yields. This is in general agreement with reports by researchers previously working on older trees (2, 5, 7). This would support speculation that information on tree size and fruit yield of young trees is an indication of their performance as mature trees. An exception to this statement would be Rusk citrange (*C. sinensis* X *P. trifoliata*), which produces vigorous and high-yielding young trees, but old trees on Rusk are small and low-yielding (3, 4, 7). The tree loss to *P. parasitica* and tristeza shows the importance of rootstock selection prior to planting citrus trees.

In conclusion, the data presented show that Carrizo citrange, rough lemon 807, Volkamer lemon, and Yuma citrange perform well as rootstocks for young trees of 'Valencia' orange in the Ft. Pierce (Indian River) area. Carrizo citrange rootstock is commonly used in Florida. Further observational and performance data are needed for rough lemon 807, Volkamer lemon, and Yuma citrange to determine their potential as rootstocks in Florida.

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EVALUATION AND NATURE OF CITRUS NEMATODE RESISTANCE IN SWINGLE CITRUMELO[1]

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Abstract. **Greenhouse and field evaluations have indicated that Swingle citrumelo** (Citrus paradisi **Macf. X** Poncirus trifoliata **(L.) Raf.) is resistant to citrus nematode** (Tylenchulus semipenetrans **Cobb) populations commonly found in Florida citrus groves. Swingle citrumelo reduced citrus nematode populations to nondetectable levels within 2 years under field conditions. In greenhouse studies, citrus nematode populations were significantly reduced by Swingle citrumelo seedlings within 2 months of inoculation. Resistance was correlated with lower numbers of nematodes becoming associated with the rhizoplane and infecting feeder roots. Citrus nematode infection of Swingle citrumelo resulted in a hypersensitive-type response in the root hypodermis accompanied by wound periderm formation.**

Introduction

The citrus nematode, *Tylenchulus semipenetrans* Cobb, is distributed throughout the citrus-growing regions of the world, and often causes significant reductions in tree growth and yield (10). In Florida, the citrus nematode is widespread, having been detected in approximately 50% of the citrus groves throughout the state (1). Symptom severity (chlorosis, twig dieback, stunting, reduced fruit quality and quantity, and poor vigor) varies with tree age, nematode population size, grove management practices, and edaphic conditions in the grove. Historically, citrus nematode control in Florida has depended upon the use of nematicides, sanitation, and a nursery-stock certification program. The importance and value of resistant citrus rootstocks in management of nematode diseases are recognized. However, the commercially acceptable citrus nematode-resistant rootstocks currently available (2) are not well adapted for general use in Florida.

In this paper, we report the results of field and greenhouse evaluations of Swingle citrumelo (*Citrus paradisi* Macf. X *Poncirus trifoliata* (L.) Raf.) for citrus nematode resistance, and laboratory research designed to determine cellular changes in roots associated with resistance.

Materials and Methods

The influence of Swingle citrumelo and Volkamer lemon (*C. limon* (L.) Burm. f.) on citrus nematode population dynamics was studied under Florida field conditions. Thirty-two 6-month-old seedlings of each rootstock were budded with a grapefruit scion, and half of the trees of each cultivar were planted in screenhouse-soil tanks infested with the citrus biotype of *T. semipenetrans* (3). The remaining trees were planted in an adjacent noninfested soil tank. Eight months later all trees were transplanted to the field in a randomized-design split plot. *T. semipenetrans*-infected rough lemon (*C. limon*) seedlings were also planted with each tree taken from the nematode-infested tank to assure the presence of the citrus nematode among all nematode-inoculated trees, but were not planted adjacent to noninoculated trees. After 1 year, the rough lemon seedlings were removed and test trees were sampled twice each year for 3 years. Nematodes were extracted from root samples taken from each tree (2 samples/tree) (11), and data expressed as numbers of nematodes/gram root (fresh weight).

The influence of Swingle citrumelo on citrus nematode reproduction under greenhouse conditions was compared with that of several other rootstocks. *C. limon* cv. Milam lemon, *C. reticulata* Blanco cv. Cleopatra mandarin, *Fortunella margarita* (Lour.) Swing. cv. Nagami kumquat,

[1]This paper reports the results of research only. Mention of a trademark, proprietary product, or pesticide does not constitute a recommendation for its use by the U.S. Department of Agriculture to the exclusion of other suitable products, nor does it imply registration under FIFRA as amended.

P. trifoliata cv. Flying Dragon, *Severinia buxifolia* (Poir.) Ten., and Swingle citrumelo were grown at 25°C ± 1° in 460-cm³ styrofoam cups containing a steam-sterilized potting medium (Astatula fine sand:peat moss:vermiculite/2:1:1; pH = 6.7). Nine 2-month-old seedlings of each rootstock were each inoculated with 4,000 larvae of the citrus biotype of *T. semipenetrans*. Sixty days after inoculation, numbers of nematodes were estimated (11). Data were expressed as the number of larvae per gram of root (fresh weight), and results subjected to analysis by Duncan's multiple range test (P = 0.05).

In a second greenhouse experiment, 4-month-old citrus seedlings of 5 *P. trifoliata* cvs., Argentina, English Large, Large Flower, Pomeroy and Rich 7-5 trifoliate oranges; 2 *C. limon* cvs., Milam lemon and Volkamer lemon; Swingle citrumelo; and diploid and tetraploid Carrizo citrange (*C. sinensis* (L.) Osbeck X *P. trifoliata*) were planted in citrus nematode-infested soil tanks for 6 months. The young trees were then transplanted into 20-cm clay pots with equal parts of Astatula fine sand and sphagnum peat moss and grown for 6 months in a greenhouse. Nematodes were extracted from roots, weighed, and data expressed as the mean number of larvae/gram of root (fresh weight). Top weight (oven-dried) was also measured to assess plant reaction to nematode attack.

To compare cellular responses in roots, Swingle citrumelo and Nagami kumquat seedlings infected by *T. semipenetrans* were grown as previously described in 460-cm³ cups. Seedling roots selected for inoculation were distributed in 16-cm³ side chambers attached to each cup. A 5-mm-i.d. plastic inoculation tube was attached to the side chamber. The apparatus was buried in a sandbath to within 2 cm of the top of each cup. The sandbaths were maintained at 26 C ± 1° throughout the experiment. This technique facilitated the application of inoculum to a small portion of the intact seedling root system; it also allowed easy access to the infected roots at the time of harvest. The roots in the side chamber were inoculated with 1,500 citrus biotype *T. semipenetrans* larvae 1 week later.

The roots in 5 of the side chambers were harvested 2, 4, 6, and 8 weeks after inoculation. Infected root segments were fixed in Randolph's modified Navashins fluid (4), dehydrated through a tert-butyl alcohol series, and embedded in Paraplast-plus at 59°C. Sections (12 μm) stained with safranin and fast green were examined and photographed with a photomicroscope at 160X and 400X.

To determine the effect of host germplasm on the rate of citrus nematode infection and nematode association with the rhizoplane, each of 6 seedlings of Cleopatra mandarin, Milam lemon, Flying trifoliate orange, Swingle citrumelo, and *S. buxifolia* was equipped with 4 side chambers as previously described. Each side chamber was inoculated with 3,900 larvae of the citrus biotype of *T. semipenetrans*. Roots in each of 4 side chambers from 4 different plants were weighed, stained in acid fuchsin/lactophenol, and cleared in lactophenol (7) 3, 6, 9, 12, 16, and 18 days after inoculation. The stained root samples were mounted in glycerin between 2 glass plates. The number of larvae associated with organic debris adhering to roots (rhizoplane) and the number of larvae penetrating roots were counted at 30X and 60X. Data were expressed as total number of larvae per gram of root fresh weight (larvae penetrating roots plus larvae in the rhizoplane). Data were analyzed by linear regression.

Results and Discussion

Swingle citrumelo significantly reduced citrus nematode populations under field conditions (Fig. 1). In contrast, the size of *T. semipenetrans* populations in roots of the susceptible Volkamer lemon increased with time. After 1.5 years, the movement of nematodes in the field resulted in the detection of *T. semipenetrans* in roots of Volkamer lemon trees which were not initially inoculated in the nematode-infested soil tanks. Significant populations were never detected in roots of Swingle citrumelo controls.

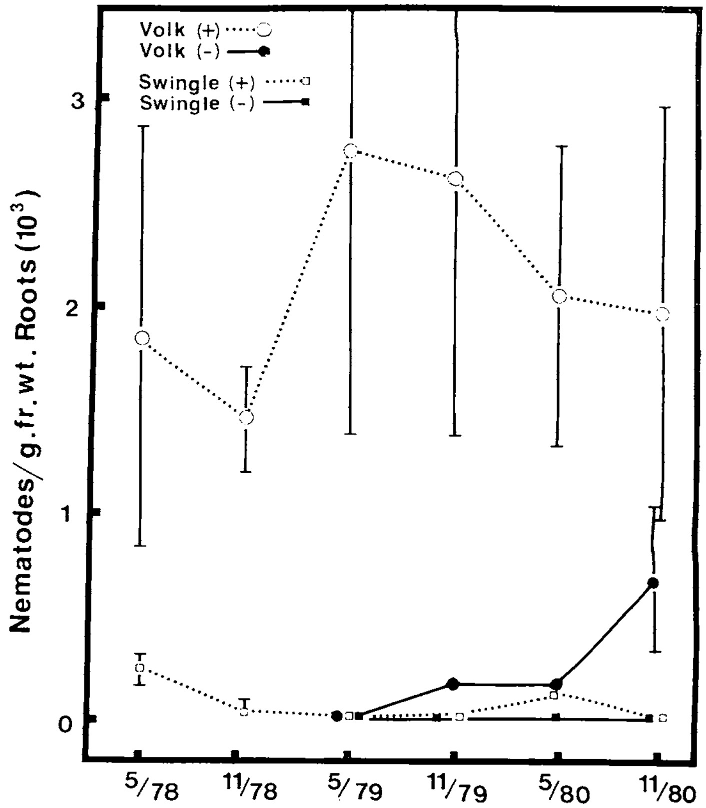

Fig. 1. The influence of Swingle citrumelo and Volkamer lemon on the population dynamics of the citrus biotype of *Tylenchulus semipenetrans* under central Florida field conditions.

Swingle citrumelo did not support *T. semipenetrans* reproduction in the greenhouse experiments. In the first greenhouse experiment (Table 1), nematode populations were reduced to very low levels in 60 days. Flying Dragon trifoliate orange and *S. buxifolia* were also effective in controlling citrus nematode reproduction. Reproduction in roots of Milam lemon and Cleopatra mandarin was significant (P = 0.05) but reduced from that in roots of Nagami kumquat.

Table 1. The influence of various citrus rootstocks on the reproduction of the citrus biotype of *T. semipenetrans* under greenhouse conditions.

Rootstock	Mean No. of larvae/g root[z]
Nagami kumquat	49.9 a[y]
Cleopatra mandarin	26.4 b
Milam lemon	15.1 bc
Flying Dragon trifoliate orange	3.3 c
Swingle citrumelo	1.3 c
Severinia buxifolia	0.0 c

[z]Fresh weight; 60 days after inoculation.
[y]Means followed by the same letter are not significantly different (P = 0.05 according to Duncan's multiple-range test ($\log \left(\frac{\text{nema}}{\text{gram}}\right) + 1$).

Numbers of *T. semipenetrans* larvae and oven-dry top and root weights from the second greenhouse experiment are shown in Table 2. The 5 *P. trifoliata* selections in this test were considered resistant, as no significant differences in growth responses of infected and noninfected plants occurred. Swingle citrumelo was also rated resistant in this test, confirming the first greenhouse experiment and previous results (8). Diploid and tetraploid Carrizo citrange seedlings supported large *T. semipenetrans* populations, but no reductions in growth were noted. Milam and Volkamer lemons supported relatively high populations of *T. semipenetrans*, and infected seedlings were significantly retarded in growth.

Table 2. Growth response of seedlings expressed by oven-dry top and root weights of *Tylenchulus semipenetrans*-infected (Inf.) and noninfected (Control) seedlings, and citrus nematodes extracted from roots of infected seedlings after 1 year.

Cultivar	Oven-dry wt. (g)[z] Top Control	Top Inf.	Root Control	Root Inf.	Mean No. of larvae/g root[y]
Trifoliate oranges					
Argentina	2.9	3.3	2.0	2.0	0.72
English Large	2.8	2.7	1.7	1.7	0.61
Large Flower	2.9	3.3	2.1	2.4	1.00
Pomeroy	3.8	3.5	2.9	2.3	1.82
Rich 7-5	3.6	3.9	2.5	2.4	2.88
Swingle citrumelo	10.2	10.2	4.5	4.2	0.53
Carrizo citrange (2N)	6.7	6.6	3.3	3.2	1528.92
Carrizo citrange (4N)	6.9	6.5	3.7	3.2	1197.20
Milam lemon	18.1	9.6**[x]	6.7	3.9**	681.40
Volkamer lemon	22.2	15.9**	8.5	7.5*	1098.68

[z]Mean of 10 seedlings of each cultivar.
[y]Fresh weight.
[x]Denotes decreased growth comparing infections with controls. * = 5% level of significance. ** = 1% level of significance using Tukey's Honestly Significant Differences.

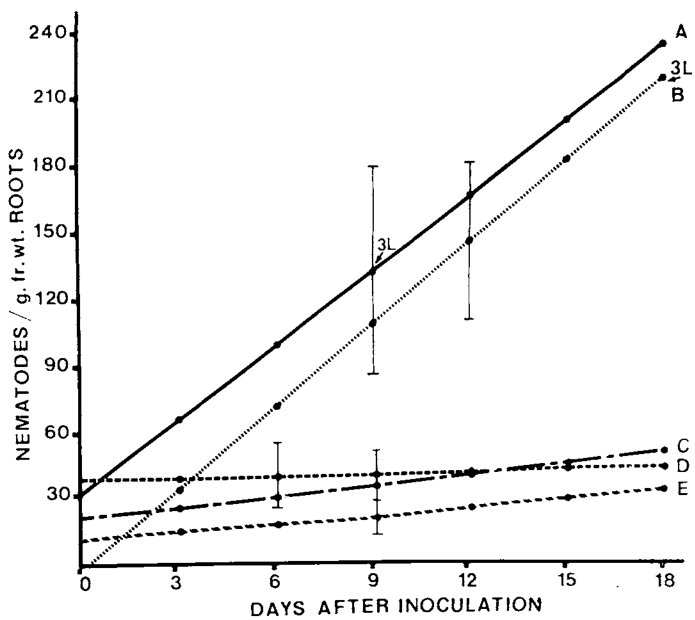

Fig. 2. Rootstock influence on the total number of citrus nematode larvae (citrus biotype) associated with feeder roots (larvae associated with rhizoplane + larvae penetrating roots). A = Milam lemon (r = 0.67), B = Cleopatra mandarin (r = 0.95), C = Flying Dragon trifoliate orange (r = 0.26), D = *Severinia buxifolia* (r = 0.0), E = Swingle citrumelo (r = 0.42). 3L = third stage larvae.

Citrus rootstock germplasm also influenced the number of citrus nematodes which were associated with roots. Within 8 days after inoculation, significantly (P = 0.01) larger numbers of citrus nematode larvae were in the rhizoplane and had penetrated roots of Milam lemon and Cleopatra mandarin than were in the rhizoplane and had penetrated roots of *S. buxifolia*, Flying Dragon trifoliate orange, and Swingle citrumelo (Fig. 2). The number of larvae in the rhizoplane and subsequent infection of citrus roots were correlated (r = 0.86). Plant-regulated attraction and repulsion of nematodes has been demonstrated in many plants (9) but had not been demonstrated in citrus. Further research should elucidate the mechanism in citrus rootstock germplasm responsible for differences in rhizoplane-nematode association. Infection of all citrus varieties was proportional to the number of larvae in the rhizoplane. Root penetration, as in other nematode-plant interactions which limit reproduction (6), did not appear to be affected by rootstock germplasm.

The correlation between nematode reproduction and the number of citrus nematodes in the rhizoplane within 2-3 weeks of inoculation may be developed into a useful procedure for preliminary evaluation of citrus germplasm in the future. Presently, however, the USDA rootstock evaluation program will continue to compare the number of citrus nematodes in the rhizoplane with nematode reproduction on roots of new germplasm in hopes of shortening the present 1- to 2-year greenhouse evaluation of rootstock germplasm to a period of 2 weeks.

In examining the cellular responses to *T. semipenetrans* infection of Swingle citrumelo and Nagami kumquat, a hypodermal hypersensitive-type response (HHR) occurred in roots of Swingle citrumelo within 2 weeks of inoculation. The HHR was characterized by safranin positive staining of hypodermal cells adjacent to the anterior portion of citrus nematode larvae. Wound periderm formation (WP), the cellular division of cortical cells associated with the HHR, also occurred within 2 weeks of inoculation. In contrast, nematode development in roots of Nagami, a susceptible rootstock, was associated with the establishment of nematode feeding sites composed of several nurse cells, but not with HHR or WP. Nurse cell cytoplasm contained central vacuoles 4 to 6 weeks after inoculation. The granular appearance of nurse cell cytoplasm increased with time, and these vacuoles disappeared by the eighth week after inoculation.

In summary, field and greenhouse studies indicated that the commercially available Swingle citrumelo was effective in controlling *T. semipenetrans* (citrus biotype). Citrus nematode resistance was correlated with reduced reproduction and fewer nematodes becoming associated with the rhizoplane and a hypersensitive-type response in conjunction with wound periderm formation. Other cellular changes in citrus nematode-infected roots which have been identified (5) as being incompatible with nematode development (cavity formation in the root cortex and vacuolation of nurse cell cytoplasm) were not observed in infected roots of Swingle citrumelo. However, the ability of Swingle citrumelo to significantly reduce *T. semipenetrans* populations in a relatively short period of time suggests that the observed responses are adequate to adversely influence the life cycle of the citrus biotype of *T. semipenetrans* commonly found in Florida.

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A COMPARISON OF LOW VOLUME SPRINKLERS

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Abstract. **The most common sizes of 9 different kinds of low volume sprinklers were tested for coverage. Manufacturers' claims were used for gallons per hour (G.P.H.). The column in the chart showing square footage covered has the best figures to enable comparison. The last column is a price comparison.**

It was found that manufacturers' coverage figures varied considerably from their published figures. Surprisingly, the published coverage is conservative in most cases.

Each sprinkler was tested for coverage under the same conditions. If a sprinkler varied from what was expected, several were tried to eliminate defective ones. Average diameter was a maximum found, since it is felt that wetted soil tends to equalize after a period of time. In other words, capillary attraction tends to pull water out of a real wet area into a less wet area. Uniformity of coverage wasn't figured for this reason. Square foot coverage was also figured on the maximum found. No attempt was made to allow for the dry areas found in most of these sprinklers' coverage, since it is felt that there is enough air movement most of the time to allow these areas to get coverage. Comparative cost figures are higher than you will pay anywhere. They are all computed on an equal percentage basis from dealer cost. No attempt has been made to compare quality and life expectancy since most of these products are too new to determine these facts. However, you need to be aware that some of them are not very uniform and have not been holding up in the field. All sprinklers were tested at 25 lb. since we have found this to be the optimum.

Results and Discussion

Any system run at low pressure is likely to have clogging problems. This has been the main problem we are called on to diagnose. Most people think the pressure on the gauge is their system pressure when, in fact, the system pressure is sometimes quite a bit lower. The filter and mainline can lose quite a bit of pressure. Any system, including artesian-well systems, ditch systems, lake-water systems should be run at 25 lb. If this can't be done, the system should be valved so that it can be run at higher pressures occasionally. The velocity of the water going through the sprinkler orifice tends to clean them out. The filtering system is extremely important with these systems. We have found almost as many problems due to the wrong type filters as to low pressure. We have never seen a properly designed low-volume sprinkler system which requires chlorination. Any pressure higher than 25 lb. is likely to cause fogging and leakage problems.

Starting in alphabetical order with the Bowsmith, we have a two-piece jet with 11 streams of water, good coverage and the best cost figure of the two-piece jets at 40¢.

The Dan Mamtiron has a spinner which gives it good coverage, but since it works best on a stake attached with spaghetti tubing, cost is high at $1.74. Maintenance is high because of the moving parts.

The Ein-Tal does not cover much area, although it should be excellent for young trees if wind isn't a problem.

Table 1. A comparison of nine kinds of sprinklers.

25# Pressure

Sprinkler	Color or Size	G.P.H.	Average Diameter	Sq. Foot Coverage	List Cost
Bowsmith	.40	12	15 ft[z]	177	$ .40
	.50	19	19 ft[z]	284	.40
	.60	27	22 ft[z]	380	.40
Dan Mamtiron	Purple	9	16 ft	201	1.74
	Red	19	20 ft	314	1.74
	Green	27	22 ft	380	1.74
Ein-Tal	35	8	6 ft	28	.45
	70	16	11 ft	95	.45
	105	24	13 ft	133	.45
Georjet	Blue	11	8x12[y]	96	.28
	Green	17	11x18[y]	198	.28
	Red	25	14x20[y]	280	.28
360° Microjet	Blue	11	16 ft[z]	201	.45
	Green	17	20 ft[z]	314	.45
	Red	26	24 ft[z]	452	.45
1-Piece Microjet	Blue	11	8x12[y]	96	.26
	Green	17	9x13[y]	117	.26
	Red	26	11x16[y]	176	.26
Nu-Jet	Blue	11	10x13[y]	130	.26
	Green	17	12x16[y]	192	.26
	Red	26	13x20[y]	260	.26
Ris Micro-Sprinkler	Black	9	20 ft	314	1.74
	White	16	22 ft	380	1.74
	Green	19	24 ft	452	1.74
	Orange	23	25 ft	491	1.74
Ris Teal	Blue	12	16 ft[z]	201	.45
	Black	19	20 ft[z]	314	.45

[z]These jets have a number of streams with dry areas between.
[y]These jets have rectangular patterns.