EFFECTS OF NITROGEN AND POTASSIUM FERTILIZATION ON PERSIAN LIMES ON LAKELAND FINE SAND

T. W. Young
University of Florida, IFAS
Sub-Tropical Experiment Station
Homestead

Robert C. J. Koo
University of Florida, IFAS
Citrus Experiment Station
Lake Alfred

ABSTRACT

Mature Persian lime trees on Lakeland fine sand were fertilized for three crop years with three levels each of nitrogen and potassium in factorial combinations. Yields increased with an increase in either nitrogen or potassium up to the maximum levels, with highest yield where both elements were used at maximum levels. Juice content, soluble solids and acid increased with increased nitrogen fertilization. Increased potassium resulted in some increase in acid. Foliage color and density improved with increasing nitrogen fertilization. Calcium and magnesium levels in leaves decreased as potassium fertilization increased, but the decrease was not sufficient to cause deficiency symptoms.

INTRODUCTION

While a tremendous amount of research has been devoted to citrus nutrition, little attention has been given Persian (Tahiti) limes in Florida. The fertilization of limes has, for the most part, followed practices used for other citrus, as modified by grower trial and error. The major portion of the lime crop is harvested during summer and fall in Florida, but some fruit can be picked every month in the year, as compared with a relatively short blooming and harvest season for most orange and grapefruit varieties. Furthermore, maturity standards for limes are quite different from those for citrus such as oranges and grapefruit. This everbearing habit of limes and their particular maturity standards suggest that more effective fertilization of limes might be developed through systematic investigation.

Working with limes on Rockdale soil Goldweber et al (1) found that increased nitrogen fertilization increased the number of fruits, total yield, juice, soluble solids and acid, but had no effect on weight of individual fruits. Increasing nitrogen also resulted in increased tree growth and improved leaf color. The effect of phosphorus was inconclusive. Yields decreased where potassium was omitted from the fertilizer.

Further studies with limes on Rockdale soil (3) showed that side dressings of potassium nitrate and Uramon increased yields, whereas ammonium sulphate decreased yields. In this investigation, it was found that the natural organic sources of nitrogen were not measurably better for limes than chemical sources. Fertilization at intervals of 60 days was recommended for best results.

It was found that limes on Rockdale soil did well on a relatively low but uniform supply of phosphorus (4).

Although most of the limes grown in Florida are produced on Rockdale soil in Dade County, there is significant production of limes on the sandy and loamy soils in warmer sections of the state. No research had been done on lime nutrition on these sands and loams. An experiment with three rates each of nitrogen and potassium was started in a bearing lime grove near Lake Placid in 1963. This paper reports data obtained between 1964 and 1967.
MATERIALS AND METHODS

At the beginning of this experiment in October 1963, the trees were approximately 10 years old. They were on rough lemon root and planted at 20 by 30 feet. The soil was Lakeland fine sand. The soil pH was maintained between 6.0 and 6.7, with extractable calcium around 600 pounds per acre six inches and magnesium around 75 pounds with annual applications of dolomite. The grove was equipped with solid-set, low volume, overhead irrigation. Adequate moisture was maintained, as far as could be determined by tree condition.

Although serious cold did not occur in this grove during the period this experiment was in progress, the irrigation system was used a few times for cold protection. There was no cold damage to trees, bloom or fruit.

Lime bark disease, with perhaps some blotch, was found throughout the experimental block. Trees used for differential fertilizer treatments in the experiment, however, were as free of the trouble as could be ascertained by normal inspection. There also was some variation in tree size in the experimental area. In laying out the plots, a selective randomization was used so as to have trees of relatively uniform size and vigor among the plots.

Three levels each of nitrogen and potash were used in factorial combination, with other fertilizer elements held constant. The four-tree plots were replicated four times in randomized blocks and completely buffered on all sides.

The total nitrogen rates for the crop year were 1.5 (N₁), 3.2 (N₂) and 4.9 (N₃) pounds per tree; potash rates were 1.4 (K₁), 3.1 (K₂) and 4.7 (K₃) pounds, with each tree receiving phosphorus and magnesium at 0.34 pound P₂O₅ and 0.54 pound of MgO. The low rates of nitrogen and potash, together with phosphorus and magnesium, were applied in a mixed fertilizer by distributor over the entire area. The intermediate and high rates of nitrogen and potash were applied as supplements with ammonium nitrate and muriate of potash spread from tree to tree by hand. These applications were made in fall, winter and spring at rates so as to supply the three levels each of nitrogen and potash in approximately equal amounts each time. The initial experimental fertilization was in October 1963 and the final one in October 1966. Thus, three full crop years, with harvests from mid-spring through late winter, were included well within these treatment limits.

Six pickings were made on the plots each year. Yields were obtained for individual plots to the nearest one-tenth of a field box (1.25 bu.).

Fruit quality studies were made in 1964, 1965, 1966 and 1967 on fruit samples taken in late spring or early summer. Leaf analyses were made in 1964, 1965 and 1966 on spring-flush leaves collected in early fall. Collections and analytical methods for fruit and leaf samples were essentially those described by Koo, et al. (2).

A visual rating of general tree condition, based on foliage color and density, was made in December 1966. In rating, chlorosis or sparse foliage obviously caused by lime bark disease or blotch was discounted. Two observations were made on each tree; one on the east side in the morning and one on the west side in the afternoon, when light was most favorable from each direction.

By late summer of 1966, several trees in the plots were out of production from lime bark disease. Several others were starting to decline noticeably from the trouble. There was no relationship between the decline and experimental treatments. Because of increase in rate of the decline, harvest data were not taken after the 1966 crop year, and the experiment was concluded with collection of fruit samples in May 1967.

RESULTS

Yield.—Yields for the three years are summarized in Table 1. There was a definite trend towards increased yield with increased nitrogen and potassium fertilization in 1964 and 1965, but variations among plots under the same treatment were great and the effects were not significant. These variations decreased with time, apparently being reduced by the treatment effects. By the third year (1966) the increase in yield with an increase in nitrogen and potassium was highly significant.

Fruit Quality.—The main effects on fruit quality of the treatments are shown in Table 2. The fruits taken for quality study were all 1% inches or larger in diameter, in accordance with established size standards, and averaged about 2 inches in diameter in all treatments. There was no measurable difference in size among treatments for the samples taken, as might have
Table 1. Main effect means of nitrogen and potassium fertilization on yield of Persian limes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>5.18</td>
<td>7.66</td>
<td>9.22</td>
</tr>
<tr>
<td>N2</td>
<td>5.20</td>
<td>8.03</td>
<td>10.17</td>
</tr>
<tr>
<td>N3</td>
<td>5.55</td>
<td>8.54</td>
<td>11.45</td>
</tr>
<tr>
<td>Fa</td>
<td>N.S.</td>
<td>N.S.</td>
<td>**</td>
</tr>
<tr>
<td>K1</td>
<td>4.87</td>
<td>7.64</td>
<td>9.41</td>
</tr>
<tr>
<td>K2</td>
<td>5.55</td>
<td>8.11</td>
<td>10.12</td>
</tr>
<tr>
<td>K3</td>
<td>5.50</td>
<td>8.47</td>
<td>11.32</td>
</tr>
<tr>
<td>Fa</td>
<td>N.S.</td>
<td>N.S.</td>
<td>**</td>
</tr>
</tbody>
</table>

* N.S. differences between means not significant
**F significant at 1%

been the case if sampling had been completely at random with respect to size. Neither did the treatment have a significant effect on weight of individual fruits. Peel thickness increased significantly with increased nitrogen fertilization in 1966, but decreased in 1967. Potassium had no effect on peel thickness.

Percentage juice by weight was taken in 1964, 1965, 1966 and 1967. However, the industry approved standard of maturity is based on percentage juice by volume, and this value also was obtained in 1966 and 1967. The relationship between average percentage juice on weight and on volume basis was rather constant at a ratio of around 50:47. As nitrogen fertilization increased, there was a significant increase in percentage juice, by weight and by volume, in 1966 and 1967. Soluble solids and acid both increased with increased nitrogen fertilization. The only significant effect of potassium on internal quality was an increase in acid with increased potassium fertilization in one out of the four years.

Leaf Analyses.—The main effects of the treatments on chemical composition of leaves are shown in Table 3. The nitrogen content of leaves increased with increased nitrogen fertilization, which in turn reduced the phosphorus and potassium contents. There was no measurable effect on leaf calcium or magnesium. Increasing potassium fertilization had no effect on leaf nitrogen or phosphorus, but significantly increased leaf potassium and decreased both calcium and magnesium contents.

Tree Condition.—The color of the leaves and density of the foliage improved with increased nitrogen fertilization (Table 3). Potassium had no effect on leaf color. While the difference was not statistically significant, there was a slight trend towards heavier foliation with increased potassium fertilization.

**Discussion**

Since there was a consistent increase in yield with an increase in both nitrogen and potassium fertilization, up to the maximum used in this experiment, it is evident that the point of diminishing returns for either element was not exceeded. For the 1966 crop, the maximum rate of both nitrogen and potash for the year amounted to slightly over 0.4 pound each per 1.25 bushel box of fruit harvested. This is as much or more than is recommended for a 2.2 bushel box of oranges or grapefruit (5). On an acre basis, 250 pounds per year for both nitrogen and potash is the maximum recommended for citrus in general. The maximum annual rate of nitrogen and potash in this experiment each amounted to about 380 pounds per acre. Therefore, as compared with citrus in general, nitrogen and potassium requirements for maximum yield of limes on deep, sandy soil is quite high.

The general condition of the trees improved with increasing nitrogen. A leaf nitrogen level of somewhat over 2.5% gave the darkest green and most dense foliage. Although the absorption of magnesium and calcium decreased with increasing potassium fertilization, the effect was not sufficient to cause deficiency symptoms. In fact, the condition of trees receiving high potassium fertilization, which gave a leaf potassium content of 1.54%, appeared slightly better than those at the low rate with leaf potassium at 1.14%.

Another bonus resulting from increased nitrogen and potassium fertilization, primarily from nitrogen, was improvement in internal fruit quality. Juice, soluble solids and acid all increased with increased nitrogen. Increasing potassium also gave some increase in acid. This increase in juice is quite important because, at the low nitrogen and potassium rates, the per-
Table 2. Main effect means of nitrogen and potassium fertilization on external and internal quality of Persian limes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% N</th>
<th>% K</th>
<th>% Juice (wt.)</th>
<th>% Juice (vol.)</th>
<th>Soluble solids (%)</th>
<th>Acid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N&lt;sub&gt;1&lt;/sub&gt;</td>
<td>2.00</td>
<td>75</td>
<td>2.95</td>
<td>43.7</td>
<td>40.7</td>
<td>8.74</td>
</tr>
<tr>
<td>N&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2.00</td>
<td>77</td>
<td>2.93</td>
<td>44.5</td>
<td>42.3</td>
<td>8.90</td>
</tr>
<tr>
<td>N&lt;sub&gt;3&lt;/sub&gt;</td>
<td>1.99</td>
<td>76</td>
<td>3.07</td>
<td>45.3</td>
<td>43.1</td>
<td>8.98</td>
</tr>
<tr>
<td>F&lt;sup&gt;c&lt;/sup&gt;</td>
<td>N.S.</td>
<td>N.S.</td>
<td>**2/2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>*1/4&lt;sup&gt;1/4&lt;/sup&gt;</td>
<td>*1/2&lt;sup&gt;1/4&lt;/sup&gt;</td>
<td>**2/4&lt;sup&gt;1/2&lt;/sup&gt;</td>
</tr>
<tr>
<td>K&lt;sub&gt;1&lt;/sub&gt;</td>
<td>1.99</td>
<td>76</td>
<td>2.99</td>
<td>44.7</td>
<td>41.8</td>
<td>8.87</td>
</tr>
<tr>
<td>K&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2.00</td>
<td>75</td>
<td>2.99</td>
<td>44.5</td>
<td>42.0</td>
<td>8.90</td>
</tr>
<tr>
<td>K&lt;sub&gt;3&lt;/sub&gt;</td>
<td>2.02</td>
<td>77</td>
<td>2.98</td>
<td>44.5</td>
<td>42.3</td>
<td>8.94</td>
</tr>
<tr>
<td>F&lt;sup&gt;c&lt;/sup&gt;</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

- **a** data for 1964, 1965, 1966 and 1967
- **b** data for 1966 and 1967
- **c** N.S. differences between means not significant
- **d** significant 2 years out of 2, etc.

Percentage juice did not average up to the 42% by volume standard required for fresh fruit. Soluble solids are not highly important in limes, but the juice and acid percentages are, the latter especially for fruit to be processed for "concentrate".

Based on yield, leaf analysis and tree condition, trees receiving the maximum rates of nitrogen and potassium in this experiment were not over fertilized, even though rates of application were considerably above those found ample for oranges and grapefruit (5). This may have been due to the difference in growing and fruiting habits of limes as compared with oranges and grapefruit. Also, the experimental block was adequately irrigated, so the trees...
Table 3. Main effect means of nitrogen and potassium fertilization on leaf analyses and tree condition of Persian limes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Chemical composition of spring-flush leaves collected in late summer (average for 1964, 1965 and 1966)</th>
<th>Tree Condition rating - 1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent Dry Weight</td>
<td>Foliation color</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>$N_1$</td>
<td>2.25</td>
<td>0.168</td>
</tr>
<tr>
<td>$N_2$</td>
<td>2.48</td>
<td>0.163</td>
</tr>
<tr>
<td>$N_3$</td>
<td>2.59</td>
<td>0.153</td>
</tr>
<tr>
<td>$F^a$</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>$K_1$</td>
<td>2.44</td>
<td>0.159</td>
</tr>
<tr>
<td>$K_2$</td>
<td>2.48</td>
<td>0.167</td>
</tr>
<tr>
<td>$K_3$</td>
<td>2.43</td>
<td>0.159</td>
</tr>
<tr>
<td>$F^a$</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

*a N.S. differences between means not significant

*F significant at 5%

**F significant at 1%

b tree condition rating 1 to 10 = poor to good

could utilize heavy applications of fertilizer to an advantage.

Results of these nitrogen and potassium fertilizer trials on acid sand were in good general agreement, for the most part, with those reported on Rockdale soil (1).

Such heavy fertilization of limes appears to be economically justifiable. For example, after the treatments became measurably effective in the second and third years (1965 and 1966), the best yield was from the maximum amounts of both nitrogen and potassium ($N_3K_3$). This treatment supplied a total of 4.9 pounds of nitrogen and 4.7 pounds of potash per tree per year, and produced a yearly average of 10.95 boxes (1.25 bu. box) of fruit per tree. The medium rate of fertilization ($N_2K_2$) supplied 3.2 pounds of nitrogen and 3.1 pounds of potash, and produced a yearly average of 9.13 boxes per tree. It required 5.1 pounds of ammonium nitrate and 2.7 pounds of muriate of potash per tree per year, at a cost of about 4c and 3c a pound, respectively, to bring the nitrogen and potash levels up from the medium rates to the...
high rates. Thus, the cost of the supplemental materials, which produced an additional 1.82 boxes of fruit per tree each year, amounted to about 28c per tree per year, or about 15c a box for the extra fruit. Since these amounts of nitrogen and potash could be included readily in the fertilizer mixtures, there would be no additional cost for application, and production cost of the extra fruit would be only that of the extra nitrogen and potash. The medium rates of nitrogen and potassium fertilization produced an average of 0.98 box more fruit than the low rates each year for the two years, at an annual cost of 29c a box for the extra fertilizer. The high rates produced an average of 2.8 boxes more per year than the low rates, at a cost of 20c a box each year for the extra fertilizer.

ACKNOWLEDGEMENTS

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LITERATURE CITED


ROOT-KNOT NEMATODE POPULATIONS ON PEACHES IN FLORIDA

R. H. Sharpe
Department of Fruit Crops
University of Florida
Gainesville

V. G. Perry
Department of Entomology
University of Florida
Gainesville

ABSTRACT

Historical notes show that peach root-knot nematode problems were serious in Florida before 1888. The reaction of 'S-37', 'Rancho Resistant', 'Okinawa', 'Nemaguard', and 'Elberta' stocks have been studied since 1948 with the conclusion that Meloidogyne javanica and M. incognita are of widespread occurrence in central Florida. Serious infections of 'Nemaguard' and 'Okinawa' have been recently discovered by a species of Meloidogyne not yet identified.

INTRODUCTION

The most serious root problems encountered in peaches in Florida have been attacks by root-knot nematodes of the genus Meloidogyne. Commercial production in the sandy soils of central Florida would hardly be feasible without rootstocks resistant to the most commonly occurring species. In heavier soils of north Florida, peaches can be grown fairly well on common rootstocks but several problem areas have been noted. This paper presents observations on rootstocks that have been used for peaches in Florida and a few notes on possible future problems with root-knot nematodes.

HISTORICAL NOTES AND STOCK REACTIONS

The first Proceedings of the Florida State Horticultural Society (3) discussed the severity of root-knot and its widespread occurrence on