ments were used with 4 replicates on each of two fertilizer levels.

2. At the end of four years, trunk diameter was not influenced by the amount of zinc or manganese applied. There appeared to be increased diameters with increased amounts of copper. The high level of fertilizer gave increased diameters as compared with the low level of application.

3. The number of fruit produced per tree in the 1952-53 and the 1953-54 seasons was not influenced by the rates of zinc or manganese used. Where no copper had been applied, some fruit was ammoniated and there were less fruits per tree. High fertilizer levels increased the number of fruits.

4. Some zinc deficiency symptoms have been present on foliage since the first year, but no really deleterious results on yield or growth have been noted as yet.

5. Several leaf patterns have been present which cannot be correlated with the use of zinc, manganese, or copper. An application of EDTA reduced some of these symptoms.

6. It is suggested that young trees require no more than one nutritional spray per year at the equivalent rate of 3 pounds of the sulfate of zinc, manganese, or copper. It is further suggested that manganese and copper be included at about .25 of a unit expressed as the oxide in all fertilizer mixtures applied on young trees for the first 7-10 years. As much fertilizer as was used at the high fertilization level in this experiment will probably be justified in young groves.

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OBSERVATIONS ON CITRUS BLIGHT

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Blight is among the oldest described citrus diseases in Florida being antedated only by foot-rot, a fungus (*Phytophthora* sp.) disease, and exanthema (copper deficiency). It has also been called orange blight, limb blight, go-back, wilt, dry wilt, leaf wilt, leaf curl, roadside decline, root-rot, and Plant City disease. According to Rhoads (4) Manville alluded to blight in 1883, but older settlers doubtless knew of the disease for a number of years before that. In 1891 Underwood (9) was sent to Florida by the U. S. Department of Agriculture to make a preliminary study of citrus diseases, and the following year Swingle and Webber (8) were sent to work on citrus diseases, especially blight in Florida. After their report was published in 1896 very little further work was done until Rhoads (4) took up the problem in 1923.

Economic Importance

Underwood (9) considered blight "the most dangerous disease that has yet appeared among the orange groves" and urged an immediate study to determine its cause and cure. Swingle and Webber (8) noted that in some localities 1 to 10 percent of the trees were annually stricken with blight. They estimated the annual loss to be about $150,000. According to Fawcett (1) the loss from blight in 1909 was probably in excess of that figure.

Between 1910 and the present time, a great change occurred in the Florida citrus industry which caused blight to be largely obscured. Thousands of acres of new land were planted with the new rough lemon (*Citrus limon*) rootstock, with the result that citrus production was approximately doubled every 10 years between 1910 and 1950. These newer plantings increased at such a rate and dominated the citrus picture to such an extent that blight seemed to decrease, and in 1918 Stevens (6) reported that blight was much less important than formerly. However, the number of trees attacked annually by blight did not decrease at any time.

In time blight began to show up in the newer rough lemon rooted plantings as the trees matured and became susceptible. To many growers it was a new disease which they sometimes called root rot. In 1947 Suit and DuCharme (7) reported that root rot (blight) was the second most frequently encountered disease (20 percent) in their survey of 204 sick groves. Foot rot was first (27 percent) and spreading decline was third (13 percent). Seven other causes of decline, ranging from water damage to drought injury were listed. Thus a large portion of the declining trees so common in older groves are affected with blight.

Figures compiled by caretakers of approximately 5,000 acres of citrus dispersed over several counties in the central part of the state reveal that more than one percent of the bearing trees are lost annually from all causes. If one-fifth of the total annual loss can be ascribed to blight, then on the basis of 28.2 million bearing trees in Florida (1951 estimate) (5) and $24.60 per tree (65 trees per acre having an average estimated value of $1,800 less land value of $200) the present annual loss from that disease is in the neighborhood of $1,400,000 or roughly ten times as great as the 1896 figure. This estimate is on the conservative side because it is based solely on the value of trees replaced each year and takes no account of production lost because of blight prior to the time of replacement or the cost of replacement.

Distribution

Blight was thought to be confined to Florida by Swingle and Webber (8) and later by Rhoads (4). Fawcett (1) stated that blight did not occur in California in 1915, and there is no record of its appearance there since that time. According to Rhoads (4), P. H. Rolfs did not see it during his 13 years in Brazil. However, Mortensen (2) described a citrus disease occurring near Winter Haven, Texas, that is strikingly similar to blight, a fact which he was first to point out. Also, in Pakistan there is a die-back of citrus trees that corresponds to blight according to A. J. Pirzada,* government horticulturist of Sind, Pakistan.

Symptoms

Blight rarely attacks trees before they are 10 to 15 years old. Florida authors agree on this point. Traveling from tree to tree in a hit or miss fashion blight spreads in all directions, sometimes rapidly and at other times rather slowly. All the trees in the affected area are not attacked at once; some may remain healthy for years in close proximity to diseased trees.

Affected trees never recover even temporarily. If the branch ends are cut back no new growth is stimulated, but sprouts may grow out from the trunk and lower branches. None of the blighted trees ever survived that were transplanted to new soil from time to time. Affected trees occasionally die quickly but more often they linger for years in a partially defoliated, unproductive condition.

The symptoms of blight were clearly described by Swingle and Webber (8) in 1896 as follows: "The first symptom is a wilting of the foliage as if the tree were suffering from drought. At first the wilting is slight and can be plainly seen only on hot dry days. However, it soon becomes very pronounced and often continues so during the wet season in summer when rains are almost a daily occurrence. . . . After wilting becomes severe the foliage begins to drop and in a few weeks or months, according to the severity of the case, the affected branches shed nearly all their leaves. This is followed by slow dying-back of the branches. In many cases the whole top of the tree is attacked at one time but very often only a single branch shows the disease at first. In such cases, however, the entire tree soon becomes affected.

"As soon as the rainy season begins, the trunk and large branches put forth numerous water sprouts (Fig. 1, A), which grow rapidly and at first seem to be perfectly healthy. (The production of water sprouts is more marked on sweet orange (*C. sinensis*) than on grapefruit (*C. paradisi*) trees. This habit of producing abundant sprouts distinguishes blighted trees from those affected with spreading decline, a different disease.) Eventually even the sprouts sicken and die-back.

"A most remarkable fact is that the roots of blighted trees invariably seem to be entirely healthy." This last statement is substantially true but occasionally a few roots are found black and necrotic (Fig. 1, B) usually towards the distal end. This condition is probably responsible for the name root rot, which is sometimes applied to this disease.

There is one important aspect of blight not discussed by previous authors, and that is minor element deficiency symptoms. Blighted trees frequently show symptoms of zinc and manganese deficiency on the water sprout foliage and occasionally show boron deficiency symptoms in the albedo of the fruit under conditions where the availability of these minor elements is entirely adequate. Such deficiency symptoms do not respond to soil applications of the appropriate minor elements. In short,

* In conversation at the time of his visit to Florida, April, 1953.

Fig. 1. A) Blight, affected sweet orange (C. sinensis) on Rough lemon (C. limon) stock; B) sections of necrotic roots, the root rot aspect of blight; C) Longitudinal sections of a Rough lemon root showing plugging of vessels, x200; D) vessel plug, showing strands or fibers, x800.

trees affected with blight seem unable to absorb or to translocate water and nutrients even when adequate amounts of both are available.

Species and Varieties subject to blight: Few figures are available on the comparative susceptibility of citrus varieties because other factors such as soil type, drainage, rootstock, etc. are seldom comparable. There is a tendency to regard as most susceptible varieties that are most widely planted and hence often seen in blighted condition. Swingle and Webber (8) and Rhoads (4) regarded sweet orange trees as considerably more susceptible than grapefruit. The latter author regarded Pineapple orange trees as more susceptible than Valencia or seedling sweet orange. Tangerines (*C. reticulata*) seem to be attacked less often than grapefruit. The present scarcity of sour lemon(*C. limon*) trees in Florida makes it difficult to judge the susceptibility of that species, although Swingle and Webber (8) rated lemon trees more resistant than sweet orange or grapefruit. Today there are probably more blighted trees on rough lemon stock than on any other merely because more citrus is grown on it. Swingle and Webber (8) considered limes, presumably seedling Mexican limes (*C. aurantifolia*), and seedling sour orange trees (*C. aurantium*) to be almost free from blight. They further remarked that "Curiously enough the sort of stock used appears to have no influence in increasing or diminishing the susceptibility of trees to the disease." That characteristic of blight has been observed recently in a grove of 50-year-old grapefruit trees on mixed rootstocks (sour orange, rough lemon, and Cleopatra mandarin, *C. reticulata*). There was no observable difference in the rate with which the trees on the three rootstocks succumbed to the disease.

Mortensen (3) studying a disease with symtoms similar to blight at Winter Haven, Texas, found that of 16 rootstocks on trial (trees, 10 years old or older) 13 were susceptible, but trees on three other stocks, Changsha tangerine, Rustic Citrange, and Kansu (Ichang) lemon expressed no symptoms (table 1). It

Table 1. Susceptibility of 16 varieties of citrus to "decline at Winter Haven, Texas, 1951 (3).

Rootstock	Declined trees	Healthy trees	Percent with decline
Calamondin	4	7	36
Citrange, Carrizo	8	17	31
Citrange, Cunningham	17	57	23
Citrange, Morton	7	9	44
Citrange, Rusk	4	37	10
Citrange, Rustic	0	11	0
Citrange, Savage	16	24	40
Citrange, Uvalde	5	21	19
Citrangedin	5	3	63
Citrangequat, Thomasville	1(?)	10	9(?)
Citrumelo, Sacaton	6	25	19
Kansu (Ichang)†	0	5	0
Lemon, Meyer	5	1	83
Sour orange	2	17	11
Tangerine, Changsha	0	3	0
Trifoliate orange	137*	119	54

? Diagnosis uncertain.
* Trees affected with exocortis were included in this figure.
† Ichang lemon according to Mortensen.

is difficult to tell whether these three rootstocks are indeed resistant or merely have escaped the disease to date.

Influence of location: According to Swingle and Webber (8) blight attacks citrus trees on all kinds of soil and is most prevalent on the best citrus lands. As a result it is obviously impractical to prevent the disease by planting on lands least subject to it. Trees on shallow, poorly drained soils are also prone to blight, but the diagnosis is often confused by damage from poor drainage. None of the previous authors mentioned the relation of soil pH to the incidence of blight. In preliminary tests by the author, soil samples down to the 30 inch level have not indicated any relation between soil pH and rate of spread within a grove of 50 year old grapefruit trees. There seems to be some relationship between blight and proximity to highways, the nature of which is not clear. Blight is quite obviously not related to leaching from lime rockbeds because there are many affected trees not adjacent to roads and some next to roads are on banks never reached by water from the road.

Cause of Blight

There have been many theories as to the cause of blight and most authors have thought blight to be contagious. Underwood (9) considered a bacterial organism to be the most probable cause. Swingle and Webber (8) hazarded no guess as to its cause but stated emphatically that it could not be attributed directly to cold, drought, wet weather, close proximity to hard pan or improper fertilizers as was often erroneously believed. Rhoads (4) however, thought blight to be related to soil moisture deficits and excesses brought on by one or a combination of causes.

The deterioration of blight affected trees is sometimes thought to result from the black and necrotic roots occasionally found on such trees. Necrosis seldom affects more than one or two roots on a tree and often affects only one side of a root (Fig. 1, B) in a strip several feet in length. It seems to start most often near the far end of the root and to progress toward the root crown. However, this type of root damage is of such sporadic occurrence and minor intensity that it seems scarcely able to account for the death of large trees.

Three genera of fungi (*Diplodia, Fusarium,* and *Phoma*) can regularly be cultured from necrotic roots. Repeated attempts were made to cause wilting by inoculating rough lemon seedlings with cultures of these fungi isolated from necrotic roots. One year old seedlings, five per pot, were transferred to 5 gallon crocks filled with sharp sand. Four series of crocks were set up and two were watered with half-strength and two with one-tenth-strength Hoagland's solution by a drip method. Nutrient solutions were adjusted to pH 4.5 for one member of each pair and at pH 6.0 for the other member. Wilt symptoms were occasionally produced in the inoculated pots and once in the checks, but only when stunted field grown seedlings of low vigor were used. This seems to indicate that root necrosis (rot) resulted when roots already weakened from other causes were attacked by weak parasites of citrus such as *Diplodia* sp. and *Fusarium* sp.

It is well known that water and dissolved nutrients are translocated from roots to the leaves by a system of tubes or vessels in the wood or xylem. These are made up of short sections or vessel elements joined end to end very much like drain tile, but with a constriction at each junction. Microscopic examination of sections cut from the roots of blighted trees reveals that the vessels are plugged by material (Fig. 1, C) of undetermined nature that collects at the constrictions. These plugs could retard or stop the flow of water and nutrients through the vessels. A species of actinomycetes (a group of organisms intermediate between fungi and bacteria) of the nocardia type has been isolated from such roots on several occasions. As yet it has not been established that the formation of plugs is related to a micro-organism although at times the plugs resemble masses of actinomycete hyphae (Fig. 1, D). Similar vessel plugging, often accompanied by brown staining of the wood, was found in the twigs of blighted trees and could account for the twig die-back which is conspicuous.

TREATMENT

After 62 years we still know very little about blight. We do not know what causes it, how to control it, or how to avoid it. However, experience has shown that blighted trees never recover and efforts in that direction appear to be futile. Thus it is suggested that blighted trees be removed as soon as the identity of the disorder is reasonably certain.

There seems to be no harm in replanting immediately. Young trees grow normally even when set out the same day the blighted trees were removed. Under such conditions blight symptoms rarely appear before the replant is 15 years old.

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COPPER OXIDE AS A SOIL AMENDMENT FOR CITRUS

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Practically all of the copper used in Florida citrus fertilizers has been in the water-soluble copper sulfate form. Recently a product containing a mixture of cupric and cuprous oxides, in which the copper is only slightly water soluble, has been offered for use in citrus fertilizers. The availability to plants of this form of copper already has been demonstrated for other crops on peat soils (1) but its value for citrus on mineral soils has not been demonstrated heretofore.

Most of the doubt concerning the availability of copper in oxide form centers around its low water solubility. While water solubility is a characteristic possessed by most fertilizer materials in use at present, a high degree of water solubility has not proved essential for availability of copper to plants. Numerous references can be found in the literature which describe the successful use of relatively insoluble compounds to overcome copper deficiency. Some of these have been copper refinery slag (6); oxidized copper ore, roaster residues from pyrite burners (9); copper pyrophosphate catalysts, tetra copper calcium oxychloride, copper hydroxide, metallic copper (2); and minerals such as chalcopyrite, chalcocite, cuprite, and malachite (8). Trials were run with these materials in some cases on organic and in other cases with mineral soils. In view of facts such as these, Steenbjerg (8)

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