P.e.p.s. and Tri-Basic Copper Sulfate or ziram and ferbam was significantly better than Triton B-1956 and the same fungicides. Thus again, as in the 1951-52 trials, data indicate the interval between spray applications can be lengthened with the addition of a suitable spreader-sticker to the spray mixture.

Of the many new compounds tested, only one, Manzate, controlled early blight as effectively as the fungicides now recommended.

SUMMARY

Early blight of celery caused by *Cercospora apii* has not been important during the months of December and January for the past five years. The failure of the disease to develop was probably due to low rainfall during this period.

In the 1951-52 and 1952-53 seasons the following gave superior early blight control: Tri-Basic Copper Sulfate, Bordeaux Mixture, nabam, Manzate, ferbam, or alternate applications of Tri-Basic Copper Sulfate and ziram and ferbam or alternate applications of Tri-Basic Copper Sulfate and nabam.

Nabam + zinc sulfate was superior to the wettable powder zineb.

The addition of polyethylene polysulfide (P.e.p.s.) to recommended fungicides indicates that the time interval between applications may be extended without affecting disease control.

Three and five nozzles per row provided better spray coverage of the plant foliage than did one nozzle, and better disease control, but no difference was apparent between three and five nozzles per row.

Pink rot increased when only nabam + zinc sulfate was used during the spray schedule.

THE EFFECT OF COPPER ON NITRIFICATION IN SOME FLORIDA SOILS

CHARLES F. ENO
Assistant Soil Microbiologist
Agricultural Experiment Station
Gainesville

During the past few years several reports have been made concerning the accumulation of copper in soils upon which citrus and truck crops are being produced in Florida. Reuther and Smith (6) found concentrations of copper as high as 480 to 640 pounds per acre in old citrus groves in the vicinity of Orlando; while Stewart and Leonard (9) reported 200 to 400 pounds of copper per acre in certain plots at the Citrus Experiment Station, Lake Alfred, Florida. Westgate (10), working with soils in the vicinity of Sanford, found old celery fields which contained 168 to 422 p.p.m. total copper. These concentrations are in striking contrast to that present in the virgin soils of the same areas. Rogers et al. (8) found less than 10 p.p.m. of copper in the virgin soils.

Recently, certain irregularities in plant growth have been correlated with large amounts of copper in the soil. Westgate (10) indicated that high total copper in the soil was associated with iron chlorosis, brown stubby roots, and stunting of sweet corn. He also found that some poor celery seed beds with severe stubby root, which have not responded to soil fumigation, contained as high as 1654 p.p.m. copper in the surface-inch of soil.

Among the several factors which may have an important bearing on the incidence of iron chlorosis in citrus groves, Reuther and Smith (6) stated that excessive accumulation of copper in the soil is probably a major factor and low pH of the soil undoubtedly greatly aggravates the toxicity of this element by increasing its availability. Reuther and Smith (7) showed that a high proportion of the copper applied experimentally to some field fertilizer plots during approximately seven years could be found in the topsoil by total analysis at the end of the period. They stated that accumulation of copper in commercial orchards is the result of the practice, common for more than a decade, of applying mixed fertilizers containing sufficient copper sulfate to add 10 to 25 pounds of copper per acre annually to mature Florida citrus groves. In addition, fungicidal sprays may provide 5 to 15 pounds an acre each year.

Peech (4), Jamison (2), and Lucas (3) found that copper availability is related to soil pH. Jamison believed fixation of copper in acid soils must be due to the formation of slowly soluble organic compounds, and when

Florida Agr. Exp. Sta. Journal Series, No. 206.

the pH is 6.0 or above, copper fixation can be due, in part, to the precipitation of basic copper compounds. Lucas, working with organic soils, stated that the reactions of copper in soils more acid than pH 4.7 are with the exchange complex and in soils less acid than 4.7 some of the copper is precipitated as the hydroxide; other exchange reactions account for the remainder.

Quastel and Scholefield (5) demonstrated that copper inhibits nitrification above certain minimal levels, depending on the soil used. They found the inhibition greater in a synthetic mineral colloid soil than in a true solution containing organic matter. They presumed that organic compounds bound copper in chelate-type complexes, removing it from action. Quastel and Scholefield also found that soil made copper deficient by treatment with sodium diethyldithiocarbamate had a low nitrifying power. Addition of copper to such a deficient soil restored nitrification, suggesting that copper is an essential element in this process.

Nitrification is an important process in the production of citrus and vegetable crops. Ammoniacal, as well as organic, sources of nitrogen are commonly used in the fertilization of these crops. Both must be nitrified for efficient nitrogen uptake, since most plants obtain a large amount of their nitrogen in the nitrate form. An evaluation of the effect of copper on nitrification in several soils containing various amounts of copper is reported herein.

Experimental Procedure

Bulk soil samples containing various amounts of copper were obtained from citrus groves in the vicinity of Orlando and Lake Alfred, Florida, and from truck farming areas in the vicinity of Sanford, Florida. In order to preserve the activity of the microorganisms, the soil was not permitted to become air-dry at any time. A five millimeter screen was used to remove extraneous materials from the soil. Pint milk bottles, with vented caps, were used for containers in the nitrification study. Triplicate 150-gram aliquots of soil were used for each level of lime and copper. Copper levels were as found in the field and, on virgin soil, copper (as copper sulfate) was added in various amounts up to 2000 pounds per acre. Lime (precipitated chalk) additions were made at rates equivalent to 0, 1, and 3 tons per acre. Thirty milligrams of nitrogen, as ammonium sulfate, were added to each 100 grams of soil. Moisture was adjusted to one-half the water-holding capacity of the soil. The soils were thoroughly mixed after all additions had been made. All soils were incubated at 28 degrees Centigrade for 28 days. Nitrate nitrogen was determined by the phenoldisulfonic acid method (1).

Results

Leon fine sand and related soils obtained in the vicinity of Sanford, Florida.

Table 1 contains the nitrification data on 8 soils upon which vegetable crops are produced. These soils contained from 100 to 1660 pounds of copper per acre. They nitrified satisfactorily at all lime levels. Soils 1 and 2 produced the least amount of nitrate when no lime was added. Nitrate production was not related to the amount of copper present in the soil. Most soils showed a direct relationship between amount of lime added and nitrate production.

TABLE 1.

THE EFFECT OF COPPER AND LIME ON NITRIFICATION IN LEON FINE SAND AND RELATED SOILS.

Soil No.	No. 3		No. 2		No. 1		No. 8		No. 9		No. 4		No. 7		No. 6	
Lime Tons/A.	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH
0	416	4.0	172	4.4	144	4.5	277	4.5	349	4.7	272	4.2	282	5.3	462	5.2
1	474	4.9	493	4.7	344	4.6	471	4.5	474	5.4	463	4.4	488	5.7	428	5.9
3	515	6.2	525	7.1	520	6.5	557	6.4	491	6.7	413	5.6	423	6.1	367	6.1
Copper Lbs/A.	100		220		300		300		340		480		820		1660	
Initial pH	6.0		6.0		5.4		6.3		7.0		5.7		7.5		7.0	

Nitrification in virgin Leon fine sand was much less than in the related cultivated soils (Fig. 1 and Table 4). The virgin soil pro-

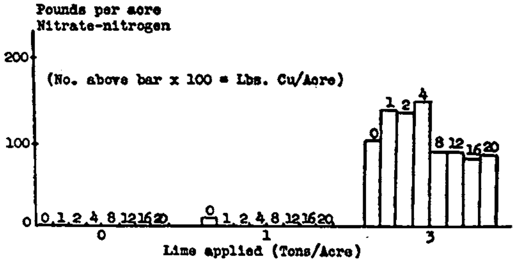

Fig. 1. The effect of copper and lime on nitrification in Leon fine sand (virgin).

duced no detectable nitrate without lime and only 10 pounds at the 1-ton lime level without added copper. At the 3-ton level, nitrification proceeded at a fair rate and appeared to be slightly stimulated by the 100-, 200-, and 400-pound-per-acre applications of copper. Higher copper rates slightly depressed nitrification.

Lakeland fine sand soils obtained at the Citrus Experiment Station, Lake Alfred, Florida.

Table 2 contains the nitrification data for Lakeland fine sand. All soils except 9-8 and 9-6 nitrified satisfactorily; of these two soils, 9-6 responded to lime applications. Apparently factors related to the initial soil pH of 4.1 were the primary cause of its low rate of nitrification at all levels of lime. Soil from plot 9-8 did not respond to any of the lime applications. This plot has had no pH control and as a result it has been in an acid state for several years. Apparently the nitrifiers were almost entirely absent or, if present, they were ineffective. Probably a year or two after an application of lime this soil would nitrify satisfactorily under field conditions.

The virgin Lakeland fine sand responded in several ways to lime and copper additions, as shown in Fig. 2 and Table 4. Where no lime was applied, copper reduced nitrification substantially. One ton of lime increased nitrification and 200 pounds of copper appeared to be slightly stimulatory. When 400 or more pounds of copper were applied, nitrification was decreased. Practically no nitrification occurred at 2000 pounds per acre level of copper. Nitrate production was drastically reduced by copper at 1200, 1600, and 2000 pounds per acre when 3 tons of lime were applied. With lime additions, certain of the low levels of copper apparently stimulated nitrification in Lakeland fine sand.

TABLE 4.

THE EFFECT OF COPPER AND LIME ON NITRIFICATION IN VIRGIN SOILS.

Copper Lbs./A.	0		100		200		400		800		1200		1600		2000	
Lime Tons/A.	NO_3-N: Lbs./A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH	NO_3-N: Lbs/A.	Final pH
Lakeland Fine Sand (1)																
0	56	4.8	33	4.9	24	4.9	10	4.7	3	4.4	4	4.3	3	4.2	3	4.2
1	167	6.1	157	5.9	205	5.8	134	6.1	68	6.5	71	6.2	121	6.5	14	5.9
3	343	7.4	344	7.1	296	7.3	377	7.2	269	6.9	121	7.4	130	7.4	75	7.7
Leon Fine Sand (2)																
0	0	4.5	0	4.5	0	4.5	0	4.2	0	3.9	0	3.7	0	3.6	0	3.6
1	10	5.3	0	5.7	2	5.9	0	5.5	0	5.5	0	5.6	0	5.3	0	5.2
3	103	7.0	118	6.4	115	6.8	148	6.6	88	6.8	89	6.8	80	6.7	85	6.7
Orlando Fine Sand (3)																
0	3	4.7	4	4.7	4	4.5	4	4.4	4	4.1	5	3.8	10	4.1		
1	29	5.7	21	5.8	31	5.7	24	5.9	21	5.5	9	5.3	16	6.2		
3	350	6.1	330	6.1	330	6.2	303	6.5	250	6.3	250	6.2	132	6.7		
Blanton Fine Sand (4)																
0	7	4.3	8	4.2	6	4.1	8	4.0	8	3.7	8	3.5				
1	75	4.9	70	5.1	55	5.3	32	5.6	35	5.8	21	5.4				
3	462	5.6	465	5.9	434	5.8	318	6.4	334	6.2	314	6.2				

Initial pH: (1) 5.6; (2) 5.3; (3) 5.5; (4) 4.8.

TABLE 2.

THE EFFECT OF COPPER AND LIME ON NITRIFICATION IN LAKELAND FINE SAND.

Soil No.	No. 9-6		No. 17-17		No. 17-2		No. 5-1A		No. 5-1B		No. 9-8		No. 9-4	
Lime Tons/A.	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH
0	6	4.3	118	5.2	154	5.0	91	4.9	454	4.9	6	4.1	286	4.8
1	30	6.4	270	5.2	267	5.2	347	5.2	515	5.7	10	7.2	372	5.4
3	202	6.5	426	6.1	317	6.0	544	6.2	525	6.1	13	7.5	433	5.8
Copper Lbs/A.	5		116		203		250		252		280		450	
Initial pH	4.1		5.0		5.1		4.9		5.7		4.3		4.9	

Orlando and Blanton fine sand obtained in the vicinity of Orlando, Florida.

Data in Table 3 show no relationship between nitrate production and the copper content of these cultivated soils. Nitrification, without the addition of lime, in the case of soil 1 was low; this no doubt was a result of the low initial reaction and was corrected by the addition of lime.

Virgin Orlando fine sand nitrified very little without lime (Fig. 3 and Table 4). When 1 ton of lime was applied, the 1200- and 1600-pound per acre rates of copper decreased nitrate production by one-half or more. At 3 tons of lime per acre all levels of copper decreased nitrification. Especially drastic were the 800-, 1200-, and 1600-pound-per-acre rates. Blanton fine sand produced essentially no nitrate without lime, as indicated in Fig. 4 and Table 4. At the 1- and 3-ton levels of lime, the 400-, 800-, and 1200-pound rates of copper reduced nitrification by as much as 50 percent.

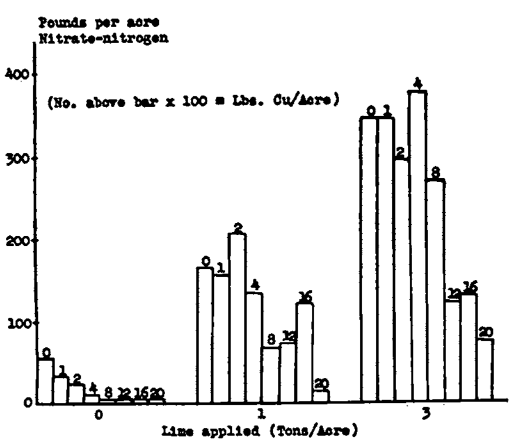

Fig. 2. The effect of copper and lime on nitrification in Lakeland fine sand (virgin).

TABLE 3.

THE EFFECT OF COPPER AND LIME ON NITRIFICATION IN BLANTON AND ORLANDO FINE SANDS.

	Blanton		Orlando-1		Orlando-2	
Lime Tons/A.	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH	NO_3-N Lbs/A.	Final pH
0	606	5.8	109	4.5	599	5.5
1	594	6.4	479	4.5	532	6.2
3	613	6.7	671	5.6	619	6.6
Copper Lbs/A.	100		360		720	
Initial pH	6.9		4.5		6.8	

Discussion

In cultivated soils containing various amounts of copper, in which the pH had been maintained between approximately 5.0 and 7.0, nitrification proceeded at a satisfactory rate. Among the cultivated sandy soils studied, copper did not appear to be limiting nitrate production. Nitrate production was closely related to soil reaction.

The virgin soils provided an insight into the action of copper in respect to nitrification. In the case of the Lakeland soil, where lime was not applied and the soil was already quite acid, nitrification was seriously inhibited by copper. With the addition of 3 tons of lime, copper up to 800 pounds per acre did not greatly affect nitrification; larger amounts inhibited the process. When 3 tons of lime were applied to Leon fine sand, levels of copper up to 400 pounds per acre stimulated nitrification, while higher rates tended to depress the process slightly.

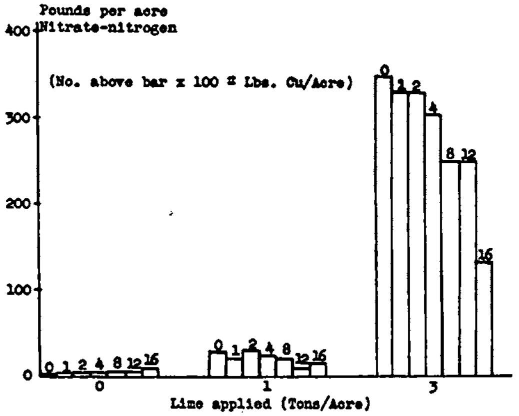

Fig. 3. The effect of copper and lime on nitrification in Orlando fine sand (virgin).

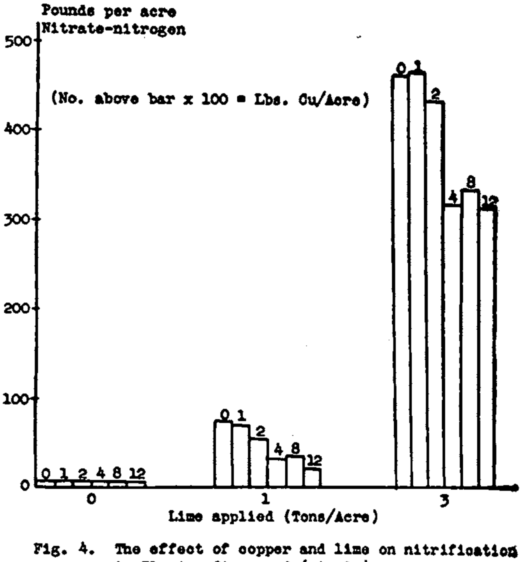

Fig. 4. The effect of copper and lime on nitrification in Blanton fine sand (virgin).

The variation in nitrification in virgin soils relative to copper is, in general, evidence in support of the work by Quastel and Scholefield (5), who obtained both a stimulation and a depression of nitrification with copper. The level at which copper stimulates or depresses nitrification is probably dependent upon many soil factors, one of which is the pH range over which nitrification occurs in a particular soil. Thus in the case of the virgin Lakeland soil, nitrification was greatly reduced by all levels of copper when no lime was applied; whereas, only the larger applications reduced it after liming. Availability of copper relative to pH probably caused this variation in response. In the case of the virgin Blanton and Orlando soils, none of the copper levels increased nitrification. Perhaps 100 pounds of copper per acre was sufficient to cause toxicity.

The fact that cultivated soils with as much as 1660 pounds of copper per acre nitrified. very satisfactorily indicates that copper is not as effective in reducing nitrate production in these soils as it is in virgin soil. Possibly cultivation and the slow build-up of copper caused it to be fixed in a relatively unavailable form and also permitted the nitrifiers to become more resistant to its action. In addition, as a result of normal leaching, the cultivated soils accumulated very little sulfate compared to the amount present in the virgin soils after treatment with copper sulfate. Sulfate at the higher copper levels may have been a factor in decreasing the production of nitrates. At what level copper depresses nitrification in these cultivated soils is not known. Certainly, the maintenance of a pH above 5.0 will do much to prevent the presence of sufficient copper in solution to be toxic to the nitrifiers.

Summary

Nitrification studies, conducted to evaluate the effect of copper on nitrate production, were made on virgin Leon, Lakeland, Blanton, and Orlando fine sands, and several related cultivated soils.

Nitrification was satisfactory in all cultivated soils except one, despite the fact that they contained from 100 to 1660 pounds of copper per acre. One soil from an experimental plot at the Citrus Station failed to nitrify. This was probably caused by the acid condition in which this soil has been for several years. As a consequence, the nitrifiers were either essentially non-existent or ineffective.

Nitrification in virgin Lakeland fine sand without lime was decreased by all copper levels. At the 1- and 3-ton levels copper up to 400 pounds per acre showed a tendency to increase nitrification; while 800 or more pounds of copper per acre reduced it. Virgin Leon fine sand nitrified at the 3-ton level only, and copper rates up to 400 pounds per acre increased nitrification; all higher rates caused a decrease. Virgin Blanton and Orlando fine sands produced essentially no nitrate when

lime was not added and, in general, copper decreased nitrification at the 1- and 3-ton per acre levels of lime.

One or more of several conditions may explain the difference in response to copper between virgin and cultivated soils. Copper has been accumulating gradually in the cultivated soils and a large portion of the sulfate probably has leached from the soil. The gradual accumulation of copper may have promoted fixation of copper in an unavailable form. The nitrifying population may have become more tolerant to copper over a period of years. All these conditions are in contrast to the application of all the copper at one time to the virgin soils and the retention of all of the sulfate. Little time occurred for a possible build-up of copper resistance by the nitrifiers in the virgin soils.

At what level copper becomes toxic to the nitrifiers in these cultivated soils cannot be ascertained from this study. The maintenance of a pH above about 5.0 will do much to prevent the presence of sufficient copper in solution to become toxic to the nitrifiers.

ACKNOWLEDGEMENT

The author takes this opportunity to express his appreciation to Mr. Paul H. Everett for his part in the laboratory work and to Dr. Walter Reuther, Dr. Ivan Stewart, Dr. C. D. Leonard, and Dr. Philip J. Westgate for providing the data on the copper content of soils from their respective areas.

LITERATURE CITED

1. Harper, H. J. The accurate determination of nitrogen in soil. Jour. Ind. Eng. Chem. 16: 180-185. 1924.

2. Jamison, Vernon C. Adsorption and fixation of copper in some sandy soils of Central Florida. Soil Sci. 53: 287-297. 1942.

3. Lucas, Robert E. Chemical and physical behavior of copper in organic soils. Soil Sci. 66: 119-129. 1948.

4. Peech, Michael. Availability of ions in light sandy soils as affected by reaction. Soil Sci. 51: 473-486. 1941.

5. Quastel, J. H., and Scholefield, P. G. Biochemistry of nitrification in soil. Bact. Revs. 15: 1-53. 1951.

6. Reuther, Walter, and Paul F. Smith. Iron Chlorosis in Florida citrus groves in relation to certain soil characteristics. Fla. State Hort. Soc. 62-69. 1952.

7. ———, ———, ——— ———. Effects of high copper content of sandy soils on growth of citrus seedlings. Soil Sci. 75: 219-224. 1953.

8. Rogers, L. H., et al. Distribution of macro and micro elements in some soils of peninsular Florida. Fla. Agr. Exp. Sta. Bul. 341: 1-31. 1939.

9. Stewart, Ivan, and C. D. Leonard. Iron Chlorosis —Its possible causes and control. Citrus Magazine, June 1952, pp. 22-25.

10. Westgate, Philip J. Preliminary report on copper toxicity and iron chlorosis in old vegetable fields. Fla. State Hort. Soc. 143-146. 1952.

FRUIT AND VEGETABLE MARKETING IN EUROPE

F. S. JAMISON
Horticulturist
Florida Agricultural Experiment Station
Gainesville

Fresh fruit and vegetables are expensive for the average worker in most European countries, not because the produce is so high-priced but because the average worker receives very low wages. Thus this relatively high price means that the per capita consumption is decidedly lower than in the United States. Not only is fresh produce high in price, but canned fruits and vegetables are even higher in price and consequently are little used.

We in the United States can be quite thankful that, for the present, at least, we are producing and merchandising fruits and vegetables that can be afforded by most workers. There are a number of reasons for the difference but probably the most important one is the small-scale production units that exist in Europe. A big vegetable farm is one of six or seven acres, a good-sized orchard of apples, pears, peaches or citrus will seldom be over 10 acres in size, and most are less than one-half this size. Each of these production units supports a family with an adequate to good living—that is, a good house, clothes and food —but there is no car, tractor, refrigerator, or washing machine. The farm is operated usually by the family. Power farm equipment would be of little value except that it might reduce the number of hours of work required; it would not increase the total output or reduce the cost of production.

These small-scale units affect production in many ways. We expected to see small production units, but we thought the culture of the crop would be excellent. This is not true. Farmers in general have either not had the advantage of a good extension system or, where a good extension system is available, it is not backed by the proper type of research facilities