sponds well with results of an experiment carried out in an Indian River Valencia orange grove with similar soil (5).

There exists no entirely satisfactory method of leaf, soil, or fruit analysis by which the nitrogen status of a tree may be satisfactorily determined. The nitrogen status of citrus trees in soils such as used in this experiment is heavily dependent upon weather conditions. It is suggested that Indian River growers compare their current nitrogen programs, for grapefruit groves on soils similar to the one used in this experiment, with the 116-pound figure found to be optimum on this site. If a distributor throwing fertilizer into the water furrow is used, proportionate increase in rate should be considered. Observations on foliage, fruit color, and tree condition will thereafter be the best guide to further adjustment of the nitrogen program in each specific grove.

Optimum fresh fruit quality was obtained from trees having only moderate green leaf color, and not those intensely green.

**Summary**

An experiment concerning the nitrogen fertilization of Marsh grapefruit trees on a hammock soil in the Indian River area was conducted over a seven-year period. The optimum rate of nitrogen under the conditions of the experiment appeared to be approximately 116 pounds per acre per year.

Arsenic was found to be equally effective at all nitrogen rates used in the experiment.

**Literature Cited**


**Recent Developments in Pruning Citrus**

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Pruning of deciduous fruit trees is a common horticultural practice. However, until recently very little pruning of citrus, other than sprouting or dead wood removal, has been practiced in this country. There has been little research in Florida relative to the responses of mature bearing citrus trees to pruning.

Early work in California by Hodgson (2) with young mature trees indicated pruning to be of dubious value, but he conceded that pruning might be useful in rejuvenating old trees. During the past decade, hedging and topping of lemons and oranges in California have been reported (3, 4) highly beneficial and are becoming a common practice. Rather severe pruning has been intensively practiced on citrus in Spain for many years. Bowman (1) reports that research in Australia showed a favorable response with lemons and mandarins to thinning-out pruning and that citrus trees were successfully rejuvenated by cutting back entire trees to limbs about two inches in diameter.

As Florida plantings have become crowded, as the cost of land has skyrocketed, and as harvest labor has become scarce, the need to investigate the influence of pruning on rejuvenating old trees and on facilitating management and harvesting has become not only apparent but imperative.

The development of the hedging machine by Prosser (6) served as an immediate solution for facilitating grove management and, as pointed by Norris (5), hedging possibly increases yield and external quality of some varieties. However, more research is needed to substantiate this.

In 1958, comprehensive research was initi-
ated concerning the responses of citrus to pruning, pruning procedures to facilitate harvesting and grove management, and the testing and development of mechanized pruning equipment. This paper is a progress report of some of the work conducted to date.

PROCEDURES

Citrus Experiment Station Block IX.—This experiment was designed to study the response of crowded grapefruit trees to various types of pruning. The trees are 30 years old and spaced 25 by 25 feet. The initial pruning was done during March 1959, using pneumatic high-speed circular saws or other hand equipment. Treatments consisted of 1) unpruned check; 2) hedge on four sides and top at 15 feet; 3) narrow hedge to a tree six feet wide (fan shape) and top at 15 feet (Figure 1); 4) hedge four sides; 5) hedge two sides. The hedge treatments consisted of hedging cuts made nine feet from the trunk at the lower portion of the canopy and slanting inwardly to seven and one-half feet at the 20-foot height. All cuts over one inch in diameter were painted with a water base asphaltum pruning compound. Each treatment was replicated four times and each plot contained six trees. With the exception of the unpruned checks, the pruning treatments were not buffered but were so placed to provide maximum protection from the influence of adjoining plots. The trees of Treatment 3 have received an annual pruning to maintain the six-foot width and 15-foot height. The experiment was complicated by having four varieties of grapefruit, Duncan, Excelsior, Walters and Marsh, uniformly present in each treatment of each replication. The varieties are on rough lemon rootstock.

Minute Maid Lynchburg Groves.—With the preliminary observations from the previous experiment as bases for further study, two fairly comprehensive experiments were established in early 1960 on 45-year-old Duncan grapefruit and 60-year-old Valencia oranges on rough lemon rootstock. The spacing in each block is 18 by 24 feet and the trees were severely crowded and canopied. The produc-

![Figure 1. Narrow hedged grapefruit trees six feet wide and topped at 15 feet (right). Original tree canopy extended to the white stake in the center of the photograph. Trees on left hedged on two sides; note sloping cut.](image-url)
tion has been declining in both blocks for several years and the trees were considered very difficult to spray and costly to harvest.

The treatments in each block consisted of 1) hedge on two sides; 2) hedge on two sides and top at 15 feet (Figure 2); 3) hedge on four sides and top at 15 feet; 4) narrow hedge to a tree six feet wide and top at 15 feet; 5) skeletonize—remove all wood less than 1½ inches in diameter (Figure 3); 6) buckhorn—cut main scaffold limbs five to six feet above ground and whitewash frequently to prevent sun scald (Figure 3). The hedging treatments were as previously described. Cuts were also painted as in the previous experiment. A randomized block design was used with five replications of five-tree plots. Treatments were imposed on the grapefruit in February 1960 and on the oranges in late May and early June 1960.

Relationship of Tree Size to Fruiting Wood vs. Supporting Structure.—Two trees in Block III of the Citrus Experiment Station grove were used to obtain some preliminary information concerning the relative proportions of fruiting wood vs. supporting structure (non-fruited wood) on trees of different size. For definition, fruiting wood was that which held live leaves; supporting structure was all the remaining live wood from the ground level upward. Dead wood was classified separately. The trees were cut up in place and fresh weight taken immediately. The leaves were included in the weight of the fruiting wood. The trees were of as near equal vigor and physical condition as could be found.

The smaller tree selected was a Ruby Red grapefruit with an average trunk diameter, six inches above the bud union, of 8½ inches. It was 15 feet tall and had a canopy spread of 15 to 18 feet. The larger tree was a Marsh grapefruit with an average trunk diameter, six inches above the bud union, of 14½ inches. The tree was 22 feet tall and had a canopy spread of 22 to 29 feet.

RESULTS

Citrus Experiment Station Block IX.—The general tree response for each treatment is summarized as follows:

Treatment 1, unpruned check—Trees are continuing to show effects of crowding, specifically, declining vigor, evidenced by small

Figure 2. Sixty-year-old Valencia oranges hedged on two sides in the background and hedged on two sides and topped at 15 feet in foreground.
leaves, short growth flushes and sparsely foliated tops. Fruit production is generally within a thin canopy of small, weak shoots in the upper portion of the trees. The trees are difficult to spray and harvest, and seriously impair general grove operations.

Treatment 2, hedge on four sides and top at 15 feet—Very vigorous shoots have been produced on the inside of the trees as well as the outside and the fruiting limbs are becoming closer to the ground as a result of their origin and from the weight of fruit. The fruit has a tendency to be produced in clusters, but this does not appear to cause a lower grade of the fruit when harvested. The pruning wounds are healing well and very little sun scald has been found. These trees appear to be easily sprayed and harvested, and do not impair other grove operations.

Treatment 3, narrow hedge to a tree six feet wide and top at 15 feet—Trees have responded remarkably well by producing strong, vigorous shoots throughout the remaining portion of the tree. The growth is quite close to the ground and the trees are growing together well at their extremities, forming a complete fruiting wall, six feet wide and 15 to 17 feet tall. The response of these trees is illustrated in Figure 4. Much of the fruit is borne in clusters but this does not appear to lower the grade of fruit appreciably. The trees appear to be easily sprayed but preliminary observations indicate that rust mite (Phyllocoptruta oleivora) and mealy bug (Pseudococcus spp.) may be more difficult to control in trees of this shape. This may be due to the large numbers of clustered fruit. The tree growth in this treatment allows for general grove operations while working with the row but prevents cross-row movements. Most of the pruning wounds are healing very well, but a few of the larger wounds are not and there is some evidence of die-back where new shoots were not quickly formed near the large cuts. This could perhaps be prevented by making the cuts near obvious lateral buds. Furthermore, no large cuts would have to be made if this type of pruning were started when trees were relatively small. There is slight evidence of sun scald on the exposed lateral limbs.

Trees in this treatment appear to be very easy to harvest and offer outstanding possi-

Figure 3. Buckhorn treatment in foreground and skeletonize treatment in background on 60-year-old Valencia oranges.
bilities for future developments in mechanical harvesting.

Treatment 4, hedge on four sides—Trees are producing fairly vigorous shoots on the hedged sides and growth is beginning to develop closer to the ground. There is also a slight increase in inside growth. However, the tops of the trees appear very much like the unpruned check trees. Trees in this treatment appear to be relatively easy to spray and harvest and do not seriously impair other grove operations. Most of the wounds are healing well and there is very little evidence of die-back and no indication of sun injury.

Treatment 5, hedge on two sides—Tree response is almost identical to that in treatment 4 except the most vigorous new growth is present on only two sides, rather than on four.

The influences of pruning treatment on yield and fruit quality are presented in Tables 1 and 2.

Minute Maid Lynchburg Groves.—The tree response can best be presented on a treatment basis and again both varieties will be discussed together. With respect to growth, the Valencia oranges responded better than the Duncan grapefruit even though the oranges were pruned nearly three months later. The oranges tended to produce new shoots more towards the base of the scaffold limbs and in greater numbers than the grapefruit. Unless specifically noted, all pruning wounds appear to be healing well with very little die-back present.

Treatment 1, hedge on two sides—Vigorous new shoots are developing on the hedged sides but the remainder of the tree does not appear to have been stimulated into vigorous growth activity. The yields for the first season after pruning were 4.3 boxes per tree for the grapefruit and 1.1 boxes for the oranges.

Treatment 2, hedge two sides and top at 15 feet—Vigorous new growth is developing not only on the hedged sides but on the top as well. Some new growth is also present in the central portion of the tree and an occasional new shoot can be found near the base of the scaffold limbs. The yields for 1960-61 were 5.3 boxes per tree for the grapefruit and .3 box for the oranges.

Treatment 3, hedge four sides and top at 15 feet—Tree response is similar to that of treatment 2 but seems to be accentuated throughout the entire tree. More shoot growth is present in the lower portions of the tree and the growth appears to be more vigorous than in treatment 2. Yields for the 1960-61 season were 2.5 boxes for the grapefruit and .2 box for the oranges.

Treatment 4, narrow hedge (fan shape) and top—The general response is similar to that described for treatment 3 in Citrus Experiment Station Block IX. However, the trees are not yet producing growth close to the ground on the “edges” of the fan. This is apparently due to the close spacing of the trees and the general lack of scaffold limbs in the lower portions of the trees. Yields for the past season were 1.3 boxes for the grapefruit and .1 box for the oranges.

Treatment 5, skeletonize—Very vigorous shoots are developing over much of the remaining framework limbs of the tree (Figure 5). The grapefruit trees produced some “late bloom” fruit in 1960 and yields averaged 2.5
of the three classes of wood for the smaller Ruby Red grapefruit tree were:

- Fruiting wood: 105.5 lbs. - 26.9%
- Supporting structure: 275.5 lbs. - 70.2%
- Dead wood: 11.5 lbs. - 2.9%

The fresh weights of the three classes of wood from the larger Marsh grapefruit tree were:

- Fruiting wood: 173.25 lbs. - 13.2%
- Supporting structure: 1,111.00 lbs. - 84.8%
- Dead wood: 25.25 lbs. - 2.0%

**DISCUSSION**

Pruning research presently in progress can generally be divided into two categories; tree rejuvenation and tree shaping to facilitate harvesting. Most of the information presented should be considered as preliminary in nature because of the short period of time this research has been underway and the consequential lack of conclusive yield data. Furthermore, observations from other experiments in progress indicate that other types of citrus do not respond the same as the Valencia oranges and the grapefruit varieties discussed in this paper.

**Tree Rejuvenation.**—The ultimate purpose of tree rejuvenation is to extend the time of economic production of a grove or to delay the date that replanting may become necessary. In evaluating a rejuvenation practice the treatment should (1) cause a general invigoration of shoot growth throughout the tree which will produce large, high quality fruit;

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield 1960</th>
<th>Yield 1961</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boxes/Tree</td>
<td>Boxes/Tree</td>
</tr>
<tr>
<td>1—Unpruned check</td>
<td>7.17</td>
<td>7.73 ab</td>
</tr>
<tr>
<td>2—Hedge 4 sides and top</td>
<td>4.68</td>
<td>8.94 c</td>
</tr>
<tr>
<td>3—Hedge fan-shape and top</td>
<td>2.73</td>
<td>6.46 a</td>
</tr>
<tr>
<td>4—Hedge 4 sides</td>
<td>5.59</td>
<td>7.13 ab</td>
</tr>
<tr>
<td>5—Hedge 2 sides</td>
<td>5.59</td>
<td>7.53 b</td>
</tr>
</tbody>
</table>

Table 1. The response of four varieties of grapefruit to various pruning treatments.
Citrus Experiment Station Block IX.
Pruned March 1959.

1/ Missing yield data prevented a proper statistical analysis of the 1960 yield. However, the trends established appear reliable.

2/ Treatment means followed by the same letter(s) are not significantly different at the 5% level.
(2) reduce the height of the bearing surface; (3) increase production; (4) reduce production costs; (5) produce a crop soon; (6) ease spraying, harvesting and other grove operations; (7) be long-lasting; (8) be easy and economic to perform; (9) maintain a structurally sound tree. Not all of these factors can yet be evaluated for the treatments included in the experiments in this report, but certain aspects of each are evident.

Hedging.—Hedging alone provides few of the desirable qualities of a rejuvenation practice. Data presented in Table 1 indicate that hedging alone does not increase production of grapefruit. However, the effects on yield are greatly influenced by the variety and the severity of the crowding problem prior to hedging. Hedging undoubtedly eases many grove operations such as spraying, cultivating and harvesting and until additional information is obtained from other pruning treatments, hedging can be recommended for alleviating a crowded grove condition.

Hedging Plus Topping. — Indications are that this treatment results in trees which fulfill many of the qualities necessary for rejuvenation. Trees exhibit a general vigorous shoot response throughout, especially trees hedged on four sides and topped; tree height is reduced; grove operations appear to be eased greatly; production appears reduced only the first year after pruning with a rapid recovery thereafter (Table 1); a structurally sound tree remains. The frequency of re-topping, and the effects on cost of spraying and harvesting, are yet unknown. The greatest disadvantage of this treatment is the high cost of the initial topping. Per tree costs have been as high as $5.50 for topping alone using power hand saws. An additional $0.50 or more per tree is required for brush disposal. Work is presently in progress on a mechanical topping machine which may reduce these costs appreciably.

Skeletonizing. — This treatment also offers considerable promise for tree rejuvenation. It has all the advantages of the hedging plus topping treatment plus the presence of new shoot growth in lower portions of the tree which indicates the fruit producing area is becoming closer to the ground. Fruit production is completely lost the first year after pruning but indications are that the crop will be quite large the second year. Costs of this type of pruning are very high and skeletonizing is not conducive to complete mechanization. Skeletonizing is recommended for grove renovation in other areas (1) but must await further evaluation in Florida.

Buckhorning.—This pruning treatment has been practiced in varying degrees of severity.

Table 2. The influence of pruning on fruit quality of the three seeded grapefruit varieties, Duncan, Excelsior and Walters. Citrus Experiment Station Block IX. 1961.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Juice (%)</th>
<th>Brix (%)</th>
<th>Acid (%)</th>
<th>Ratio Brix/Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1—Unpruned check</td>
<td>44.36</td>
<td>10.52</td>
<td>1.34</td>
<td>7.83</td>
</tr>
<tr>
<td>2—Hedge 4 sides and top</td>
<td>46.05</td>
<td>10.36</td>
<td>1.37</td>
<td>7.54</td>
</tr>
<tr>
<td>3—Hedge fan-shape and top</td>
<td>47.19</td>
<td>9.72</td>
<td>1.31</td>
<td>7.41</td>
</tr>
<tr>
<td>4—Hedge 4 sides</td>
<td>45.22 ab</td>
<td>10.41 b</td>
<td>1.39 b</td>
<td>7.52</td>
</tr>
<tr>
<td>5—Hedge 2 sides</td>
<td>43.87 a</td>
<td>10.51 b</td>
<td>1.39 b</td>
<td>7.55</td>
</tr>
</tbody>
</table>

1 Treatment means followed by the same letter(s) are not significantly different at the 5% level.
2 No significant differences.
in Florida for several years. Certainly this treatment has several advantages; namely, long-lasting, reduces tree height, lowers the producing area, and grove operations are greatly facilitated. The undesirable effects are also great; production is lost for nearly three years, it is costly to impose on the trees, and the resulting trees appear to be structurally unsound. The large wounds heal very slowly and are a constant source of entrance for decay organisms. Also, the attachment of the shoots appears to be very weak and breakage from strong winds and heavy crops is a common occurrence.

Tree Shaping to Facilitate Harvesting.—Data presented concerning the relationship of tree size to proportion of fruiting wood and supporting structure indicate that as a tree becomes larger, the relative proportion of fruiting to non-fruiting wood becomes less. Thus, an increasing amount of photosynthates must be used to support the increasing amount of non-fruiting wood from a decreasing proportion to leaf surface (the source of photosynthates). Furthermore, the fruiting area on a mature citrus tree is generally confined to a three-foot zone of the tree canopy. Observations also reveal that a fruit picker can easily reach into a tree about three feet from his supporting platform. With this information in mind, a tree six feet wide and 15 feet tall was conceived which would theoretically produce a complete fruiting wall with a minimum amount of supporting or non-fruiting wood and a maximum amount of fruiting wood and foliage which could be easily picked.

Preliminary results indicate that this severe pruning treatment does produce a tree of the type described with a very favorable yield the second year after pruning. Indications are that per acre production from this type of tree can theoretically exceed the conventional tree shape by planting additional trees in the wide spaces between the hedged rows to increase the number of trees per acre. This premise is being investigated. Methods for harvesting these fan-shaped trees are also under investigation.

Summary

Several methods of pruning for rejuvenating crowded and canopied citrus groves are under investigation. The most promising treatments appear to be hedging on two or four sides plus topping, and skeletonizing. Observations and limited data indicate that tree responses are favorable, and yields from these treatments, although reduced the first year after pruning, compare well with unpruned and hedged trees by the second year.

Hedging appears to be a beneficial practice to facilitate grove operations.

Severe hedging to form a tree six feet wide and 15 feet tall offers considerable promise for producing a tree which can be easily harvested and which will produce a good crop of fruit. Furthermore, the possibility exists that by closer spacing, increased yields per acre might occur.

Data are presented which indicate that as tree size increases the proportion of fruiting wood to supporting structure or non-fruiting wood becomes smaller.

LITERATURE CITED