Effects of Citrus Nematode—and On Nutrient Concentrations in

C. K. LABANAUSKAS · R. C. BAINES · L. H. STOLZY

THE TWO EXPERIMENTS described here were initiated to evaluate the influence of citrus nematode infestations on 12 nutrients in the leaves and roots of three-year-old Frost Nucellar navel orange trees grown in well-nourished soils under two levels of irrigation.

For the first experiment in 1959, sixteen cylindrical concrete tanks 4 ft in length and 3 ft in diameter were placed in the soil to a depth of 3 ft and filled with 41 inches of a Tujunga fine sandy loam. The soil in the cylinders was sterilized with ethylene oxide. Three sweet orange seedlings (*Citrus sinensis* var. Homasassa), grown in steam-pasteurized soil in 1-gallon cans, were planted in each cylinder. At the time of planting the trees in eight of the cylinders, a suspension of surface-disinfected citrus nematode larvae was poured over the roots, while the remaining eight cylinders were not inoculated, and served as the controls. In April, 1961, the seedling tops were cut off slightly below the soil surface, and two one-year-old Frost Nucellar navel orange trees on sweet orange rootstock were planted in each cylinder. These trees with scion shoots 5 to 6 inches long were grown in 1-gallon cans containing soil that had been steam-pasteurized.

All trees received similar irrigation the first year. In 1962, treatments were started with irrigation levels of 9 and 60 centibars, as follows: (A) nematode-free soil irrigated when the soil suction reached 9 centibars at the 18-inch soil depth; (B) nematode-free soils irrigated when the soil suction reached 60 centibars at the 18-inch soil depth; (C) nematode-infected soil irrigated when the soil suction reached 9 centibars at the 18-inch soil depth; (D) nematode-infected soil irrigated when the soil suction reached 60 centibars at the 18-inch soil depth.

TABLE 1. EFFECT OF CITRUS NEMATODE ON NUTRIENT CONCENTRATIONS IN THE LEAVES AND ROOTS OF 3-YEAR-OLD NAVEL ORANGE TREES

		Experiment I†			Experiment II‡		
		Non-infected	Infected	C.V.	Non-infected	Infected	C.V.
		Percent oven-dried material					
N	Leaves	2.20	2.25	7	1.51	1.57	9
	Roots	1.46	1.42	12	1.15	1.49**	13
P	Leaves	.17	.18	2	.12	.14*	10
	Roots	.16	.14*	15	.13	.18**	14
K	Leaves	2.29	2.03	6	1.40	1.16**	12
	Roots	2.44	1.61*	14	2.20	1.57**	15
Ca	Leaves	3.62	3.17*	6	1.44	1.02**	15
	Roots	1.09	1.35	30	.73	.77	10
Mg	Leaves	.21	.19**	2	.13	.13	11
	Roots	.46	.47	25	.21	.20	8
Na	Leaves	.01	.01	25	.01	.01	49
	Roots	.31	.25	29	.10	.05**	22
Cl	Leaves	.08	.10	12	.04	.03	19
	Roots	1.17	.81*	18	....	....	..
		PPM oven-dried material					
Zn	Leaves	83	90	10	11	10	1
	Roots	243	181	46	70	71	28
Cu	Leaves	9	9	19	5	5	3
	Roots	39	53**	25	22	21	26
Mn	Leaves	28	27	7	15	13	24
	Roots	338	368	48	158	83**	30
B	Leaves	98	108**	8	37	33	21
	Roots	21	17*	19	20	17	29
Fe	Leaves	60	61	22	38	30*	20
	Roots	2018	2093	20	1708	1179**	29

† Each value is a mean of 16 individual determinations for nutrient concentrations in the leaves, and 24 individual determinations for roots under two differential irrigation levels.

‡ Each value is a mean of 12 individual determinations where one-half of the nematode-infected and one-half of non-infected trees were sprayed with Cu Bordeaux.

* = F value significant at the 5% level.

** = F value significant at the 1% level.

C.V. = coefficient of variability expressed in per cent.

Wet, dry, soils

Soils irrigated when the soil suction reached 9 centibars are referred to as "wet soils," and soils irrigated when the soil suction reached 60 centibars are referred to as "dry soils." Before the experiment ended on November 11, 1963, 30 five-month-old terminal leaves per tree, or 60 leaves per cylinder, were collected. Two grams of roots were sampled at three depths (0 to 15 inches; 15 to 30 inches; and 30 to 40 inches) for nematode determination. Fifty grams of fresh feeder-root material also were taken from the three above-mentioned depths for the determination of nutrient concentrations in the roots. Preparation of the samples and the methods used to determine the nutrients were the same as those used in previous tests.

The second experiment was begun in 1961 to study citrus nematode effects on growth of Frost Nucellar navel orange trees and on the concentrations of nutrients in the leaves and roots. Soil was prepared, and young seedlings were infected with nematodes as in the first experiment. Frost Nucellar navels on Homosassa sweet orange were planted in May, 1961. Two trees were inoculated with citrus nematode larvae at the time of planting, and the other two remained noninfected during the course of the experiment. Since previous research has shown that citrus nematodes induce copper (Cu) deficiency in citrus plants, half of the nematode-infected plants and half of non-infected were sprayed with 2 lbs of copper Bordeaux (20.6% metallic Cu) per 100 gallons of water to eliminate possible Cu deficiency effects on plant growth. Thus, four treatments were replicated six times. The treatments were as follows: (A) no nematodes, no Cu sprays; (B) nematodes, no Cu sprays; (C) no nematodes, Cu sprayed; (D) nematodes, Cu sprayed.

Just before the experiment ended in November, 1963, 30 leaves per plant were taken for chemical analysis. Root samples were taken at a 15-inch depth. Nematode counts on the roots and the effects of nematode infection and copper sprays on the nutrient concentrations in the leaves and roots of Frost Nucellar navel orange trees were determined in the same manner as those used in the first experiment.

Nematode effects

The two grams of feeder roots infected with citrus nematodes contained 6,684 nematode larvae as compared with no nematode larvae in the analogous sample from the noninfected roots. The dry weight of 100 g. of fresh root sample from the nematode-infected roots was significantly lower than a similar sample from the noninfected roots (16 g. vs. 19 g.). The data in table 1 (first experiment) show that the leaves from three-year-old navel citrus trees infected with citrus nematodes contained significantly lower calcium (Ca) and magnesium

Irrigation—
Navel Orange Leaves, Roots

Reductions in citrus yields caused by nematode infestation may vary from 10 to 50%, according to nutritional and environmental conditions—particularly under different soil moisture and soil oxygen conditions—since some citrus plants achieve apparently normal growth even in the presence of nematodes. These studies indicate the possibility that differences in soil environmental conditions (texture, pH, moisture, diffusion rates, salinity, nutrient availability, and other factors) may have more influence on good growth and performance of citrus than nematode populations on the roots.

(Mg), but higher boron (B) concentrations than the leaves from non-infected trees. Although not significant, there was a numerical trend suggesting that the leaves from the infected trees contained lower potassium (K) and higher Chlorine (Cl) concentrations than analogous leaves from the noninfected plants.

In the second experiment, the nematode-infected, three-year-old Frost Nucellar navel orange trees produced significantly smaller amounts of top growth than the nematode-free citrus trees (356 g. vs. 533 g.). The leaves from the nematode-infected trees contained significantly lower K, Ca, and iron (Fe), but higher phosphorus (P) concentrations than the leaves from noninfected trees.

Roots of the citrus trees infected with nematodes contained significantly lower P, K, Cl, and B, but higher Cu concentrations than noninfected roots (table 1, first experiment). Although not significantly different, the concentration of sodium (Na) in the nematode-infected roots was numerically lower than in the noninfected roots. Roots of the Frost Nucellar navel orange trees (table 1, second experiment) that were infected with citrus nematodes contained significantly lower K, Na, manganese (Mn), and Fe, but higher nitrogen (N) and P concentrations than the roots from noninfected plants. The nematode-infected Frost Nucellar navel orange trees produced significantly smaller amounts of root growth (662 g. vs. 929 g.) than the roots from the citrus nematode-free trees.

Nematodes did not reduce Cu concentration in the leaves of the navel orange trees in these two experiments. Foliar application of copper Bordeaux sprays in the second experiment did not affect significantly the dry weight of the tops or the nutrient concentrations in the leaves and roots of the navel orange trees. Therefore, the main effects of copper Bordeaux sprays on the nutrient concentrations and dry weight of plant material are not presented in this article. There was, however, an increase in Cu concentration (from 4 to 6 ppm) in the new unsprayed leaves which flushed out after Cu sprays were applied.

TABLE 2. EFFECTS OF IRRIGATION TREATMENTS ON THE NUTRIENT CONCENTRATIONS IN THE LEAVES AND ROOTS OF 3-YEAR-OLD NAVEL ORANGE TREES

Nutrients	Material	Irrigation levels†		C.V.
		9 centibars	60 centibars	
		Percent oven-dried leaves and roots		
N	Leaves	2.20	2.26	7
	Roots	1.48	1.39	12
P	Leaves	.19	.16	2
	Roots	.16	.14	15
K	Leaves	2.28	2.03	6
	Roots	2.03	2.03	14
Ca	Leaves	3.17	3.62*	6
	Roots	1.16	1.28	30
Mg	Leaves	.18	.20*	2
	Roots	.51	.42	25
Na	Leaves	.01	.01	25
	Roots	.28	.28	29
Cl	Leaves	.07	.10	12
	Roots	.90	1.08	18
		PPM oven-dried leaves and roots		
Zn	Leaves	87	86	10
	Roots	223	201	46
Cu	Leaves	10	8	19
	Roots	46	46	25
Mn	Leaves	27	28	7
	Roots	444	262*	48
B	Leaves	103	103	8
	Roots	19	19	19
Fe	Leaves	55	66	22
	Roots	1857	2254	20

† Each value is a mean of 16 individual determinations for nutrient concentrations in leaves and 24 individual determinations for roots. Each value represents one-half from the infected plants and another half from the nematode non-infected plants.
* = F value significant at the 5% level.
C.V. = Coefficient of variability expressed in per cent.

TABLE 3. EFFECTS OF THE ROOT DEPTH ON NUTRIENT CONCENTRATIONS IN THE NEMATODE-INFECTED AND NON-INFECTED ROOTS OF 3-YEAR-OLD NAVEL ORANGE TREES

	Depths of root sampling in inches			C.V.
	0 - 15	15 - 30	30 - 40	
	Percent oven-dried roots			
N	1.30_x	1.34_x	1.67_y**	12
P	$.18_y$	$.14_x$	$.13_x$**	15
K	1.91	2.02	2.15	14
Ca	1.03_x	1.26_{xy}	1.37_y*	30
Mg	$.38_x$	$.49_{xy}$	$.52_y$**	25
Na	$.14_x$	$.30_y$	$.40_z$**	29
Cl	$.81_x$	1.06_y	1.11_y**	18
	PPM oven-dried roots			
Zn	355_y	139_x	142_x**	46
Cu	49	49	41	25
Mn	217_x	298_x	544_y**	48
B	15_x	20_y	23_y**	19
Fe	2216_y	2190_y	1760_x**	20

Subscript letters x, y, and z after values indicate statistical populations. Mean values with different subscript letters are significantly different. Each value is a mean of 16 individual determinations for each depth sampled.
* = F value significant at the 5% level.
** = F value significant at the 1% level.
C.V. = Coefficient of variability expressed in per cent.

Irrigation effects

The soil irrigated when the soil suction reached 9 centibars at the 18-inch depth contained a lower number of citrus nematode larvae in 2 g. of feeder roots than the roots from the soil irrigated when the soil suction at the 18-inch depth reached 60 centibars (2,320 vs. 4,364 nematode larvae). The concentrations of Ca and Mg were significantly higher in the leaves of navel orange trees grown in "dry soil" than in "wet soil." The concentrations of other nutrients in the leaves were not significantly different for the two irrigation treatments. The roots of navel orange trees grown in "dry soil" contained significantly lower concentrations of manganese (Mn) than the roots of trees grown in "wet soil." When the soil suction did not exceed 9 centibars, iron (Fe) concentration in the leaves and roots decreased but not significantly from that in the plants irrigated when the soil suction reached 60 centibars (table 2).

Root depth effects

The number of citrus nematode larvae in 2 g. of feeder roots was reduced with the depth of soil. Roots within the first 15-inch depth contained more nematode larvae than the deeper levels of roots sampled (0 to 15 inches, 5,806; 15 to 30 inches, 2,432; 30 to 40 inches, 1,787). Concentrations of macro- and micronutrients varied greatly with the depth of the roots sampled (table 3). The cylinders did not have drain holes at the bottom and soluble nutrients from the upper layers of soil apparently moved downward with water. Since the surface of the soil was covered to reduce evaporation, the salts did not move upward. More

N, Mg, Na, Cu, and B were found in the roots sampled from the 30- and 40-inch depths than in the upper layers. Higher amounts of P, zinc (Zn), and Fe were found in the roots from the upper layers than from the lower. A solution of phosphoric acid was used to drench the soil of all of the pots and apparently was fixed in the surface soil.

Previous reports indicated that citrus seedling leaves from plants infected with citrus nematode contained lower concentrations of Cu and Zn than the leaves from noninfected plants. Even though the Cu and Zn concentrations are slightly affected by nematode infections of the plant roots, the concentrations of Cu and Zn in the leaves of navel orange trees in both experiments were above the deficiency range and, therefore, had no detrimental effect on the growth of the plants.

Copper sprays

One-half of the nematode-infected navel orange trees and one-half of the non-infected trees in the second experiment were sprayed with copper Bordeaux to eliminate any possibility that copper deficiency may affect the citrus growth. The plants did not show any Cu-deficiency symptoms in the presence or absence of nematodes, so the vegetative growth did not benefit from Cu foliar applications. Therefore, the reduction in vegetative growth of navel orange leaves and stems of trees infected with nematodes was not due to Cu deficiency but directly or indirectly to nematode soil infestation. A reduction in K and Ca concentrations in the leaves due to nematode infection occurred in both experiments. There again, even though the concentration of K was found lower in nematode-infected citrus plants, the reduction in dry weight of plants apparently was not due to K deficiency, since the K values in the leaves were adequate for optimum growth. The results obtained in this experiment demonstrate that under optimum soil conditions the citrus nematode has little effect on nutrient concentrations of host plants and that severe growth reduction must then be related to the quantity and/or quality of feeder roots.

Soil moisture

The roots from "dry soil" contained more nematode larvae than did comparable samples from the "wet soil." According to previous findings, nematode reproduction processes are slowed down because of lower oxygen availability in "wet soils." Therefore, the smaller number of citrus nematodes found in the "wet soil" may be due to reduced supply of oxygen. The increase in Mn concentration in the roots of plants grown in "wet soil" is probably due to lower amounts of oxygen in these soils. In poorly aerated soils, soluble Mn ions are increased due to reduction from manganic to the more readily available manganous form.

Micronutrients

Root sampling for macro- and micronutrient determination from cylinders that are not provided with drainage is very important. The data obtained in this experiment clearly show that soluble nutrients were being leached into lower layers of the soil; therefore, the roots from these layers contained higher concentrations of soluble nutrients (table 3). The less soluble nutrients like P, K, and Zn remained closer to the surface of the soil; as a result, roots in the upper layers contained higher concentrations of these nutrients than did roots in the lower layers. Thus, nutrients taken up by the feeder roots are not distributed uniformly within the root system. Nutrient accumulations in the roots may occur in the same manner in fields where hardpans exist. Therefore, sampling of roots under such conditions is of critical importance. Samples should be taken from the same depth. Otherwise, erroneous conclusions might be drawn concerning the concentrations in roots.

Charles K. Labanauskas is Associate Horticulturist, Richard C. Baines is Nematologist, and Lewis H. Stolzy is Associate Soil Physicist in the Experiment Station, University of California, Riverside.

CALIFORNIA AGRICULTURE
Progress Reports of Agricultural Research, published monthly by the University of California Division of Agricultural Sciences.

William W. Paul .... *Manager* Agricultural Publications
Jerry Lester.................... *Editor*
Chispa Olsen .... *Assistant Editor* California Agriculture

MAJOR

W. L. ENGVALL

THE CONTINUING SHIFT of market milk production from a farm-oriented operation to a factory-type enterprise increases the importance of making management decisions based on factors other than feed production and family labor. Selection, economical purchasing and wise use of feeds will always be important profit factors, since feeds make up more than half the cash cost of dairying in California. Labor costs may have a major influence on profits in smaller herds, but are usually of decreasing importance as herds become larger and certain efficiencies are realized.

Cost studies

Cost studies conducted in past years have indicated that herd size, production levels and the percentage of Class I milk usage have often been the most important factors in determining profits. These factors are interrelated and changes in any one will affect the others. Class I usage is that portion of market milk sold to the consumer as fluid milk, cream and similar products. The minimum price for this milk is set by the state and is considerably higher than the price of milk used for manufacturing purposes. Profit is what remains after cash costs are paid—and all labor, interest on investment, depreciation and a charge for management have been allocated as costs.

Operation

In this study the dairy operation is considered separately from feed production and the raising of replacement animals. Home-produced feed is charged for at current market levels. All calves are considered sold at market value and replacements purchased at market value. The cost of management is figured at 5% of total income. These figures are based on cost data sheets developed by farm advisors in cooperation with dairymen in the North Bay production area of Marin and Sonoma counties.

The larger herd obviously has the