3	2.00 ± 0.00	2.27 ± 0.24	1.93 ± 0.31	19.28 ± 5.40	3 a
Fs	0.0	3.13 ± 0.23	2.51 ± 0.21	1.53 ± 0.29	9.88 ± 4.52	1 a
Cx + Fs	4.0	3.14 ± 0.34	2.74 ± 0.29	2.79 ± 0.48	28.76 ± 7.61	4 a
Cx + Fs[4]‖	4.0	3.75 ± 0.31	2.20 ± 0.26	2.36 ± 0.60	28.74 ± 9.27	5 a
Contrasts¶						
Fs vs. Cx + Fs and Cx + Fs[4]	—	NS	NS	*	*	+
Cx vs. Cx + Fs and Cx + Fs[4]	—	*	NS	NS	NS	NS
Fs vs. Cx, Cx + Fs, and Cx + Fs[4]	—	NS	NS	+	NS	NS

† R = final population divided by the initial (Pi); Pi = 5,000 Cx/pot.
‡ Root index: 0 = no root necrosis; 1 = less than 10%; 2 = 11–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100% necrotic.
§ Numbers within each column followed by the same letter were not statistically different ($P < 0.10$) according to Fisher's Exact Test.
‖ Cx + Fs[4] = Fusarium added 4 weeks after inoculation with Cx.
¶ * = $P = 0.05$; + = $P = 0.10$; NS = no significant difference. Data are means ($\bar{x}$ ± SE) of eight replicates.

was also greater for plants receiving Fo alone vs. those receiving Cx alone. The nematodes were actively feeding in all nematode-infested treatments, as indicated by the R values and Fo was isolated from necrotic feeder roots of Fo-inoculated plants.

Dry root and shoot weights were not influenced by Cx or Fo alone or in combination (Table 1). Root weight, however, was less ($P = 0.10$) in treatments inoculated with Cx + Fo and Cx + Fo[4], compared with Cx alone. Shoot weight and height increase were greater ($P = 0.05$) for treatments Cx + Fo and Cx + Fo[4] than for Fo.

More plants with active apical meristems ($P = 0.05$) were in pots infested with Cx + Fo and Cx + Fo[4] than in pots infested with Cx or Fo after 90 days (Table 1). There were no differences between the noninoculated and any of the inoculated treatments. No differences occurred after 130 days among any treatments.

Effect of Fs/Cx on peach: Feeder root necrosis was greater ($P = 0.05$) for treatments Cx + Fs and Fs[4] than for Cx alone (Table 2). Root necrosis, based on treatment means and standard errors, was also greater for plants receiving Fs alone vs. those receiving Cx alone. As in the experiment with Fo, nematodes fed and reproduced in all nematode-infested treatments and Fs was isolated from necrotic roots of Fs-inoculated plants. No differences occurred among treatments for root weight; however, shoot weight and height increase were greater ($P = 0.05$) in treatments Cx + Fs and Cx + Fs[4] than in Fs alone. The greatest height increase, as in the experiment with Fo, occurred in treatments including Cx. Apical meristems of plants growing in pots infested with Cx + Fs and Cx + Fs[4] remained active longer ($P = 0.10$) than those infested with Fs alone.

DISCUSSION

Our findings suggest that Fo and Fs, both previously detected in PTSL orchards (8), can cause peach feeder root necrosis alone and in combination with Cx, and that Fs or Fo alone caused more necrosis than Cx alone.

It appears that the fungi are more detrimental than Cx to peach seedlings, at least after 90 and 130 days, since both fungi alone suppressed shoot weight and stunted plants more than when combined with Cx. This may be because Cx is not a typical

root rotting pathogen and growth suppression may not have been evident over the duration of these studies. Past pot experiments demonstrated that significant symptomatology was not that obvious in the presence of Cx unless exposure time was lengthy (8+ months) (5). However, growth suppression may be the reason a greater number of plants inoculated with Fo or Fs alone initiated dormant apical buds sooner than plants infested with Cx. Apical bud dormancy occurs on peach grown in pots in the greenhouse, but it can be avoided if plants are watered and fertilized adequately. In these experiments watering and fertility were not limiting factors, so dormancy appears to have been caused by fungal parasitism. Even though Fo and Fs alone had detrimental effects on certain peach growth parameters, such as height and apical meristem activity, these effects were alleviated when the fungus and nematode were combined. It is not certain at this time why the presence of Cx alleviated growth suppression induced by Fo and Fs and it would be premature to speculate, but it was observed in both the Fo and Fs experiments that plant height was correlated ($P = 0.01$, $r = 0.63$; $P = 0.07$, $r = 0.34$, respectively) and influenced by the presence of Cx. It should be noted, however, that peach growth in the presence of Cx and Fo was not different from the noninfested control, suggesting that the nematode is more detrimental to the activities of these fungi than to peach seedling growth under these conditions.

We conclude that besides Cx, other organisms such as Fo and Fs can cause peach feeder root necrosis, but neither synergistic nor additive effects on plant growth or root necrosis were demonstrated.

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