Reprinted from
*Proc. Fla. State Hort. Soc.* 109:115-117. 1996.

Castle, W.S.

# INTERPLANT COMPETITION AND ROOTSTOCK AFFECT THE GROWTH AND YIELD OF 'HAMLIN' ORANGE TREES USED FOR REPLANTING

WILLIAM S. CASTLE AND JAMES C. BALDWIN
*University of Florida, IFAS*
*Citrus Research and Education Center*
*700 Experiment Station Road*
*Lake Alfred, FL 33850*

*Additional index words. Citrus sinensis.*

*Abstract.* **'Hamlin' trees on several rootstocks of different vigor were randomly planted in 1986 throughout part of a 30-year-old grove in central Florida to study the effects of tree vigor and the competitive environment on tree behavior. The 30-year-old trees were on rough lemon (*C. jambhiri* Lush.) rootstock in N-S rows. The experiment trees were used for interplanting and resetting. The in-row spacings between the experiment trees and the adjacent ones varied from 7 ft to 15 ft. All trees were irrigated with microsprinklers; cultural practices were typical for the Astatula fine sand soil at the site. Heights of the test trees were measured periodically, and yield was rated annually between 1991 and 1996. These data were used at the end of the study to compare each experiment tree to a ranking of its competitive environment based on the size and proximity of the two possible adjacent trees. Heights of the 10-year-old test trees on the citrange or mandarin rootstocks were about 11 ft to 13 ft, and were 6 ft to 8 ft for those on C-35 citrange. Tree heights generally decreased 30%, and yield 50%, as tree-to-tree competition increased. These responses were independent of tree vigor for the rootstocks tested.**

Common sense and various economic considerations essentially dictate the fullest utilization of land planted with citrus trees. There are two commonplace strategies to increase land use after a grove has been planted: interplanting, and replanting at in-row spacings less than those used originally. In mature groves, the trees may not form continuous canopies because of "excessive" in-row distances (e.g. > 15 ft between trees) by modern standards. In such groves, there are often extra spaces between trees that are considered plantable. Also, the loss of a tree in any grove with trees about 12 ft or more apart in the row, is frequently considered an opportunity to replant with additional trees closer together. These trees can be set about 8 ft to 10 ft apart and are presumed to fill the vacant space rapidly while ultimately enhancing overall productivity of the grove.

Citrus trees in a grove compete for resources like water, nutrients, and light. As the distance between trees decreases and resources become more limiting, competition increases, and there are notable tree responses. Spacing experiments show that the growth of individual trees becomes more upright, and yield per tree declines as they are planted closer together (Boswell et al., 1975; Phillips, 1974; Wheaton et al., 1995). These behaviors are useful for establishing expectations when interplanting and replanting, but they may not completely describe tree responses in the generally more competitive environment of new trees planted among older ones.

This report concerns trees leftover from a formal rootstock experiment planted near St. Cloud. The extra trees were used as interplants and replants in a mature grove near Sebring where we planned to make casual observations that would supplement the data from the formal trial; however, many of these extra trees were planted in situations that affected tree growth and yield because of apparent interplant competition. Therefore, our objectives were an examination of the assumptions that: (1) the trees would respond to increased competition in the same manner as reported for trees in spacing trials; and, (2) the trees on the more vigorous rootstocks would show relatively less effect from interplant competition than those on less vigorous rootstocks.

## Materials and Methods

*Site description and plant material*

The 40-acre experiment grove is located in north Sebring, FL (81°28'W longitude, 27°31'N latitude) in an area of Astatula fine sand, a deep, excessively drained soil of mostly brownish yellow sand with <1% organic matter. The grove was planted in the 1930s, but about 20 acres were removed in the 1950s because of burrowing nematodes. The land was fumigated and left fallow, then replanted with 'Pineapple' sweet orange (*Citrus sinensis* (L.) Osb.) trees on rough lemon (*C. jambhiri* Lush.) rootstock in the early 1960s at 15 ft × 25 ft. The grove has been replanted with 'Hamlin' sweet orange since the 1970s. The trees have been well cared for with cultural practices typical of fruit raised for juice; microsprinkler irrigation was installed prior to 1986. Heights of the mature trees were from 18 ft to 24 ft.

Unequal numbers (ranging from < 5 to ca. 15) of 'Hamlin' trees on 22 rootstocks were randomly planted in Dec. 1986 throughout the 20-acre area fumigated earlier. The rootstocks included C-35, Carrizo, Rusk, and Troyer citranges (*C. sinensis* × *Poncirus trifoliata* (L.) Raf.), Cleopatra, Shekwasha, and Sunki mandarins (*C. reticulata* Blanco), × 639, a Cleopatra mandarin-trifoliate orange hybrid, and others (see Castle et al., 1993, p. 45). Some trees were used to replace original trees and some were used as interplants between existing trees spaced 15 ft apart. Other trees were used for replanting where, instead of replacing one tree with another, the 30 ft-space created in the row by removal of an older tree was filled with two trees spaced 10 ft apart.

Experiment-tree height was measured periodically with the last measurement in Sep. 1996. Beginning in the 1991-92 season, yield/tree was estimated for six years with the following ratings: 0 = no fruit to 0.5 boxes; 1 = 0.6 to 1.5 boxes; 2 = 1.6 to 3.0 boxes; 3 = 3.1 to 4.5 boxes; and 4 = > 4.5 boxes. The annual ratings were compiled into a cumulative yield estimate. Also in 1996, the distances from the experiment trees to the immediately adjacent in-row trees on the north and south sides were measured; and, the type of adjacent tree was noted (Table 1). In this report, the experiment tree and the adjacent trees and/or spaces are collectively referred to as a "plot," and each such plot is named according to the combi-

Florida Agricultural Experiment Station Journal Series No. N-01367. We thank Marvin Kahn, Wayne Douberley and Jay Whittaker of Kahn Grove Service for their support; also, Drs. Jim Syvertsen, Dave Tucker and Adair Wheaton for helpful critiques of the manuscript. This research was supported in part by funding from the FCPRAC: Project 928-27.

Table 1. Types of trees immediately adjacent to the north and/or south of each experiment tree.

| Type | Description |
|---|---|
| 0 | No adjacent tree within 15 ft to 20 ft. |
| 1 | Adjacent tree is the same age and size as the experiment tree. |
| 2 | Adjacent tree is a declining mature tree with less than a full canopy. |
| 3 | Adjacent tree is a healthy, large mature reset. |
| 4 | Adjacent tree is a healthy, large, original. |

nation of adjacent tree types. Thus, a [0-0] plot (or combination) consists of an experiment tree with no adjacent trees; a [1-3] plot consists of an experiment tree with a type 1 tree on the north side and a type 3 tree to the south as compared to a [3-1] plot with is just the opposite. Combinations of adjacent tree types were ranked for degree of interplant competition with [0-0] being the least, and [4-4] being the most competitive environment (Fig. 1). Distance to the adjacent trees was not considered in the ranking. This ranking was the basis for evaluating tree height and yield responses within a rootstock. In order to have one to three replicates at enough points along the continuum of interplant competition to establish a trend, it was necessary, in some instances, to combine the data of trees on various rootstocks that behaved similarly. By this means it was possible to make comparisons between two rootstock groups, and several individual rootstocks. There were insufficient data to include the remaining rootstocks in this report.

## Results and Discussion

The 10-year-old experiment trees in the relatively uncompetitive plots [0-0] and [1-0], had grown to reasonable heights (7.5 ft to 12.5 ft) considering their age and known differences in rootstock vigor (Table 2; Castle et al., 1993). Trees on F80-3 citrumelo were among the tallest. Their heights and yield ratings declined when there were one or two adjacent mature trees even when the distances to these trees were 12 ft to 15 ft (Table 2). For Smooth Flat Seville, tree height was about 2.5 ft shorter in the [2-3] plot, and the yield estimate was much lower than in the [0-0] or [1-0] plots (Table 2).

Among the combined 15 trees on mandarin rootstocks, those with no adjacent trees, or with similar-aged trees on one or both sides, were about the same height, 13 ft, but the yield ratings varied with tree proximity (Table 2; Fig. 1). The adjacent trees were 7 ft from the experiment tree in the [1-1] plot (Fig. 1), a spacing which limits individual tree yield (Wheaton et al., 1995). The one tree in the [0-0] plot was on Cleopatra mandarin rootstock and it had relatively low yield estimates for no apparent reason; perhaps root rot was affecting its performance (Castle et al., 1993).

The heights and yield ratings of the trees on the mandarin stocks did not change consistently as the level of interplant competition increased. Tree height and the yield rating decreased in the plots where there was one adjacent healthy, mature tree (Fig. 1: [0-3]); but, the trees were taller with high yield ratings in the [1-2] plot. When the experiment trees were between a similar-aged tree and a healthy mature tree, [1-3], or two declining older trees, [2-2], they were smaller and had lower yield ratings. In the most competitive situation, [2-3], the adjacent trees were mostly about 15 ft away which allowed more normal tree growth, but the yield ratings still remained well below those for the trees in the least competitive environments (Fig. 1).

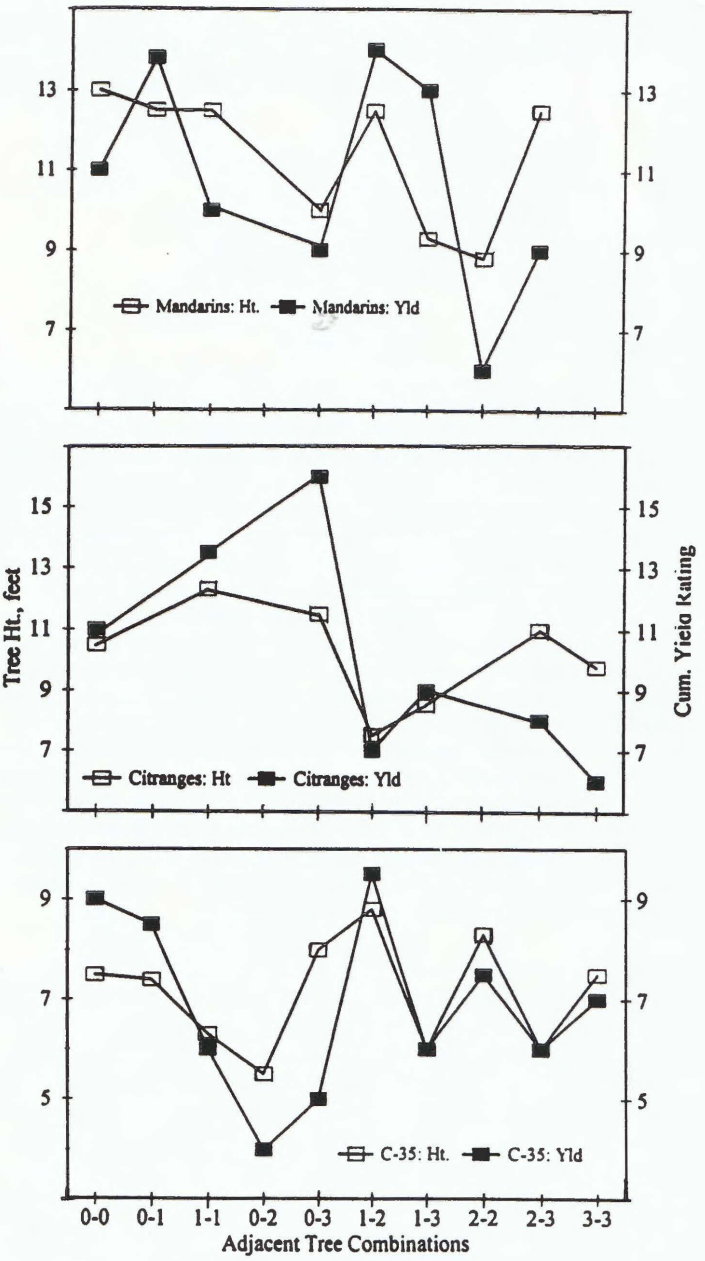


Figure 1. Growth and estimated yield responses of 'Hamlin' sweet orange trees on several mandarin rootstocks (top panel), on Carrizo and Troyer citranges (middle panel), and on C-35 citrange (bottom panel) planted in N-S rows among several types of trees adjacent to the experiment tree (see Table 1 and text). Each combination gives the adjacent tree types but not their relative position, (i.e., [1-2] also represents [2-1]. The adjacent tree combinations are ranked, left to right, in increasing degree of competitive effect on the experiment tree with types 3 and 4 (not listed) being considered equivalent in the ranking. The distances to adjacent trees varied from 7 ft to 15 ft (see also Table 2).

The overall height and yield rating trends of the normally vigorous 'Hamlin' trees on Carrizo or Troyer citrange were similar to those for the equally vigorous trees on the mandarin rootstocks. However, there were also differences between the two rootstock groups that illustrate the importance of the specific field situation. The trees on Carrizo or Troyer were between about 10 ft and 12 ft tall when growing with little competition, [0-0], in the more typical grove situation, [1-1],

Table 2. Tree heights and cumulative yield ratings for 10-year-old 'Hamlin' trees on several rootstocks used for replanting in an older grove where the adjacent trees in the row were similar or different in age, size, and proximity.

| | Adjacent tree combination[z] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1-0; 0-1 | | | 1-1 | | | 1-2; 2-1 | | | 2-3; 3-2[y] | | |
| Rootstock | Distance to adj. tree, ft | Tree ht, ft[x] | Cum. yield rating[w] | Distance to adj. tree, ft | Tree ht, ft[x] | Cum. yield rating[w] | Distance to adj. tree, ft | Tree ht, ft[x] | Cum. yield rating[w] | Distance to adj. tree, ft | Tree ht, ft[x] | Cum. yield rating[w] |
| Carrizo and Troyer citranges | —[u] | 10.5 | 11 | 10-10 | 12.5 | 13 | 14-11 | 7.5 | 7 | 13-10 | 9.8 | 6 |
| Mandarins[v] | 10-10 | 12.5 | 14 | 7-7 | 12.5 | 10 | 7-13 | 12.5 | 14 | 10-15 | 12.5 | 9 |
| Smooth Flat Seville | 10-10 | 10 | 11 | | | | 7-15 | 10.5 | 10 | 10-15 | 7.5 | 4 |
| F80-3 citrumelo | 10-7 | 12.5 | 11 | | | | 15-10 | 9.0 | 10 | 15-12 | 9.5 | 7 |
| C-35 citrange | — | 7.5 | 9 | 10-10 | 6.3 | 6 | 10-15 | 8.5 | 9 | 15-15 | 7.0 | 6 |

[z]See Table 1 and text for explanation of tree types. A particular type of tree may occur on the north or south side of the experiment tree. Blank spaces indicate that there were no experiment trees in those settings.
[y]Also includes all combinations of type 2, 3 and 4 trees.
[x]Measured in Sep. 1996.
[w]Based on six crop ratings from 1991-92 through the 1996-97 season.
[v]Includes data of trees on Sunki, Shekwasha, and Cleopatra mandarins, and hybrid × 639.
[u]Dash (-) indicates no trees within 15 to 20 ft, or only very young resets planted nearby.

of two adjacent same-aged trees planted within 10 ft, or in the [0-3] plot (Fig. 1). Tree height changed very little across the [0-0] to [0-3/3-0] adjacent tree combinations, but the yield ratings increased substantially. In the latter plot, the adjacent type 3 tree was located 10 ft to the north side, and there was no competition in the row to the south side which allowed the experiment tree to develop a relatively large canopy volume and yield. In the remaining more competitive plots [1-2] to [3-3], the trees were shorter, and the yield ratings declined markedly to the overall lowest values. The relatively high yield rating of 9 within this group of more competitive plots, is the result of a situation similar to the one described for the tree in the [3-0] plot.

Trees on C-35 are normally of lower vigor than those on most other citrange and mandarin rootstocks (Castle et al., 1993). The 'Hamlin' trees ranged from 6 ft to 8 ft in height when there was little adjacent tree competition (Table 2; Fig. 1). Tree height remained within this range as tree-to-tree competition increased, but there were fluctuations in the heights and yield ratings that can be explained based on the specific circumstances. All yield ratings for trees in the more competitive settings were below those of trees in the [0-0], [0-1], or [1-1] plots with one exception, the two trees in [1-2] plots (Fig. 1). The latter trees had a declining, mature tree on the south side, spaced at 15 ft, and a same-aged tree on the north side at 10 ft. The [1-2] experiment trees grew well and were particularly productive suggesting that their competitive environments were more comparable to those of the [0-0] and [0-1] trees. The fluctuations in tree heights and yield ratings between the trees in the [1-3] to [3-3] plots were largely due to differences in the distances to the adjacent trees. The experiment trees in the [2-2] plots had relatively high values because the large, adjacent trees were 15 ft away as compared to those in the [1-3] or [2-3] plots where the adjacent trees were within 7 ft to 10 ft.

The various adjacent tree combinations were ranked for their degree of competition on the assumption that the older trees would have roots throughout the soil into which the new trees were planted. There would be competition for water and nutrients, and the large canopies of the older trees would create competition for light if these resources were limited. This assumption of resource competition was not directly evaluated, but decreases in tree growth and productivity were the ultimate manifestations. Within the range of interplant competition in this experiment, the effects on tree heights and yield ratings were consistent across rootstocks and appeared to be related to the types of adjacent trees, and their proximity. The trees responded to increased competition in the same manner as trees in spacing trials. In the most competitive environments, tree growth tended to be more upright, but low tree productivity was the primary consequence of interplant competition apparently because of restricted canopy volume development. Such responses show that young 'Hamlin' trees planted among mature ones spaced 15 ft apart, or when replanted at closer than the original spacing, will survive and grow, but with less effect on growth than yield. The extra trees may have increased yield/acre but an economic analysis is needed to demonstrate an overall financial benefit.

## Conclusion

Interplanting or replanting in a mature grove seems justified only when a minimum of 8 ft is available for canopy development of the new trees. Trees 8 ft apart from trunk-to-trunk do not meet this criterion. The needed space must be between canopy driplines. Furthermore, this conclusion seems to be independent of tree vigor at least for the rootstocks included in our study.

## Literature Cited


1. Boswell, S. B., C. D. McCarty, K. W. Hench and L. N. Lewis. 1975. Effect of tree density on the first ten years of growth and production of 'Washington' navel orange trees. J. Amer. Soc. Hort. Sci. 100:370-373.
2. Castle, W. S., D. P. H. Tucker, A. H. Krezdorn and C. O. Youtsey. 1993. Rootstocks for Florida citrus, second edition. Univ. Fla. Coop. Ext. Pub. SP 42.
3. Phillips, R. L. 1974. Performance of 'Pineapple' orange at three spacings. Proc. Fla. State Hort. Soc. 87:81-84.
4. Wheaton, T. A., J. D. Whitney, W. S. Castle, R. P. Muraro, H. W. Browning and D. P. H. Tucker. 1995. *Citrus* scion and rootstocks, topping height, and tree spacing affect tree size, yield, fruit quality, and economic return. J. Amer. Soc. Hort. Soc. 120:861-870.