SWEET LIME, ITS PERFORMANCE AND POTENTIAL AS A ROOTSTOCK IN FLORIDA

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ABSTRACT

The current decline of many trees on rough lemon, Florida's major rootstock, suggests the need for an alternate stock. A review of the world literature on rootstocks and data obtained in Florida, indicate sweet lime, (C. limettioides Tan.), has many of the same basic advantages as rough lemon. It is deeply rooted and as well or better adapted to sandy soils. Trees on sweet lime are large, yield well and produce large fruit if budwood free of damaging viruses, such as xyloporosis and exocortis, is used. Like rough lemon, they also have lower juice quality and less resistance to cold than trees on sour orange. Certain combinations on sweet lime are susceptible to damage by tristeza, but less so than sour orange.

Knowledge of this rootstock is imperfect and its use would involve some risk. This is true, however, of other stocks and rough lemon itself. Choice of sweet lime would appear reasonable in some cases, particularly on the deep sands of central Florida.

INTRODUCTION

Many trees of sweet orange, Citrus sinensis (L.) Osbeck, have declined in recent years, leading to the names of “young tree decline” and “sand hill decline.” The cause of this disorder is unknown. It might better be called “rough lemon decline” because rough lemon rootstock, C. jambhiri Lush., appears to be implicated.

This decline is of great concern to citrus producers because rough lemon has long been the basic rootstock for Florida's sandy soils. Camp (3) reported in 1940 that the adequate fruit quality, ease of handling and greatly superior yields of trees on rough lemon gave it an advantage over all other rootstocks tried to that date on sandy soils. This has remained true until the present and it is only the decline of trees on rough lemon that has now made its use questionable and the search for an alternate rootstock appropriate.

Unfortunately, there are only partially tested alternative stocks. It is the purpose of this report to review the status of the sweet lime, C. limettioides Tan., as a possible replacement for rough lemon, based on results published in the literature and recent experimental data.

MATERIALS AND METHODS

Review of literature.—A comprehensive review of the world literature on the sweet lime and its use as a rootstock was conducted. Information has been extracted from the literature and presented with new data for comparison and discussion.

New data.—Data on the depth of rooting and mineral content of leaves of trees on sweet lime, rough lemon and sour orange were obtained from a previously described experiment (20) and are presented in Tables 1 and 5. Data on the influence of rootstock on cold hardiness were obtained from a young rootstock planting at Gainesville and are presented in Table 4.

RESULTS AND DISCUSSION

Nomenclature and description.—The sweet lime (C. limettioides Tan.) is distinct from the acid limes (C. aurantifolia Swing. and C. latifolia Tan.). The sweet lime is sometimes called the Indian sweet lime but more commonly Palestine sweet lime. The 'Columbian' sweet lime is a clonal selection that appears indistinguishable from seedling sources. Sweet lime is often incorrectly called sweet lemon but it is distinct from true sweet lemon (C. limetta Risso.). The floral biology has been well described by Singh and Dhuria (32). They reported that sweet lime flowers only in the spring of the year and produces a single annual crop, unlike acid limes which flower more or less continuously. A sample of 50 sweet lime fruit from a tree in the variety collection at Gainesville contained an average of 14 and a range of 10 to 16 highly polyembryonic seeds per fruit following open pollination. The fruit is slightly larger and rounded than the 'Tahiti' lime which it resembles somewhat.

Bud union.—Mendel (21) presented a classical study of the anatomy of the bud union of 'Sham-outi' sweet orange on sweet lime. He did not report any abnormalities. Other reports from Israel
Table 1. Mean tree height, depth of rooting, yield, fruit size and fruit quality of 'Orlando' tangelo on 3 rootstocks. Lake County, Florida. 1969.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Rootstock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sweet lime</td>
</tr>
<tr>
<td>Tree height (ft.)</td>
<td>12.1 a</td>
</tr>
<tr>
<td>Root depth (ft.)</td>
<td>11.2 ab</td>
</tr>
<tr>
<td>Yield/tree (90 lb. bxs.)</td>
<td>4.69 a</td>
</tr>
<tr>
<td>Soluble solids (%)</td>
<td>9.5 b</td>
</tr>
<tr>
<td>Titratable acid (%)</td>
<td>.95 b</td>
</tr>
<tr>
<td>Brix/acid ratio</td>
<td>10.0 c</td>
</tr>
<tr>
<td>% juice/wt.</td>
<td>55.6 a</td>
</tr>
<tr>
<td>Wt./fruit (grams)</td>
<td>174 a</td>
</tr>
</tbody>
</table>

Values in each line not followed by like letters are significantly different at the .05 level of probability.

1Data on additional rootstocks in this experiment is available in previous reports (4, 20).

2Mean calculated from 5 trees on each rootstock. All other means calculated from 15 trees per rootstock.
Table 2. Yield of a 'Shamouti' orange grove budded on sweet lime. Israel.1

<table>
<thead>
<tr>
<th>Year</th>
<th>Age of grove (yrs.)</th>
<th>Yield/tree2</th>
<th>Yield/acre2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954/55</td>
<td>20</td>
<td>1.4</td>
<td>358</td>
</tr>
<tr>
<td>1955/56</td>
<td>21</td>
<td>1.7</td>
<td>437</td>
</tr>
<tr>
<td>1956/57</td>
<td>22</td>
<td>1.2</td>
<td>324</td>
</tr>
<tr>
<td>1957/58</td>
<td>23</td>
<td>.9</td>
<td>245</td>
</tr>
<tr>
<td>1958/59</td>
<td>24</td>
<td>2.1</td>
<td>540</td>
</tr>
<tr>
<td>1959/60</td>
<td>25</td>
<td>1.7</td>
<td>334</td>
</tr>
</tbody>
</table>

1Data extracted from report by Mendel (24). Planting distances were 13' x 13', 284 trees/acre; 70% of the trees exhibited visible symptoms of xyloporosis.

2Converted from kg./tree and tons/acre to 90 lb. boxes.

(16, 22, 29) have described the anatomy of bud unions of 'Shamouti' on several rootstocks and the unions of sweet lime interstocks. Viewed in their entirety, the union of sweet lime is strong and compatible in the absence of damaging viruses.

Viruses.—Information in the literature clearly indicates the damaging effects of tristeza, exocortis and xyloporosis to citrus on sweet lime rootstock.

Xyloporosis has been commonly associated with stunted growth of trees on sweet lime. Results from both rootstock trials and commercial plantings on this rootstock have often been invalidated because xyloporosis-infected budwood was used (1, 7, 21). However, it has been shown xyloporosis is transmitted only through infected budwood (6) and xyloporosis-free budwood of virtually all important citrus varieties is available. Strains of xyloporosis which produce primarily dwarfing effects might be used advantageously, Table 2, but the use of viruses to control tree size is not recommended.

Exocortis effects on sweet lime have not been widely noted or discussed in the literature, probably because of the emphasis placed on xyloporosis damage, but researchers in California (35) and Texas (27) have reported a bark splitting disorder of sweet lime infected with exocortis. Budwood free of exocortis is available for most important commercial varieties.

In 1951 sweet lime was reported as somewhat susceptible to tristeza by Grant and his co-workers (14). Giacometti (15) reported in 1965 that sweet lime is more tolerant to the severe strain of tristeza (seedling yellows) than sour orange and

Table 3. Growth and yield of nucellar and old-line 'Redblush' grapefruit trees on sweet lime and rough lemon rootstocks. Texas.1

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Sweet lime</th>
<th>Rough Lemon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nucellar</td>
<td>Old-line</td>
</tr>
<tr>
<td>Tree height</td>
<td>12.5</td>
<td>9.0</td>
</tr>
<tr>
<td>(ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield/tree</td>
<td>4.1</td>
<td>7.7</td>
</tr>
<tr>
<td>(90 lb. bxs.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Data extracted from report by Young and co-workers (38). Trees were 12 years old, having been planted in 1956 but were severely damaged in a freeze in 1962.


Table 3. Growth and yield of nucellar and old-line 'Redblush' grapefruit trees on sweet lime and rough lemon rootstocks. Texas.1

Table 4. Freeze damage to 'Orlando' tangelo trees on sweet lime, rough lemon and sour orange rootstocks. Gainesville, Florida. 1970.

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Severity of damage1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Sweet lime</td>
<td>0 16 16 11 5</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>0 16 16 10 6</td>
</tr>
<tr>
<td>Sour orange</td>
<td>12 3 1 0 0</td>
</tr>
</tbody>
</table>

1Rating of freeze damage: 1, no damage; 2, leaf damage only; 3, leaf and small branch damage; 4, killed to major scaffold branches; 5, killed to top of protective soil bank about 2.5 ft. above the ground level. There were 16 trees on each rootstock. Trees were evaluated 1 month after growth in the spring.

Table 5. Mean values of macronutrients in leaves of 'Orlando' trees on rough lemon and sweet lime rootstocks. Lake County. 1970.1

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Macronutrient (% dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N  P  K  Mg  Ca</td>
</tr>
<tr>
<td>Sweet lime</td>
<td>2.45** .116 .208 .690 .314</td>
</tr>
<tr>
<td>Rough lemon</td>
<td>2.29 .114 2.11 .696 3.51*</td>
</tr>
</tbody>
</table>

1Means of samples from each of 15 trees on each rootstock.

*Significantly higher at the .05 level of probability.

**Significantly higher at the .01 level of probability.
that neither sour orange nor sweet lime reacted to a mild strain. The most efficient vector of tristeza, Toxoptera citricidus Kirk., is not in Florida and the strain or strains of tristeza present generally cause only mild reactions. Thus, the threat of tristeza appears to be less for sweet lime than for sour orange.

Foot rot.—Information on the susceptibility of sweet lime to foot rot, Phytophthora sp., is sparse. There are occasional suggestions that sweet lime is relatively susceptible to foot rot (5, 19) but Olson and his co-workers (23) in Texas, where the soils are heavy and foot rot common, reported that none of the trees on sweet lime in a rootstock experiment with grapefruit tops had succumbed after 10 years, while a large proportion of the trees on 9 sweet orange selections had died, largely from foot rot. No mention was made of foot rot on rough lemon but 2 trees had succumbed to what was termed “wet feet.” Klotz (18) presented quantitative data on the relative susceptibility of a number of rootstock and scion varieties to Phytophthora, rating sweet lime more susceptible than sour orange but less so than rough lemon.

No foot rot has developed in the ‘Orlando’ rootstock trials reported in this work but neither was foot rot noted in trees on any other stock, including sweet orange. A fairly comprehensive survey of the few commercial plantings on sweet lime in Florida failed to disclose any trees with foot rot.

The senior author has made gross observations on hundreds of sweet lime, sweet orange and sour orange trees in tropical areas where the incidence of Phytophthora is great. These observations, along with data in the literature, lead to the conclusion that sweet lime is more susceptible to foot rot than sour orange but appreciably more resistant than sweet orange and slightly more resistant to this disease than rough lemon.

Nematodes.—The sweet lime is damaged by both the citrus nematode (Tylenchulus semipenetrans Cobb) and the burrowing nematode (Radopholus similis (Cobb) Thorne). Rough lemon is similarly susceptible to these nematodes, with the exception of ‘Estes’, which is rated tolerant to R. similis (12). Where the burrowing nematode is the limiting factor, the ‘Milam’ variety appears to be a reasonable replacement stock, but there are many acres of land in Florida without nematode problems where other rootstocks could be considered.

Tolerance to cold.—Tolerance to cold of sweet lime itself is poorly defined in the literature. One report evaluated hardiness in a freeze so severe that very hardy varieties such as ‘Orlando’ were killed to the ground (36) and another contained insufficient plants for an accurate evaluation (37). However, gross observations of old trees near Avon Park and young trees at Gainesville indicate sweet lime is much hardier to cold than acid limes and rough lemon.

It is difficult to generalize on the influence of rootstock on cold hardiness of the scion. Certain citrus, such as ‘Mexican’ lime, do not go dormant regardless of the rootstock and remain sensitive to cold; whereas when some scion varieties become fully dormant, rootstock has little influence on their hardiness to cold (39). Evaluations of the cold hardiness of scion varieties on sweet lime have varied from extremely sensitive to cold (1) to moderately sensitive (13). In the winter of 1968-1969 the trees in a rootstock planting at Gainesville were subjected to freezing temperatures of 17°F for several hours. Some of the trees were killed back to the ground or damaged, despite the use of heaters. The damage to 2-year-old trees on sweet lime and rough lemon was about equal and more severe than that encountered on sour orange, which was used as a standard for comparison, Table 4.

Leaf mineral content.—Mineral content of leaves is well recognized as a good measure of the nutritional status of the tree and ability of the root system to obtain mineral elements from the soil. Rough lemon is recognized as the standard against which others are compared (33). A comparison of the macronutrient content of ‘Orlando’ tangelo on sweet lime and rough lemon respectively is shown in Table 5. Levels of P, K and Mg were similar but leaves from sweet lime plots were significantly higher in N and lower in Ca than those from the trees on rough lemon. Cooper’s (8) survey of the nutritional status of ‘Orlando’ trees in Florida in 1968 contained 1 planting on sweet lime and 5 on rough lemon, with the great majority on ‘Cleopatra’ mandarin. Trees on sweet lime compared very favorably with those on rough lemon. Mendel (21) reported N and P contents in leaves on ‘Shamouti’ sweet orange on sweet lime and rough lemon respectively were similar. These limited data, coupled with observations of vigor and yield, support the conclusion that sweet lime is at least the equal of rough lemon in its ability to obtain mineral elements from the soil.

Tolerance of sweet lime to high concentrations of salt, boron and lime in the soil was ranked by Cooper and his co-workers (9, 26) in Texas as moderate to poor, poor, and moderate respectively.
Rough lemon by comparison rated moderate, moderate, and good, indicating a slight superiority to sweet lime. The sandy soils of Florida, however, are more likely to be deficient in boron than in excess. They generally require liming, and salt intrusion is limited to a few coastal areas.

Tree size.—Trees on sweet lime rootstock have been reported as stunted or below normal size in California (1), Texas (25, 26, 38), Florida (7) and Israel (23, 24), but stunting was the result of infection with xyloporosis. However, trees on sweet lime have been vigorous and equal in size to those on rough lemon wherever budwood free of these viruses has been used (20, 38). Data obtained in Florida (20) demonstrates this very well, Table 1. Moreover, ‘Orlando’ trees in commercial groves in Florida are extremely vigorous and equal in size to adjacent trees on rough lemon.

Depth of rooting.—There are some reports that state or imply the sweet lime is shallow rooted but data are sparse or lacking (23, 30). Data obtained from an extensive sampling of root systems with ‘Orlando’ tops are contained in Table 1. Rough lemon was the deepest rooted of the standard rootstocks which agrees with previous work by Ford (11)—and sweet lime compared very favorably with it. This is by far the most extensive examination of the root system conducted and it leaves little doubt that sweet lime can be very deep rooted in Florida’s sandy soils. The type of root system that would develop in Florida’s coastal and flatwood areas where the water table is at 2 to 3 feet would be restricted to the depth at which the water table is maintained. This is also true for rough lemon and other rootstocks.

Yield of fruit.—Rootstock trials in various parts of the world have often indicated low yields on sweet lime from the use of budwood infected with xyloporosis (1, 7, 23, 24, 25, 26, 38). Actually, xyloporosis infected trees on sweet lime may yield well, even though the trees are dwarfed. In 1956 Mendel (23) reported satisfactory yields from trees on sweet lime, even though some trees were affected by xyloporosis. Mendel (24) later suggested that the semi-dwarfing effect of xyloporosis can be used to advantage in controlling tree size. He presented data of very satisfactory production of sweet orange on sweet lime that contained xyloporosis, Table 2.

Old, commercial grapefruit and sweet orange trees containing xyloporosis in Florida have presented a pattern of erratic tree sizes, ranging from pronounced dwarfing to normal sizes, and satisfactory fruiting for the respective tree size. The yield evaluation is observational and quantitative data are not available.

Yield data from an experiment in Lake County with xyloporosis-free budwood, presented in Table 1, and in earlier reports (20), show clearly that yields of trees on sweet lime are excellent and as good or better than those on rough lemon. Moreover, there are 3 mature ‘Orlando’ groves on sweet lime near Avon Park and 1 near Haines City. The trees are uniformly large and yielding excellent crops according to their owners. Cooper’s (8) survey of 30 ‘Orlando’ plantings showed that the highest 2-year average yield was 587 boxes per acre from a planting on ‘Cleopatra’ mandarin with ‘Temple’ pollinators. The only planting on sweet lime had the second highest yield, 575 boxes per acre, even though it was only 7 years old and did not contain a pollinator. The highest yield from the 5 blocks on rough lemon was from a 12-year-old planting without pollinators which produced 397 boxes per acre. The plantings on ‘Cleopatra’ and sour orange under 15 years of age produced very little fruit in the absence of pollinators. Unfortunately, the only yield data available in Florida are from ‘Orlando’ tangelo and it is reasonable to assume that the yields of other varieties would be good, even though all varieties do not perform precisely the same on a given rootstock.

In Texas (26), 12-year-old ‘Valencia’ orange trees on sweet lime that were respectively free and infected with xyloporosis were compared in a trial with several other rootstocks. Trees on rough lemon, both with and without xyloporosis, were about equal in yield, but those with xyloporosis on sweet lime were stunted and reduced in yield. In another experiment in Texas (38), nucellar ‘Redblush’ grapefruit trees without xyloporosis were much larger than old-line trees with xyloporosis and exocortis on rough lemon and sweet lime, Table 3. Nucellar ‘Redblush’ yielded slightly more fruit on sweet lime than on rough lemon but the old-line trees yielded more on rough lemon than on sweet lime. However, the old-line trees yielded more on each stock than did the nucellar selection on either stock. The greater yields of the virus-infected trees undoubtedly resulted from the difference in the nucellar and old-line selections rather than to the viruses per se.

Much of the past research is clouded with the effects of viruses, but there is evidence that trees on sweet lime yield as well or better than those on rough lemon both on the sandy soils of Florida and the fertile alluvial soils of the Texas citrus...
were infected with xyloporosis. Fruit sizes of sweet lime are limited. All information indicates, however, that the rootstock area if the trees are free of damaging viruses.

Fruit size.—Results of some rootstock trials (2, 31) have indicated fruit sizes on sweet lime were smaller than on a number of other rootstocks, including rough lemon; however, the trees were infected with xyloporosis. Fruit sizes of trees on sweet lime have been excellent, Table 1, and comparable to that occurring when rough lemon was the rootstock where trees free of damaging viruses were used (20, 35). Also, general observations of growers indicate that large fruit size is characteristic of trees on sweet lime free of viruses.

Fruit quality.—The juice quality of citrus on sweet lime has been low regardless of the virus status of the trees. Extensive research in Israel (23), Florida (7, 20), Texas (35) and California (31) all place sweet lime in about the same category as rough lemon in this respect. Data in Table 1 illustrate the quality of fruit from trees on sweet lime as compared to that from fruit on rough lemon and sour orange.

CONCLUSIONS

Sweet lime has generally been discarded as a possible rootstock for Florida because trees in initial rootstock experiments and commercial trials were severely stunted and yielded poorly. This rootstock deserves a reevaluation in light of the current knowledge of viruses and the excellent performance of sweet lime on sandy soils.

Performance of commercial plantings and data from trees in rootstock experiments utilizing trees on sweet lime that are free of damaging varieties are limited. All information indicates, however, that this rootstock is very well adapted to Florida’s sandy soils.

Knowledge of the performance of trees on sweet lime justifies limited commercial plantings even in the absence of rough lemon decline. In the presence of rough lemon decline, trial plantings on sweet lime appear even more attractive. Of course, there are always risks involved with any new rootstock. There is no guarantee sweet lime or any other rootstock will not ultimately succumb to whatever is causing rough lemon decline or to something else. These risks will always be present.

LITERATURE CITED


PROBLEMS ENCOUNTERED IN OVERHEAD IRRIGATION OF CITRUS WITH WATER OF RELATIVELY LOW SALINITY

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ABSTRACT

Salt burn symptoms and leaf loss were noticed on citrus trees in the Indiantown area in April, 1971. This was after an extended dry period in areas under daytime overhead irrigation (14 irrigations from December 2, 1970, to May 26, 1971). The water for irrigation was drawn from the St. Lucie Canal which contained total soluble salts in a range from 510 ppm to 590 ppm.

Leaves were analyzed for Na, Ca, Mg, K and Cl. Ratios of Ca: K + Na are included and discussed.

INTRODUCTION

Extremely dry conditions were encountered this past year which necessitated repeated irrigations to replenish soil moisture in East Coast groves.

On April 21, 1971, some Marsh grapefruit on Macrophylla rootstock in the Hodgson Grove (near Indiantown) were noticed to have severe salt burn symptoms on the leaves. Irregular brownish areas developed on the leaves, usually near the leaf tips. Considerable leaf drop occurred. In checking other varieties near this location, the salt burn symptoms were noted to a lesser degree. In spot checks over the lemon planting on this grove the leaf drop was seen to be very heavy and most of the dropped leaves exhibited a salt burn pattern.

In checking neighboring groves we found the same situation present. The worst leaf burn found was in a section of a grove south of the Hodgson Grove that had been irrigated with low volume overhead sprinklers operated during daylight hours. In all of these groves the source of the irrigation water was the St. Lucie Canal.

LITERATURE REVIEW

Calvert (1) observed salt burn symptoms in several Indian River citrus groves during the severe spring drought of 1965. He reproduced the leaf burn symptoms on Ruby Red grapefruit by sprinkling the trees with artesian water containing 1,000 ppm. total dissolved solids, at the rate of 0.8 gallons per minute (equivalent to 0.07 inch of water per hour) for a period of nine hours. The damage was increased with the increase in evaporation of water from the leaf surfaces.

Harding and Chapman (5) have suggested that leaf chloride contents exceeding 0.25% be considered indicative of chloride toxicity. They found even lower level of chlorides (although not always leading to obvious chloride toxicity symptoms) may still effect the longevity of leaves, and perhaps, lead to reduced yields.

Ehlig and Bernstein (2) found that although foliar absorption of sodium and chloride by citrus leaves from sprinkle irrigation is slower than for some stone fruits, severe injury can occur within one season. They also observed that foliar absorption during the evening was only one-half as rapid as during the day.

Harding (4) found that even in the absence of specific injury symptoms resulting from exces-