SPREADING DECLINE OF CITRUS IN FLORIDA

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INTRODUCTION

Within the past 10 to 15 years a diseased or declining condition has appeared in various groves. This condition is being called "spreading decline" because of the manner in which the trouble gradually spreads through a grove from a focal point of one or two trees that first showed the disease.

It has been reported (7) that there are 10 major causes for tree decline in Florida. Of these 10 causes, spreading decline is third in importance, being surpassed in prevalence by foot rot and root rot. Since this type of decline is a comparatively recent development and is becoming more prevalent each year, it is a serious threat to the groves of Florida. While most of the other causes of decline usually attack scattered trees in a grove, the spreading decline has a potential possibility of causing a whole grove to go out of production over a period of several years.

Investigations were started in 1945 to determine the nature and cause of this type of decline and to develop measures for its control. Although the work has not been completed, sufficient results have been obtained to indicate the nature and probable cause of the spreading decline.

SYMPTOMS

A spreading decline area in a grove shows certain characteristics. All of the trees in the declining area show the symptoms while there is a sharp contrast at the border of the area or margin with declining trees on one side and healthy appearing trees next to them on the other side. A map of a typical spreading decline area is shown in Fig. 1. A diseased tree gradually becomes weakened by loss of foliage coupled with a lack of new growth. Such trees bear no fruit of commercial value and show sparse foliage and many dead twigs and branches. Data show that the first visible symptoms of spreading decline appear in a healthy tree adjacent to the margin of the decline area at the time of the spring flush of growth. These symptoms are: a variation in the amount of new growth in which some

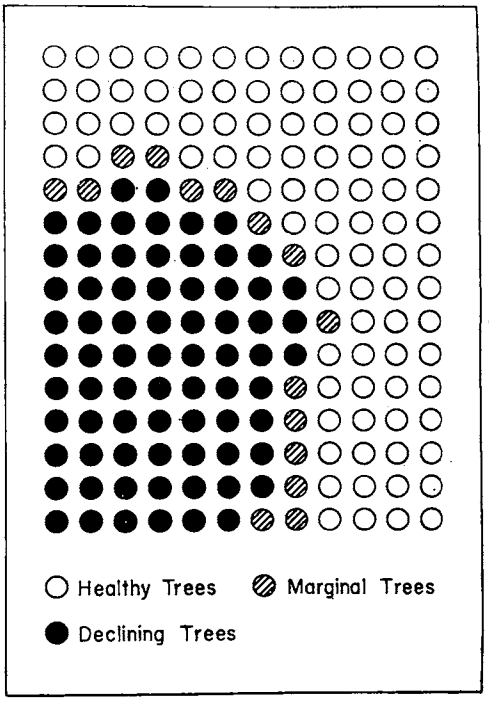

Figure 1. Map of a portion of grove No. 1 showing the typical localized distribution pattern for spreading decline.

trees produce no new growth at this time and others only a scattering; in others the flush is delayed 2 to 3 weeks; and in all cases there is a loss of a large percentage

of the older leaves causing the tree to have sparse foliage.

This decline of the tree is the effect of the condition of the roots. The root system shows a scarcity of fibrous or feeder rootlets and a certain proportion of the fibrous rootlets that are present have an abnormal appearance. These rootlets are distorted, stunted, thickened and have soil particles adhering to them that can not easily be shaken off. When such rootlets are examined the cortex readily comes off leaving the white woody cylinder of xylem tissue.

Trees which show spreading decline never die but usually maintain a weak type of growth. As long as there is sufficient moisture in the soil the foliage appears to be in good condition except that it is sparse. When adverse moisture conditions prevail, the spreading decline trees show a wilting condition while the healthy appearing trees adjacent to them show no wilting until the lack of moisture becomes critical.

Another characteristic of this type of decline is the gradual spread of the condition in the grove. A total of 10 blocks of trees have been mapped for decline occurrence during the past two years. The rate of spread of the decline in these blocks for 1945-46 and 1946-47 is shown in Table 1. The data show that the rate spread for 1946-47 was 64.5 percent greater than in 1945-46. One possible explanation for this difference is the fact that the spring of 1945 was exceptionally dry while the spring of 1946 was more nearly normal in the amount of rainfall. There was considerable variation in the rate of spread found in the various groves. Those groves which had received proper nutritional, spray and irrigation programs showed, in general, the lowest rate of spread. This condition will spread in any direction regardless of the elevation of the land.

TABLE 1.

RATE OF INCREASE OF SPREADING DECLINE IN GROVES UNDER OBSERVATION

Grove No.	Increase in number of diseased trees per tree on margin of declining area	
	May 1945 to April 1946	April 1946 to May 1947
1	0.56	1.12
2	1.00	0.82
3	0.21	1.65
4	1.58	1.10
5	0.27	0.77
6	0.47	1.06
7	0.61	0.64
8	1.00	2.00
9	1.22	1.38
10	0.66	1.50
Average	0.79	1.20

OCCURRENCE

Spreading decline has been found on Hamlin, Parson Brown, Pineapple, Valencia and Temple varieties of orange trees, on Marsh and Duncan grapefruit trees and on tangerine trees. Grapefruit trees show a greater effect from the spreading decline than the other two kinds of citrus. The condition has been found on trees with rough lemon, grapefruit and sour orange rootstock. To date, spreading decline has

been found in 54 blocks of citrus trees. The trees have ranged in age from 9 to 50 years. There were 24 blocks of grapefruit, 27 blocks of oranges and 3 blocks of tangerines in which the condition was found. The location of the blocks in which the decline occurred was as follows: 44 in Polk County, 3 in Hillsborough County, 2 in Orange County and 1 each in De Soto, Highlands, Lake, Pasco and Pinellas Counties. A systematic survey of all citrus groves throughout the citrus areas in the state has not been made to determine the actual situation, but the data at hand gives a relative indication of the prevalence of spreading decline.

CAUSE

The peculiar condition of the rootlets found on the trees showing spreading decline might be caused by a fungus disease, a virus disease or by nematode infestation. In the experiments to determine whether the trouble was a fungus disease, several fungi (*Fusarium* spp., *Diplodia* spp., *Cephalosporium* spp., and a few unknown species) were isolated from the affected rootlets but none of them proved to be pathogenic. Also, there was no significant difference in the microflora of the soil in the declining area compared to that of the soil in the healthy area in four groves where an intensive study was made. Numerous experiments were conducted in which budding, grafting and leaf grafting tests were made to determine if a virus could be transmitted. So far there has been no evidence obtained which would indicate that the spreading decline is a virus disease.

Although it had been considered that a nematode might be associated with spreading decline, it was not until in November, 1946, that they were actually found. Since that time, examination of the abnormal rootlets from the 54 blocks under observation has shown that a nematode was associated with the condition in all cases. In 16 of the blocks typical female nematodes were found that identified the nematode as *Tylenchulus semipenetrans* Cobb, the citrus nematode.

A survey of the available literature on the citrus nematode (1, 2, 3, 4, 5, 6, 8, 9, 10) gives the following information concerning this pest. The only known host of *Tylenchulus semipenetrans* is citrus and this nematode was first discovered in California in 1912. It was first found in Florida in 1913 and between 1914 and 1917 was found at Glen St. Mary, Gainesville and Brooksville. Today the nematode has been found in most of the citrus producing areas throughout the world. In Argentina, Mr. E. P. Du Charme who is on leave from the Citrus Experiment Station and who is working on the Tristeza Project at the Experiment Station, Concordia, reported that the citrus nematode was present in most groves and that the *Poncirus trifoliata* rootstock showed some resistance to nematode infestation (unpublished data).

The male and larval stages of the nematodes are worm-like and less than one-half millimeter long. These forms are usually free-living in the soil adjacent to the rootlets although they may feed on the outer layer of cells of the rootlet. The female penetrates the cortex of the rootlet with the anterior portion while the posterior part swells up and remains outside of the rootlet. Once the female penetrates the root it becomes fixed in that position for its life. The eggs are laid in the soil adjacent to the rootlet and hatch within two or three days. It requires about 6 to 8 weeks for a complete life cycle. The feeding of the nematode in the cortex results in a disintegration of the cambium region which causes the rootlets to become distorted, stunted and thickened. The infested rootlets eventually die. It is reported that the appearance of the tree is an indication of the amount of infestation of the roots. The citrus nematode has been found to exist in the soil for as long as three years without citrus being present and has been found in the soil to a depth of 6 feet in California. The nematode is usually introduced into a grove by plant-

ing infested trees and also may be spread by cultivation operations as well as irrigation water and rain. In California the effect of the citrus nematode on citrus is known as "slow decline."

A random survey of some groves in Florida indicate that the citrus nematode is quite widely distributed. As shown in Table 2, the nematode has been found in 10 of the 12 counties where samples have been obtained. Nematodes were found in all areas of spreading decline observed and *T. semipenetrans* females were present in 30 per-

further tests will show the nematodes to be present throughout a grove which has a spreading decline area in one corner. It is also shown in Table 2 that nematodes have been found in 23 groves that do not have spreading decline. Of these 23 groves there were 9 in which *T. semipenetrans* females were found while in the other 14 groves the nematode count was very low. It is possible that, where nematodes are found in healthy groves, the infestation has not developed sufficiently to cause the spreading decline. There appears to be no definite time

TABLE 2.

OCCURRENCE OF THE CITRUS NEMATODES IN GROVES EXAMINED

County	Number of Groves			
	With Spreading Decline		Healthy	
	Nematodes Absent	Nematodes Present	Nematodes Absent	Nematodes Present
Polk	0	44	26	11
Highlands	0	1	11	2
Lake	0	1	9	0
Orange	0	2	1	1
Hillsborough	0	3		
Sarasota	0	0	4	0
Osceola	0	0	1	0
Pasco	0	1		
De Soto	0	1		
Pinellas	0	1		
Manatee	0	0	0	6
Indian River	0	0	6	3
Total	0	54*	56	23**

* Positive identification of *T. semipentrans* in 16 of the groves.
** Positive identification of *T. semipentrans* in 9 of the groves.

cent of the areas. In the other location the nematodes found appeared to be male or larval stages of the citrus nematode. The healthy appearing trees around the spreading decline area also had nematode infestation. The nematodes have been found on healthy appearing trees in the same block as far as 500 feet from the area showing the decline but a study of the relationship has not been completed. It is possible that

limit on the occurrence of spreading decline. As previously mentioned the condition has been found in groves from 9 to 50 years of age. In one grove it is known that the trees have been infested with nematode for at least 11 years but show no decline symptoms in the above ground parts. Thomas (9) obtained decline symptoms in young trees that had been growing in pots of infested soil for 4 years. In another case

(4) field tests with young trees grown for 4 years in old citrus soil showed no decline symptoms but had grown only half as much as similar trees planted in virgin soil. This lack of growth has also been observed in young trees planted in an area where spreading decline trees had been removed here in Florida.

There are a number of facts which indicate that *T. semipenetrans* is probably associated with the spreading decline, although it may be that there are some factors which have an effect.

1. The nematodes have been found in all areas that show spreading decline.
2. In the soil extraction tests about 80 percent of the nematodes are the citrus nematode, which is approximately the same relation as found with the nematodes from the slow decline in California (4).
3. The abnormal appearance of the infested rootlets is identical with the illustrations and descriptions of citrus-nematode rootlet injury given in the literature.
4. A *Fursarium* spp. was isolated most frequently from the abnormal rootlets and this fungus has also been reported as associated with slow decline in California (3, 4, 9).
5. Trees which show the spreading decline never die unless foot rot or some other disease is present. If the condition was caused by a fungus or a virus disease, it is probable that the tree would die. It appears that the tree is able to maintain a few healthy roots even though a large proportion of them may be infested with the nematode.

One characteristic of this type of decline which has not been reported in connection with citrus nematode infestation in other regions where citrus is grown is the gradual spread of the condition in a grove. Generally the decline is first observed in 1 or 2 trees and then gradually spreads in all directions from this focal point affecting every tree as it goes. Thus it would appear that the casual agent or agents is primarily spread by root contact from one tree to another. Because of this peculiar behavior of the decline it is possible that there are factors in addition to the citrus nematode that have an effect.

Control Experiments

Before the probable cause of the spreading decline was determined experiments on control of the condition was of three types: severe pruning, tree injection and soil treatment in an effort to induce renewed growth. Approximately 500 trees have been treated in various ways. Some trees were cut back to 3/4-inch wood which removed all of the foliage, while other trees were buckhorned. During the season following pruning, the treated trees made excellent growth but during the second season the growth was retarded and the trees again started to show the typical spreading decline appearance. In some experiments solutions of different concentrations of 8-hydroxyquinoline sulfate, sulfanilamide and other similar materials were injected into the declining trees through the roots. No beneficial effect was obtained. Treatments have been made to the soil around declining trees to try to induce recovery and to the soil around healthy appearing trees adjacent to the decline area in an attempt to keep them from becoming diseased. Copper sulfate at 5 to 20 pounds, sulfur at 50 to 100 pounds, ammonium sulfate at 20 to 60 pounds, sodium chloride at 10 to 40 pounds, aluminum sulfate at 15 pounds, hydrated lime at 50 pounds and Dithane at 3 pounds per tree have been tried at various times and in different groves. None of the treatments caused any beneficial effects to the declining trees. Typical results from the treatments on the healthy trees adjacent to the spreading decline area are shown in Table 3 which is the data obtained from one experiment. None of the

treatments prevented the healthy trees adjacent to the decline area from becoming diseased within one to two years. Thomas (9) tried a total of 16 materials as soil treatments and obtained no control of the citrus nematode.

After it was established that the citrus nematode was associated with spreading decline, experiments were conducted to determine the effect of certain soil fumigants on the citrus nematode and on the trees. Injection of D-D (equal parts of 1,3 dichloropropene and 1,2-dichloropropane) into the soil were made to a depth of 6 inches at rates of 2, 3, 4 and 5 ccs per square foot of surface area. Examination of the rootlets from the treated trees showed that all of the dosages had given control of the citrus nematode, at least in the top two feet of soil. Since the nematode is known to exist to depths of 6 to 8 feet under California conditions and to a depth of at least 3 feet in Florida, the higher dosages of D-D per square foot would result in more effective control. However, dosages of 2, 3, 4 and 5 ccs per square foot resulted in the death of the trees when the whole root area (625 square feet) was treated either in February or April. The trees treated in April died more rapidly than those treated in February. If only half of the root area (312 square feet) of the tree was treated, excessive injury was caused by the 3, 4 and 5 ccs per square foot dosage while those treated with 2 ccs per square foot showed a shock from the treatment and were in poor condition on October 15, 1947, but may recover. It is doubtful if D-D can be used to treat the soil in which trees are growing.

Additional tests were made with Dowfume W-10 (10% Etheylene dibromide) and two Dow materials labelled S-991 and S-684. These materials used at 2 and 4 ccs per square foot were not as effective as the D-D for the control of the citrus nematode. However, at the 2ccs per square foot dosage there was apparently no serious injury to the trees.

TABLE 3.

EFFECT OF SOIL TREATMENT ON THE CONTROL OF SPREADING DECLINE

Material	Pounds Per Tree	No. Trees Treated*	No. diseased trees on 4/19/46	11/21/46	5/26/47
Copper Sulfate	10	34	9	10	31
Sulfur	50	35	1	6	31
Ammonium Sulfate	20	36	4	6	32
Non-treated	—	35	5	8	32

* Treatments were applied in December, 1945.

It would be possible to control the citrus nematode by removing the declining trees and treating the soil with a fumigant. The area could then be replanted with young nematode-free trees. This has been reported (4) as the only treatment found to be beneficial wherever properly tried.

At the present time it appears that the citrus nematode is probably one of the factors responsible for the spreading decline in Florida. However the spreading characteristic of the decline has not been reported from other areas where the citrus nematodes occurs. Thus, it would appear that there may be other factors which have not been discovered at this time and which may be

responsible for the spreading condition. Further investigations will give some information on this point and will also determine whether a material can be found that will control the citrus nematode without serious injury to the tree. It is also possible that a rootstock may be found that is resistant or immune to infestation.

Summary

Spreading decline has been increasing during the past 10 to 15 years and is now third in importance as a cause of decline in a grove. It occurs on grapefruit, oranges and tangerines budded on rough lemon, grapefruit or sour orange rootstock.

To date the condition has been found in 54 blocks of citrus ranging from 9 to 50 years of age. It has been found in 8 counties, but is most prevalent in Polk County.

The spreading decline is apparently not caused by a fungus or a virus disease but appears to be the result of the infestation of the rootlets by *Tylenchulus semipenetrans* (Cobb). The citrus nematode was also found in 9 of the 81 healthy groves examined and was found in 10 of the 12 counties where groves have been examined.

The average rate of spread of the decline in 1945-46 was 0.79 trees per tree on the margin of the declining area and in 1946-47 was 1.20 trees in the 10 groves which were under observation.

No control of the spreading decline was obtained by various types of pruning, tree injection with various chemicals in solution or by soil treatments with copper sulfate, sulfur, ammonium sulfate, sodium chloride, aluminum sulfate, hydrated lime or Dithane. The citrus nematode was controlled by dosages of D-D at the rate of 2, 3, 4 and 5 ccs per square foot of area, but in practically all cases the trees were killed by this treatment, except when only half of the root area was treated with the 2ccs per square foot, in which case the trees lost considerable foliage but were not killed.

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