alone, there is evidence that the optimum temperature for degreening grapefruit may be as high as 88° F.

4. There is evidence that any increase in degreening temperature above 85° F. may cause increased fungal rots in grapefruit and excessive shrinkage. Further research is necessary on these points.

5. No correlation was found between humidity and rate of degreening of oranges.

LITERATURE CITED

1. Baier, W. E., H. J. Ramsey, et al., "Coloring Citrus Fruits", Bulletin, California Fruit Growers Exchange, June 1932.

2. Citrus Rules and Regulations, Florida Citrus Commission, Lakeland, Florida.

3. Clark, C. K., Ann. Rept. Fla. Agr. Expt. Sta., 1942, pp. 155-156.

4. Clark, C. K., Progress Report, Citrus Expt. Sta., Lake Alfred, Fla. June 30, 1942.

5. Munsell Book of Color: Munsell Color Co. Inc., 10 East Franklin St., Baltimore 2, Maryland.

6. Rose, D. H., H. T. Cook and W. H. Redit, "Harvesting, Handling and Transportation of Citrus Fruits", U.S.D.A. Bibl. Bull. No. 13, Jan. 1951. pp. 19-23.

FACTORS IN THE CONTROL OF THE BURROWING NEMATODE ON CITRUS[1]

R. F. Suit, E. P. DuCharme, T. L. Brooks, and H. W. Ford
Florida Citrus Experiment Station
Lake Alfred

Recently it has been established that the burrowing nematode, *Radopholus similis* (Cobb) Thorne, is the cause of spreading decline of citrus in Florida (4). To develop a program for the control of this nematode, information is needed regarding a number of factors that have a direct bearing on this problem. Answers to questions such as the susceptibility of other plants to the nematode, the depth to which the nematode may occur in the soil, and the number of apparently healthy trees adjacent to the decline area that may be infested are of importance in planning a satisfactory control program.

Although our experiments have not been completed, sufficient evidence has been obtained to give a partial answer to these questions and for a discussion of the overall aspect of control.

Susceptibility

The known hosts of the burrowing nematode are citrus, pineapple, sugar cane, tea, coffee, banana, bamboo, nut grass, edible canna, pigeon pea, sweet potato, and abaca.

Some growers have asked for information on the advisability of growing other tree crops in areas infested by the burrowing nematode. Our recent results (1) have shown that the avocado tree develops a decline condition when the feeder roots are infested by the burrowing nematode. Therefore avocados should not be planted in infested areas without soil treatment. In one area lychee trees had been planted on infested soil for three years and appeared to be healthy. The burrowing nematode was not found either in soil and lychee root samples by the sieve-Baermann technique or in the lychee feeder roots by dissection. Experiments are in progress to further test the susceptibility of the lychee to the burrowing nematode under controlled conditions.

A number of weeds and cover crops are present in the groves. If any of these are susceptible to this nematode, the problem of control will be more difficult. To date, 10 species of these, which were growing in infested soil where the citrus trees had been removed have each been examined twice. They are Sandspur (*Cenchrus echinatus* L.), crab grass (*Digitaria sanguinalis* (L.) Scop.), goose grass (*Elensine indica* (L.) Gaertn.), spanish needle (*Bidens bipinnata* L.), coffee weed (*Emelista Tora* (L.) Britton & Rose), crotalaria (*Crotalaria spectabilis* Roth.), hairy indigo (*Indigofera hirsuta* L.), pig weed (*Amaranthus retroflexus* L.), beggar weed (*Lappula virginiana* (L.) Greene), and mexican clover (*Richardia brasiliensis* (Moq.) Gomez.). The burrowing nematode was not found associated with the roots of any of these plants. From this preliminary survey it would appear that these common cover crop plants found in the grove are not susceptible.

Distribution in Soil

In an effort to control the disease, some growers removed all visibly affected trees but the spread was not checked. This would indicate that the nematode was already infesting the feeder roots of apparently healthy trees.

[1] Florida Agricultural Experiment Station Journal Series, No. 198.

Table 1.

Occurrence of the burrowing nematode in samples from different depths in the soil

Grove	Series	Depth from which sample obtained							
		0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	5-6 ft.	6-7 ft.	7-8 ft.
A	1	+[1]	++	+++	+	—	+	—	—
	2	—	++	+++	++	+	—	—	+
B	1	—	—	+	+	+	—	+	—
	2	—	+	++	+	—	+	—	—
C	1	+	++	—	—	—	+	—	—
	2	—	—	—	+	—	—	—	—
D	1	—	++	+++	+++	++	+	—	+
	2	—	—	++	+	—	—	—	—
E	1	—	+	—	—	—	+	—	+
	2	+	+	—	++	+++	+	—	—

[1] + = 1-4 burrowing nematodes per sample.
++ = 4-12 burrowing nematodes per sample.
+++ = over 12 burrowing nematodes per sample.
— = no burrowing nematodes in sample.

When trees in advance of the decline area in eight groves were examined for the presence of the burrowing nematode, it was found that the first and second apparently healthy trees beyond the decline area were infested in all cases. In such instances the nematode population had not increased sufficiently to cause decline symptoms and this explains why the disease was not checked by removing only visibly affected trees. The lateral distribution of the burrowing nematode is at least 50 feet in advance of the last visibly affected tree.

The depth to which the burrowing nematode may be found in the soil has a direct bearing on the amount of soil fumigant needed for satisfactory control. To determine the vertical distribution of the nematode two series of samples were taken from the decline area in each of five groves. In each series a sample was taken from each one-foot-zone to a depth of eight feet. The results from the examination of these samples are given in Table 1.

Two conclusions can be drawn from these data. First, the greatest population of the nematode is between one and five feet in the soil. Second, nematodes were found at all depths sampled. It will be noted that there is considerable variation in the results from counts at the various depths and in each series. This variation is due to the fact that the nematodes are not distributed uniformly in the soil but are associated with the feeder roots. The actual depth to which the burrowing nematode might be found is probably limited by the presence of feeder roots. The nematode was dissected from lesions on feeder roots that were in a sample obtained at a depth of 10 to 12 feet in the soil.

These findings would indicate that the vapors of the soil fumigant should penetrate the soil at least to this depth. However, if the nematodes were killed to a depth of eight feet, it is possible that those deeper in the soil would die before they could migrate upwards or the roots of replanted trees could grow to that depth.

CONTROL

One phase of the research on the control program is to determine if the declining trees can be rejuvenated. Experiments are in progress using foliage applications of systemic pesticides and soil applications of several new chemicals. To date none of the treatments have reduced the nematode population or shown beneficial results in the growth of the trees. It does not seem likely that a treatment of this type could give complete control of the nematode since the nematode is usually inside of the root and anything that would kill the nematode would cause injury or kill the roots. Lacking complete control, it would be necessary to apply an effective treatment —if such could be found—once or twice each year to keep the nematode population at a low level. This would not prevent continued spread of the nematode to adjacent healthy trees. If the treatment were discontinued at any time, the decline condition would again be prevalent.

Another phase of the control program is to determine if an eradication procedure will control the disease. As previously suggested (3), the removal of the diseased trees plus four healthy trees in advance is the basis of the procedure. Since at least the first and second apparently healthy trees are already infested by the nematode, this leaves only the third and fourth trees as a possible safety zone. Following the removal of the trees, the area might be fallowed for a number of years in the hope that the nematodes would die, or a soil fumigant could be used to kill them.

There is no available information on the length of time the burrowing nematode might remain alive in the soil without suitable food. One decline area has been fallow for nearly three years and two others for about two years. The burrowing nematode was not found in subsoil and cover crop root samples from these areas. Subsoil samples from these areas have been planted with sour orange seedlings which are growing under controlled soil temperature to study the persistence of the nematode in the soil.

The first experiment on the use of a soil fumigant for the control of the burrowing nematode was started in 1948 when D-D was used at the rate of 400 pounds per acre. Six weeks later Pineapple orange trees on rough lemon were planted. In July, 1953, the nematode was not found in the roots of the trees that had been planted on the treated soil, but was found in the roots of trees planted on the nontreated soil.

Since the spring of 1951, 25 decline areas have been treated by the suggested procedure of removing the diseased trees plus four good trees in advance and treating the pulled area with the D-D. In 1951 and 1952 the suggested dosage of D-D was 400 pounds per acre. However, in view of the fact that the nematode has been found to a depth of 10-12 feet in the soil and considering the recent results from California experiments on fumigation prior to replanting (2), it was thought advisable to increase the dosage of D-D to 600 pounds per acre as an additional safety factor. This change was made in the spring of 1953 and control programs followed since that time have used the higher rate of application.

Three of the areas treated in 1951 and three of those treated in 1952 have been examined for the presence of the burrowing nematode. Samples were taken from the young, replanted trees and from the mature trees at the edge of the treated area. In no case was the burrowing nematode found. As an additional check on the presence or absence of the nematode, subsoil samples have been taken from these areas and planted to sour orange seedlings under controlled temperature conditions.

At the present time it appears that the best way to control the burrowing nematode is to follow the eradication program. That is, remove the diseased trees plus four good trees in advance and treat the soil with D-D soil fumigant at 600 pounds per acre injected at a depth of 10 to 12 inches. Young trees should not be replanted in the area until at least two months after treatment. The map used to determine the trees to be pulled should be made within one month of the time of removal. The nematodes are constantly on the move in the soil and if a map is three months old, the margin of the diseased area may have advanced a row farther than shown. In one case, the full four-tree margin of healthy trees was not removed. Three months later some of the trees at the edge of the pulled area were showing decline symptoms and the burrowing nematode was present.

The third phase of the investigation on a control program is the search for possible resistant rootstocks. To date, burrowing nematode is known to cause a decline of the four common rootstocks: rough lemon, sour orange, sweet orange, and grapefruit. The susceptibility of other possible rootstocks is being tested in two ways; as seedlings growing in infested subsoil under controlled temperature and as budded Valencia trees planted in a diseased area. The testing of rootstocks is a long-term proposition, because both the disease reactions and the horticultural characteristics must be studied in detail.

LITERATURE CITED

1. DuCharme, E. P. and R. F. Suit. 1953. Nematodes associated with avocado roots in citrus spreading decline areas. Plant Disease Reporter 37(8): 427-428.
2. Martin, J. P., R. C. Baines and Fred Foote. 1953. Fumigating soil for citrus replants. Calif. Citrograph 38(6): 216-218.
3. Suit, R. F. and H. W. Ford. 1950. Present status of spreading decline. Proc. Florida State Hort. Soc. 63: 36-42.
4. Suit, R. F. and E. P. DuCharme. 1953. The burrowing nematode and other parasitic nematodes in relation to spreading decline of citrus. Plant Disease Reporter 37((7): 379-383.

CHELATED IRON AS A CORRECTIVE FOR LIME-INDUCED CHLOROSIS IN CITRUS

C. D. Leonard and Ivan Stewart
Florida Citrus Experiment Station
Lake Alfred

Iron chlorosis of citrus occurs widely throughout Central Florida on both acid and calcareous soils. The acreage of citrus grown on acid soils in Florida is much greater than that on calcareous soils, and iron chlorosis is also more extensive on acid soils. Iron deficiency on calcareous soils, usually called "lime-induced chlorosis" is, however, a matter of serious concern to many citrus growers along Florida's east coast. Some groves in this area have shown severe iron chlorosis for many years. Many of the old trees have been replaced with young trees which have subsequently become chlorotic.

The symptoms of lime-induced chlorosis in citrus are the same as those of iron deficiency in citrus grown on acid soils. The veins of the leaves remain dark green, whereas the interveinal areas turn lighter green in mild chlorosis and yellow or almost white in severe chlorosis.

Cause of Lime-induced Chlorosis

The occurrence of iron deficiency in citrus and other plants growing on calcareous soils is associated with the high lime content and alkaline reaction of the soil. Thorne et al. (10) discussed several hypotheses in an attempt to explain the cause of lime-induced chlorosis. They believe there is not conclusive evidence that iron assimilation by plants is reduced by lime in the soil. Many experiments have been conducted on various aspects of this problem without definitely establishing the cause of the deficiency or finding a satisfactory method of correcting it. In addition to high lime and high soil pH (3, 7, 10), lime-induced chlorosis in plants has been attributed to high soil moisture, poor aeration of the soil, cool soil temperature (3, 10), excessive phosphate (2, 3, 4), too little potassium (3), and high potassium (6) among other possible causes. *Some* workers believe that chlorotic plants take up as much iron as green plants, but that the iron is immobilized in the roots or elsewhere in the plant and fails to reach the leaves in adequate amounts. Others believe that the iron is rendered largely unavailable in the soil and that very little iron actually enters the roots. It still is not definitely known why some calcareous soils will produce iron chlorosis in plants growing on them, while other soils of similar pH and content of total iron and calcium carbonate will produce green plants.

Florida Agricultural Experiment Station Journal Series, No. 216.

Experimental

In previous papers (5, 8, 9), it was reported that the iron chelate of ethylenediamine tetraacetic acid (Fe-EDTA) brought about complete recovery of iron-chlorotic citrus trees growing on acid soils when applied to the soil at the rate of only 10 to 20 grams of iron (Fe) per tree. Subsequently, field plots were set up to test the effectiveness of Fe-EDTA on chlorotic orange trees growing on calcareous soils. The chelate was applied at rates varying from 40 to 600 grams of iron per tree. Inconsistent results were obtained with single soil applications of amounts varying from 40 to 180 grams of iron per tree, but greening of a few trees was observed when 100 or more grams of iron was applied. Single applications of either 300 or 600 grams of iron as Fe-EDTA resulted in excellent greening of the trees. Although this is believed to be the first