unfruitful, even though they were the oldest and largest trees found of this variety.

Multiple pollinators may be needed for 'Nova' and 'Osceola' if it develops they will not successfully induce fruiting in the variety pollinating them. For example, a 'Nova'-'Orlando'-'Robinson' planting would result in fruiting of all 3 varieties while 'Nova' with 'Orlando' would result in only 'Nova' fruiting. As of this date, the limited data reported (2) indicates 'Nova' may be a poor pollinator for other self-incompatible varieties. 'Temple', which is self-fruitful, might prove successful for pollinating 'Nova' but its tenderness to cold is objectionable.

Other varieties may be satisfactory in certain combinations but have faults that make their use questionable. 'Dancy' was effective with 'Robinson' and 'Orlando' but in many years it blooms little or none at all and its bloom period is often short and late. 'Murcott' is often an effective pollinator for some varieties but its bloom period is frequently later than varieties requiring cross-pollination. 'Duncan' and other seedy grapefruit produce little bloom in certain years and the general use of arsenic on grapefruit also poses a problem since spray drift to the variety being pollinated would render it unmarketable. Some sweet oranges might be satisfactory pollinators, as indicated from data in Table 3, but their performance is erratic and their cultural requirements are sufficiently different to make management a problem.

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PERFORMANCE OF CLOSELY SPACED TREES

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ABSTRACT

High-density plantings offer a way for citrus growers to meet the challenge of rising costs of land, production, and harvesting. Results of an experiment initiated in 1960 clearly indicate that earlier economic returns may be realized from closely spaced trees. In the 1968-69 season, trees in a 10' x 15' spacing produced 619 boxes of 'Pineapple' oranges per acre. This was nearly twice the per acre yield of trees at a 15' x 20' spacing and almost 3 times that of a 20' x 25' spacing.

Frequent pruning was required to maintain the vigorous trees in the closest spacing within their allotted space. This further stimulated excessive vegetative growth at the expense of fruit producing wood. Water requirements have also been higher for the closer spacings.

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INTRODUCTION

Citrus growers are approaching an economic situation where drastic changes may be needed if groves are to be profitable in the future. Increasing land values and taxes, a decreasing availability of desirable citrus land, rising costs of materials and equipment, higher harvesting costs, and an uncertain labor supply are causing

citrus growers to look for the most effective use of land and the most efficient means of fruit production and harvesting. In recent years, there has been a trend toward closer tree spacings in an effort to maximize fruit-bearing surface and to obtain earlier economic returns on initial investments (2). The smaller trees required in a high-density planting may also be more effectively and economically sprayed for pest and disease control and be more easily harvested.

Reports of high initial yields have been made for high-density plantings (7); but the trees tend to compete at an early stage, and this advantage may be short-lived (1, 4). Proper control of tree size is essential to the success of closely spaced groves (6).

In order to make a direct comparison of the performance of trees at different spacings, a tree-spacing experiment was initiated at the CES Davenport grove in 1960. This paper reports the performance of these trees to date.

Materials and Methods

'Pineapple orange trees on rough lemon rootstock were planted in 1960 at spacings of 20′ x 25′, 15′ x 20′, and 10′ x 15′. Each treatment plot consists of 2 rows of approximately 650 feet in length, bordered by buffer rows of the same spacing. The treatments are replicated 3 times in an area of approximately 10 acres.

Fruit yield, fruit size, fruit quality, tree height, and trunk circumference were recorded. Soil moisture was measured in each plot with a Nuclear-Chicago d/m gauge. Readings were made at depths of 1, 2, 3, 4, and 5 feet during the spring months of 1967, 1968, and 1969 to determine relative water usage. An overhead sprinkler system which allows separate irrigation of each plot or combination of plots made it possible to apply water when and where it was needed.

Efforts were made to select scaffold limbs running parallel to the row in the 10′ x 15′ spacing in order to obtain a narrow hedge or "fruiting wall.' The only pruning done thus far in the other treatments is removal of a few sprouts and broken branches.

Results

The trees were just getting off to a good start when they were frozen down to the banks in the severe freeze of December, 1962. They have recovered well following this set back, but considerable variability in tree size existed for 2 years.

In the 10′ x 15′ spacing, early attempts to select scaffold limbs which grew parallel to the row proved to be discouraging because of the numerous growth flushes produced each year by these young trees and their tendency to produce new shoots in unlikely places. It is questionable if selection of scaffold limbs is practical until the trees have reached a stage when apical dominance is more evident and less resprouting occcurs on the trunk. Since 1966, a light annual hedging has been necessary to maintain these trees within their allotted space, to insure adequate sunlight on the hedged sides, and to keep the middles open for equipment. This has tended to stimulate excessive vegetative growth at the expense of desired fruiting wood.

Trunk circumference was almost the same for trees in all spacings in 1965 but was appreciably smaller for those in the closest spacing in 1969 (Table 1). Little difference in circumference existed between trees at the wilder spacings. The growth rate of trees in the closest spacing was obviously influenced to a greater extent by competition between trees for water and nutrients.

In contrast, it was found that the trees in the closest spacing were taller than the others. A small difference was measured in 1965, but they were approximately a foot taller in 1969. Reduction in outward growth by pruning and competition for space forced the trees to grow more in an upright direction.

Fruit yields for the last 3 seasons are most interesting (Table 2). In the 1966-67 season, the trees produced a good crop for their size. Per tree yield difference was not significant between the 20′ x 25′ and 15′ x 20′ spacings but was lower for the 10′ x 15′ spacing. This may be attributed to hedging, to greater competition between trees, and to smaller tree size. Yield was down slightly

Table 1.--Effect of spacing on tree growth.

Tree spacing	Trunk circ. (cm)*		Tree height (ft)*	
	1965	1969	1965	1969
20' x 25'	23.3a	46.6b	6.1a	10.7a
15' x 20'	23.0a	45.1b	6.2a	10.9a
10' x 15'	23.1a	42.1a	6.4a	11.7b

*Treatment means within a column not followed by the same letter are significantly different at the .05 level.

Table 2.--Effect of spacing on fruit yield.

Tree spacing	Trees /acre	Boxes per tree* 1967	1968	1969	Boxes per acre* 1967	1968	1969
20' x 25'	87	1.65b	1.48b	2.44a	144a	128a	212a
15' x 20'	145	1.53b	1.40b	2.25a	222b	203b	326b
10' x 15'	290	1.24a	0.93a	2.13a	360c	269c	619c

*Treatment means within a column not followed by the same letter are significantly different at the .05 level.

the following year, possibly because of the alternate bearing tendency of 'Pineapple' oranges and because of a severe aphid problem during the previous bloom. There was an even greater yield reduction for the 10′ x 15′ spacing, possibly because they were hedged later than usual. Last season yields were up considerably for all trees, and differences between spacings were not significant.

What we are most interested in, of course, is boxes per acre; and this is where the closer spacings are dramatically ahead at this stage. In the 1966-67 season, the 15′ x 20′ spacing resulted in a 54% increase in yield per acre over the 20′ x 25′ spacing while an increase of 150% was realized by the 10′ x 15′ spacing. A similar pattern occurred the following year except for a diminished yield advantage of the closest spacing. In the 1968-69 season, with over 2 boxes per tree, results were very encouraging. The 619 boxes per acre picked from trees at the 10′ x 15′ spacing is almost twice the yield of the 15′ x 20′ spacing and almost 3 times that of the 20′ x 25′ spacing. These results accentuate the early yield advantage of a closely spaced planting.

The size of fruit produced on trees in the 10′ x 15′ spacing was slightly larger in the 1967 and 1968 harvests but not in 1969 (Table 3). This may be related to less fruit on these trees, but tree size was also smaller. The yield difference per tree was smaller in 1969.

Table 3.--Effect of spacing on fruit diameter (cm).

Spacing	1967	1968	1969
20' x 25'	7.42a*	7.52a*	7.21a*
15' x 20'	7.45a	7.54a	7.19a
10' x 15'	7.53b	7.65b	7.23a

*Treatment means within a column not followed by the same letter are significantly different at the .05 level.

Internal fruit quality was not affected by tree spacing until the 1969 season (Table 4). Samples obtained early in February, 1969, showed that fruit from trees in the 10′ x 15′ spacing contained appreciably more juice which was lower soluble solids and higher in acid. This gave a lower Brix/acid ratio, indicating a delay in maturity. These results could be related to frost damage which occurred earlier since fruit in the closest spacing was less exposed; and less preharvest fruit drop was observed. This could explain the higher juice and lower soluble solids content but not the higher acid present. The lower ratio may be a result of less sunlight reaching these fruit.

Water requirements may be greater in a closely spaced grove (Table 5). In 1967, water usage tended to be greatest with the high-density spacing; but differences were small. In 1969, water use was greatest in the 10′ x 15′ spacing; but this was followed closely by the 15′ x 20′ spac-

Table 4.--Effect of tree spacing on internal fruit quality.

Tree spacing	Juice* (%)	Brix* (%)	Acid* (%)	Brix* /acid
20' x 25'	43.8a	9.70b	0.65a	14.9b
15' x 20'	44.2a	9.65ab	0.65a	14.9b
10' x 15'	47.1b	9.33a	0.72b	13.0a

*Treatment means within a column not followed by the same letter(s) are significantly different at the .05 level.

Table 5.--Percent soil moisture at different spacings.*

Spacing	1967	1969
20' x 25'	3.23	4.01
15' x 20'	3.19	3.01
10' x 15'	3.10	2.76

*Average of all readings in the years shown.

ing. Soil moisture use was substantially less in the 20′ x 25′ spacing since the trees are drawing water from a smaller portion of their available soil and are competing very little with each other. Water usage is also influenced by the amount of foliage per acre, the average leaf exposure to the sun, and air movement. It should be recognized that supplemental irrigation may be required more frequently in a grove with a higher tree density.

Discussion

A high-density planting appears to be an effective way of meeting the challenge of spiraling costs of land, production, and harvesting. The higher initial production results in a quicker return on the grower's investment; and this should more than offset the higher costs of trees, planting, and care. Growers could use this higher early income for reinvestment, further increasing its advantage. With proper management, fruit production should remain high for some time. If unsurmountable maintenance problems do eventually arise, it may even be economically feasible to push out and replant such a planting whenever the situation demands it.

High density plantings may also have advantage from a harvesting standpoint. The smaller trees could be more easily picked by hand from the ground or from short ladders. Narrow, 6-foot wide hedges would also facilitate harvesting from platforms since pickers could reach the centers of the trees as they move down the row. Theoretically, a 6-foot wide hedge could result in the greatest amount of bearing surface per acre since most fruit is normally located in the outer 3-foot vegetative shell of a tree (5). Small trees may also be more adaptable to mechanical harvesting equipment of the future, especially if arranged in hedgerows where machines could be utilized in assembly line fashion.

Proper control of vegetative growth is a very important aspect in the success of a closely spaced planting. Vigorous shoot growth necesitates frequent pruning to hold the trees within their allotted space. Pruning further stimulates excessive vegetative growth and may perpetuate the problem at the expense of fruit production. Hedging should be started early in a closely spaced grove to avoid heavy cutting and some selective pruning may be desirable to remove excessively vigorous shoots.

Because of problems associated with excessive vegetative growth and its control by pruning, it would seem advantageous to use other methods to reduce tree vigor without sacrificing yield. Research is being conducted to find a satisfactory growth retardant which can be used to control vegetative growth and reduce pruning requirements in present plantings. In future high-density plantings, it would seem highly desirable for growers to plant trees propagated on rootstocks which have a dwarfing influence on the scion (3). With such a combination, less vegetative growth would occur, the pruning requirement would be reduced, and more desirable fruiting wood would be retained.

There are still unknown factors involved in closely spaced plantings, and the prudent grower will carefully consider all aspects before undertaking such a venture. However, experimental results have thus far been most encouraging and clearly indicate the feasibility of high-density plantings as a means of attaining profitable citrus groves in the future.

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