more highly toxic levels, growth was completely arrested, and general yellowing of foliage was induced. This series of symptoms re-emphasizes the fact that copper-induced iron chlorosis appears after some decrease in growth already has occurred. While copper-induced iron chlorosis rightfully deserves study, another general need is an accurate criterion to use in determining whether groves have proper copper supplies for optimum growth of both tops and roots.

SUMMARY

Relative availability and toxicity to citrus seedlings of copper supplied as oxide or sulfate was studied in pots of Lakeland, Ft. Meade, and Parkwood soils. Soil copper levels ranged from less than 5 ppm to 1,000 ppm.

With previously uncultivated soils, copper additions of 9.5 or 10 ppm copper slightly increased seedling growth, and increased copper content of leaves significantly. Differences due to source were minor and not statistically significant.

Generally at high copper levels, the oxide and sulfate forms were about equally toxic. However, the sulfate form was somewhat more toxic than the oxide on acid sands in early stages of the experiment, presumably due to temporary residues of soluble copper. Copper oxide was more toxic in Parkwood soil, possibly because of more uniform distribution of the finer particles throughout the soil.

Cleopatra mandarin showed iron chlorosis more commonly than did sour orange and accumulated less copper in leaves than did sour orange and rough lemon.

Soil toxicity level of copper was demonstrated to be slightly higher for Ft. Meade than for Lakeland, and much higher for Parkwood.

Copper oxide can be tentatively recommended as a soil amendment for citrus, and may be used at rates equivalent in metallic copper to those recommended for copper sulfate.

LITERATURE CITED

1. Allison, R. V., W. T. Forsee, Jr., and T. C. Erwin. 1949. Copper availability tests. Fla. Agr. Expt. Sta. Ann. Rept. 1949: 192.

2. Brown, John C., and Paul M. Harmer. 1950. The influence of copper compounds on the yield, growth pattern, and composition of spring wheat and corn grown on organic soils. Proc. Soil Sci. Soc. Amer. **15:** 284-291.

3. Floyd, B. F. 1908. Symptoms of citrus die-back. Fla. Press Bull. 93.

4. Jamison, Vernon C. 1944. The effect of particle size of copper- and zinc-source materials and of excessive phosphates upon the solubility of copper and zinc in a Norfolk fine sand. Proc. Soil Sci. Soc. Amer. **8:** 323-326.

5. Lucas, Robert E. 1948. Chemical and physical behavior of copper in organic soils. Soil Sci. **66:** 119-29.

6. Nicolaisen, W., W. Seelbach, and B. Leitzke. 1939. Experiments on combatting the heather moor disease with copper slag. Bodenkunde u. Pflanzenernahr. **13:** 156-69. (C. A. **34:** 211.)

7. Smith, Paul F., and Alston W. Specht. 1953. Heavy-metal nutrition and iron chlorosis of citrus seedlings. Plant Physiology **28:** 371-382.

8. Steenbjerg, F. 1950. Investigations on micro-elements from a practical point of view. Trace Elements in Plant Physiology. Chronica Botanica Company, Waltham, Mass.

9. Teakle, T. J. H., I. Thomas, and A. G. Turton. 1941. Experiments with micro-elements for the growth of crops in Western Australia. I. Experiments in the wheat belt with cereals. J. Dept. Agr. W. Australia **18:** 70-86. (C. A. 36, 606.)

DEGREENING CONDITIONS FOR FLORIDA CITRUS

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Ethylene degreening of Florida citrus is commonly carried out at 85° F., which is the maximum temperature allowed by State regulations when heat is applied in the degreening process (2). This temperature is considerably higher than is used in most other citrus growing countries, or even in other parts of the U. S. A. (6).

Approximately eleven years ago (in the season of 1941-42) C. K. Clark at the Citrus Experiment Station, Lake Alfred, initiated an investigation into the optimum degreening conditions for Florida-grown citrus fruits (3, 4). The preliminary experiments were conducted with Hamlin oranges and, to a lesser extent, with Duncan grapefruit. Temperatures used ranged from 80° to 100° F. The degreened fruit was graded visually into three grades. Grade I showed no green at all. Grade II was commercial No. 2 as far as color was concerned and showed some green cast. Grade III contained all fruit too green to fall in the other two classes. The degree of "color break" was expressed by a color index calculated by means of the relation:

Color Index = % No. I + ½ (% No. II).

These results were presented in tabular

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form (4), and from them Clark concluded: "It is evident . . . that an optimum temperature exists, at which coloring proceeds at a maximum rate and that this temperature lies in the neighborhood of 85° F. . . . In addition it was noticed that fruit colored above 90° F. did not reach a final normal color but acquired a grayish cast."

Clark also tested the effect of humidity on the rate of coloring, using relative humidities from 69 percent to almost 100 percent. He found no relationship between humidity and rate of color change and concluded that regulation of humidity was necessary only to control shrinkage. This conclusion is in striking contrast to the views of Baier and Ramsey (1) who state that lowering of relative humidity drastically slows up the rate of degreening.

1952-53 Experiments

Experimental Methods. Four small degreening cabinets of 50 cu. ft. internal capacity, equipped with thermostatically controlled electrical heating elements, were used in these studies. When it was necessary to use lower-than-ambient temperatures pails of ice were placed in the cabinets. This proved effective although laborious. Humidity was raised when necessary by wetting the interior of the cabinets and using lengths of partially immersed cheesecloth as evaporating surfaces. The relative humidity was reduced by means of trays of calcium chloride. Ethylene was supplied by individual "trickle" units as used in commercial degreening rooms. Small fans with ducts and adjustable vents provided for internal circulation and/or ventilation.

The initial temperature range employed was 70° F. to 100° F. This was subsequently narrowed as the experiment proceeded. The samples were removed periodically and their averaged color recorded. This "average color" was read by comparing the light reflected from the surface of the whole sample with selected Munsell colors (5), by a method similar to that described by Baier and Ramsey (1). A sample was considered to be degreened when it reached an arbitrarily selected point on the color scale corresponding to Munsell code numbers "gY 8/10" for oranges and "yGY 8/8" for grapefruit. The efficacy of a treatment was measured in terms of "time to degreen".

With only four cabinets available, it was apparent that the experiment would extend over a considerable portion of the growing season and during this period the time necessary for degreening would change. For this reason one control sample was always degreened at 85° F. and medium (80 to 90% R. H.) humidity. This made it possible for all results to be expressed as a percentage of the time required for the control.

Eight experiments were carried out in all, five with Hamlin oranges, three with Marsh grapefruit and one with Valencia oranges. The number of replicates in each experiment was always at least two and as many as five when sufficient green fruit was available. Each replicate included at least 20 and sometimes as many as fifty fruits.

The trials on Hamlin oranges started approximately three weeks prior to the commercial picking period and extended into the regular harvests. The Valencia and grapefruit experiments were conducted in the course of the normal harvesting season.

Results

With Hamlin oranges the results indicated very definitely that 85° F. was optimum with regard to rapidity of degreening (see Figure 1). Above or below 85° F. the time to degreen was sharply increased.

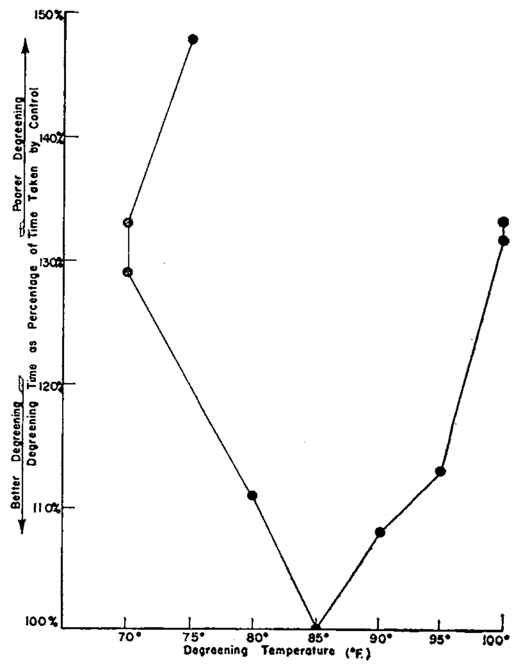

Fig. 1. Effect of Temperature on Rate of Degreening of Hamlin Oranges.

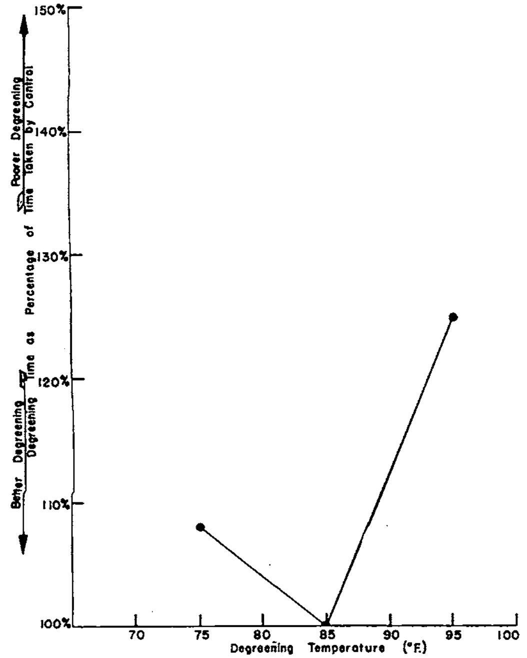

Fig. 2. Effect of Temperature on Rate of Degreening of Valencia Oranges.

No ethylene burn was encountered with mature fruit. However considerable ethylene burn was encountered in the Hamlin oranges degreened prior to commercial maturity. The amount of this ethylene burn (numerous dark sunken spots) was directly related to degreening temperature. When immature oranges were degreened, only 2 percent of those at 85° F. were affected with ethylene burn, whereas 50 percent of those degreened at 100° F. suffered from ethylene burn. At 70° F. no ethylene burn was encountered even with immature fruit. With fully mature oranges, no ethylene burn was encountered at any temperature.

The experiments with Hamlins included trials at a constant temperature and high, medium and low humidities. This was repeated at temperatures of 70°, 85°, and 100° F. Humidities employed ranged from 60 percent to 95 percent R. H. No relationship at all was discernible between humidity and rate of degreening. Even fruit that was so badly dessicated as to be unmarketable degreened fully as rapidly as that degreened under medium or high humidity. This confirms the observations of Clark who failed to find any correlation between humidity and rapidity of degreening.

The single experiment with Valencia oranges again indicated that (of the temperatures tried) 85° F. gave the most rapid degreening (see Figure 2). In this experiment, records of losses from stem-end rot and blue mold were kept during subsequent holding at 70° F. for a period of three weeks. Total losses at three weeks were 32%, 28% and 37% for fruit degreened at 75° F., 85° F. and 95° F. respectively.

The results with Marsh grapefruit were much less consistent than those with oranges. However, the existence of an optimum temperature, above or below which degreening is slowed up, is still apparent. But the optimum temperature range is much wider and there is less consistency within any given temperature range than was found with oranges. For this reason, a mathematically calculated "curve of best fit" as shown in Figure 3 was constructed instead of a line joining the actual datum points. This curve indicates that the most rapid degreening is to be expected at about 88° F.

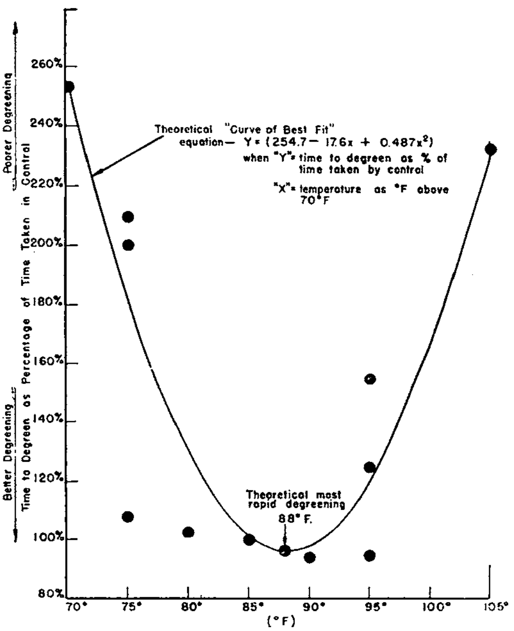

Fig. 3. Effect of Temperature on Rate of Degreening of Marsh Grapefruit.

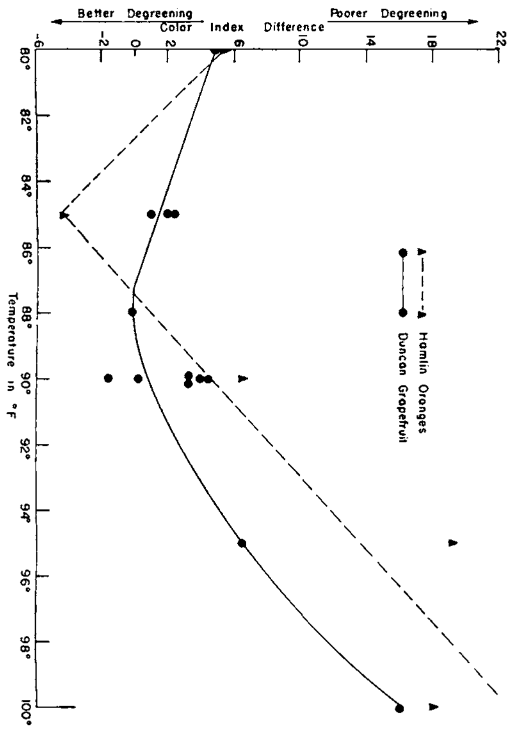

Fig. 4. Degreening 1941-42 from Clark's Data, Plotted by Grierson.

This is of particular interest when these results are compared with those of Clark. Figure 4 shows data from the tables in Clark's report (4) plotted in a manner comparable with the data in Figures 1, 2, and 3. It will be noted that these early studies also indicated a narrow optimum range for oranges, centered on 85° F., and a wide optimum range for grapefruit, centered approximately on 88° F. The grayish color that Clark reported finding with fruit degreened at temperatures above 90° F. was not observed in 1952-53. Shrivelling was, however, more pronounced at temperatures above 90° F. After one degreening trial, using temperatures ranging from 70° F. to 100° F., samples of grapefruit were juiced and the freshly extracted juice submitted to a taste panel. No consistent differences in flavor were noted.

The grapefruits used in these experiments were afterwards held at 70° F. and the losses from stem-end rot and other fungi noted at periodic intervals. Figure 5 shows the relationship between degreening temperatures and the amounts of fungal loss after three weeks subsequent storage at 70° F. Because susceptibility to fungi varied with picking dates all results are expressed as a percentage of the values for control samples degreened at 85° F. Most of the fungal loss encountered was stem-end rot, loss from which ran as high as 53%. Loss from other causes (principally *Penicillium*) never exceeded 4.3%. The tendency for subsequent fungal losses to increase across the range of degreening temperatures from 75° F. to 95° F. appears to be quite consistent. In view of this it is felt that, at present, no recommendation can be made that the maximum degreening temperature for grapefruit should be raised above the present limit of 85° F.

Summary

1. Hamlin and Valencia oranges were found to degreen most rapidly at a temperature of 85° F. Minor variations above or below this temperature caused appreciable slowing up of the degreening process.

2. Optimum degreening temperature for grapefruit was found to be much less sharply defined.

3. When considering rapidity of degreening

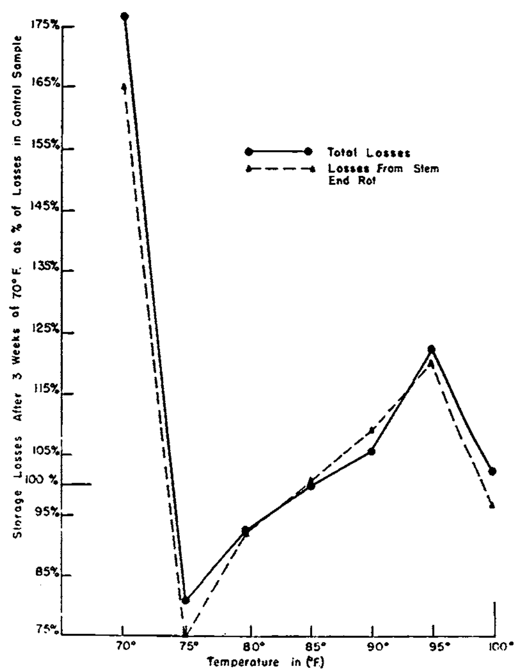

Fig. 5. Losses from Fungi after 3 Weeks at 70° F. in Marsh Grapefruit degreened at Various Temperatures.

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]

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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.