Properties of Young and Mature 'Valencia' Oranges Related to Selective Harvest by Mechanical Means

G. E. Coppock
MEMBER ASAE

FLORIDA produced over 6 million tons of oranges in 1970. About 50 percent of this production was "Valencia," a late season variety. The remaining production was early and midseason varieties ("Hamlin" and "Pineapple"). Research has been underway for several years to mechanize the harvest. Several promising mechanical concepts have been demonstrated for early and midseason varieties, Coppock (1969). These varieties have only one crop on the tree at harvest time and it can be harvested in a once-over operation. The problem of harvesting "Valencia" oranges is unique in that the trees bear both young fruit, which will develop into next year's crop, and mature fruit at harvest time, Fig. 1. To harvest this variety maximum mature fruit removal is desired with a minimum removal of young fruit so as not to cause a reduction in the subsequent crop.

Several of the harvest concepts for early and midseason varieties have been tried for the selective harvest of the "Valencia" variety. Hedden and Coppock (1968) reported a reduction in yields for trees harvested with a limb shaker. Whitney (1968) found evidence of a yield reduction for trees harvested with a forced air shaker.

This research was conducted to obtain information on properties of young and mature "Valencia" fruit which may contribute to the apparent yield reduction with limb shakers and to relate these properties to each other. These relationships might be used as criteria for selective harvest. Coppock, et al (1969) reported on the biophysical properties of mature citrus fruit as related to mechanical harvesting.

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The author is: G. E. COPPOCK, Agricultural Engineer, Florida Dept. of Citrus, University of Florida, IFAS, AREC, Lake Alfred, Fla.

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FIG. 1 A limb from a "Valencia" orange tree showing the relative size of young and mature fruit on May 19, 1970. About 50 percent of Florida's orange production is of the "Valencia" variety.

EQUIPMENT AND METHODS

Research was extended over the 1968, 1969 and 1970 harvest seasons to determine the effects of a limb shaker on subsequent yields. Nine 3-tree plots were used in which the trees were selected for similar harvesting characteristics. The trees were on 18 by 24-ft spacing and averaged 18 ft in height. Three replications of three harvest treatments were applied at three dates of harvest for each season. One of the following treatments was applied to each tree in a plot for three seasons: 1. subdued shaking intensity, 2. maximum shaking intensity, and 3. handpicked. At maximum intensity, the objective was to obtain maximum removal of mature fruit without regard to the removal of the young fruit while at subdued intensity maximum removal of mature fruit with a minimum removal of young fruit was the objective. A shaker designed similar to the one reported by Coppock and Hedden (1968) was used. The stroke of the unbalanced weight was 6 in. and the maximum frequency was 350 cpm. Performance data for the shaker are given in Table 1. In the test mature and young fruit removed and the mature fruit left on the trees were counted. Subsequent yield was measured by counting the mature fruit produced the following season.

"Valencia" trees normally tend to compensate for fruit lost when young fruit is thinned by increasing the weight of the fruit remaining on the tree, thus weight would be a better measure of total fruit production. However, it was felt that fruit count would be a better measure of the yield as affected by selective harvesting. The two measures would give the same yield if it were assumed that the thinning of the young fruit was not high enough to cause the remaining fruit on the tree to increase in weight. It should be recognized that cultural practices and the alternate bearing characteristic of this variety have a large influence on subsequent yeilds. These factors were kept as uniform as practically possible. For this experiment the first year's yield (1968) was used to represent the bearing potential of the trees.

Following are definitions of the terms used in this study:

Harvest date – date when harvest was performed.

Harvest season – period each year when mature fruit of a particular variety has economic value. It can also be used to refer to the harvest season of a group of varieties.

TABLE 1. AVERAGE PERFORMANCE OF LIMB SHAKER PER SEASON

Year	Harvest treatment	Actual shake time per tree min	Mature fruit removal, percent	Yield, no. of fruit
1968	Maximum intensity	1.20	88	1072
	Subdued intensity	0.51	80	951
	Handpicked	——	100	988
1969	Maximum intensity	1.27	84	742
	Subdued intensity	0.54	76	742
	Handpicked	——	100	1012
1970	Maximum intensity	2.17	86	731
	Subdued intensity	0.62	73	761
	Handpicked	——	100	900

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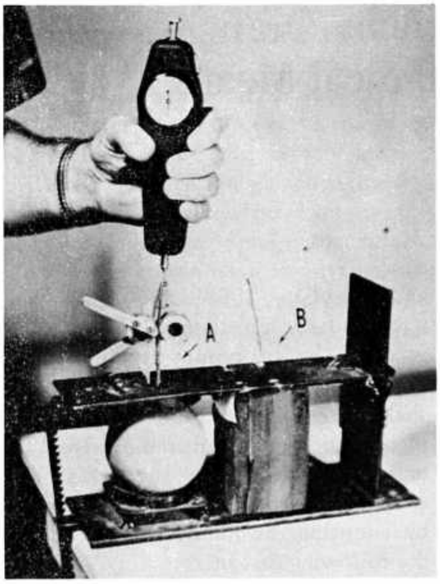

FIG. 2 Instrument used to determine fruit detachment force. Circular opening (A) for clamping mature fruit was 1/2-in. diam. Slotted openings (B) for clamping young fruit were of various sizes to accommodate different size fruit.

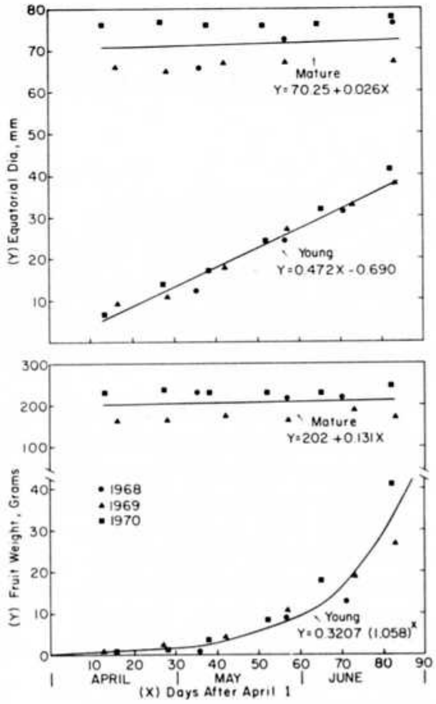

FIG. 3 Influence of the harvest date on the weight and equatorial diameter of young and mature "Valencia" oranges for three seasons.

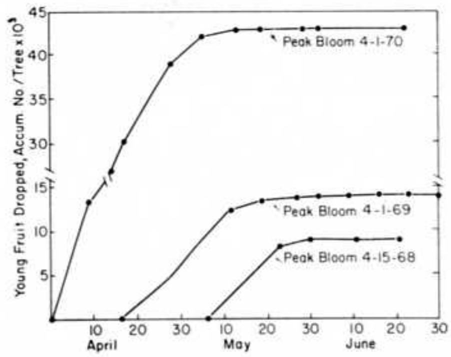

FIG. 4 Accumulated young fruit dropped per tree at various dates during the harvest season for three seasons.

Detachment angle – angle detachment force was applied with respect to the major fruit axis.

Detachment force – force in kilograms required to separate the stem from the fruit.

Fruit weight – weight of fruit in grams.

Fruit diameter – equatorial diameter of fruit.

Fruit droppage – the number of young fruit that drops off a tree in a unit of time.

Yield – number of mature fruit produced by one tree in one season.

Subsequent yield – number of mature fruit produced by one tree the following season.

Crop – fruit produced by several trees in one year.

Fruit properties were determined at intervals during the harvest season from a composite sample of 60 mature and 60 young fruit taken at random at a 6-ft height on the trees. Each fruit was clipped off leaving a stem 4-6 in. long. Subsamples of 20 fruit each were used to determine the weight, diameter, and detachment force at 0, 45, and 90 deg detachment angles for both mature and young fruit.

The detachment force was determined at different angles relative to the major fruit axis on the instrument shown in Fig. 2. Samples with stems attached were brought into the laboratory, fruit and stem clamped and the detachment force measured on a Hunter scale (Model No. L30M) by pulling the stem off with a smooth motion at the desired angle. This resulted in a loading rate on the stem of approximately 10 pounds per second for mature fruit. The circular opening in the clamp to hold the mature fruit is 1/2-in. diameter. Slotted openings of various sizes along the clamping bar are for clamping the young fruit. The fruit was weighed and then the equatorial diameter determined with calipers.

The young fruit droppage was determined by placing cloths under nine randomly located trees in the grove area and counting the fruit that dropped at intervals during the harvest season.

RESULTS

The influence of date on the weight and diameter of both young and mature fruit for three harvest seasons is shown graphically in Fig. 3. Each point is an average of 20 randomly selected fruit. Young fruit weight increased according to the exponential equation, $Y = 0.3207 (1.058)^X$ where X is the number of days after the reference date of April 1. Weight increased rapidly after May 15. Mature fruit increased in weight only slightly after April 1.

The diameter of young fruit increased according to the linear equation, $Y = 0.472X-0.69$ where X is the number of days after April 1, while the diameter of mature fruit changed very little during the same period.

Fig. 4 shows the accumulated number of young fruit dropped per tree at various dates for three seasons beginning at different dates after peak bloom. Each point is the average from nine trees. Young fruit droppage leveled out in May each season but the date this occurred varied from season to season. This variation is probably the result of differences in dates of peak bloom each year.

The influence of date on detachment force of both young and mature fruit determined at 0, 45 and 90-deg angles of detachment for one season is shown in Fig. 5. Each point is the average of 20 randomly selected fruit. Young fruit detachment force at 0-deg angle increased rapidly from a low of 1.2 kg to a high of 11 kg for the season. Mature fruit detachment force did not change materially. Detachment force for other angles of detachment followed the same general trend but increased at a slower rate. The detachment force of young fruit at 0-deg angle equaled that of mature fruit at 90-deg angle about May 7. By July 10, the forces for young and mature fruit were almost equal. This indicates that some degree of selectivity may be possible based on differences in detachment force at different angles of detachment.

The influence of harvest date on subsequent yield of trees that were shaken, measured as a percentage of the yields of handpicked trees over three seasons is shown in Fig. 6. Each point is the average of 6 trees adjusted for the original differences between yield of trees to be shaken and those to be handpicked. The yields were adjusted according to the following formula:

Adjusted yield (percent of handpicked)

$$= 100 \left[\frac{SS}{SH} \div \frac{OS}{OH}\right]$$

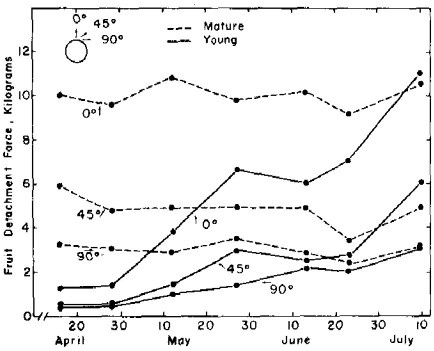

FIG. 5 Influence of harvest date on young and mature fruit detachment force at 0, 45 and 90-deg angles of detachment.

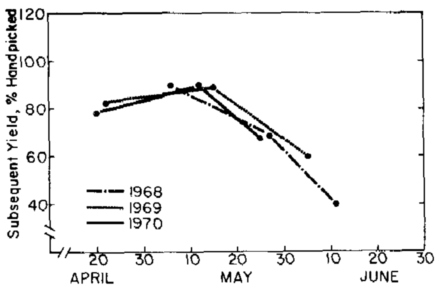

FIG. 6 Influence of date on subsequent yield of trees harvested with a limb shaker measured as a percentage of the yield of handpicked trees (check).

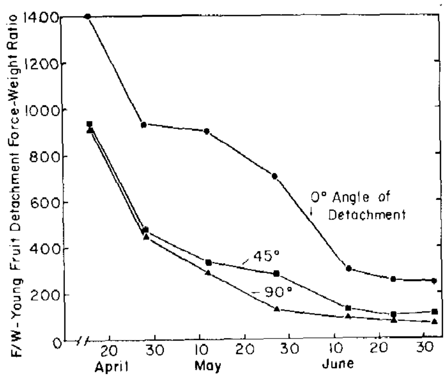

FIG. 7 The detachment force to weight ratio over one season for detachment forces determined at 0, 45 and 90-deg angles of detachment.

where

SS = Subsequent yield of shaken trees

SH = Subsequent yield of handpicked trees

OS = Original yield of shaken trees

OH = Original yield of handpicked trees

This formula assumes the original yields to represent the bearing potential of the tree.

Subsequent yield of shaken trees ranged from 80 percent at the beginning of the season to 94 percent about May 15 after which it decreased rapidly. It should be noted that this is about the date when the young fruit weight began to increase rapidly and the natural droppage of young fruit approached zero. Differences between subdued and maximum shaking intensities were not statistically significant, therefore the results of these treatments were averaged in Fig. 6.

The number of young fruit removed correlated poorly with subsequent fruit yields for the shaker treatment. This was expected because the number of young fruit removed was confounded with the natural fruit drop at harvest dates prior to the end of the main young fruit drop period (Fig. 4). No attempt was made to separate these two factors.

DISCUSSION

The differentials in weight and diameter of young and mature fruit are criteria for selective removal of mature fruit. They decrease as the harvest season progresses.

Stripper, spindle and shaker mechanisms show potential for selective removal of mature fruit. Strippers and spindles depend on differential in the diameter of young and mature fruit. Shakers depend on the differential in fruit weight. Variation in tree structure and fruiting habits influence the efficiency of selection which poses the problem of how much young fruit is it possible to remove without reducing the subsequent crop. The answer to this problem is complex because it involves not only the fruit removal methods but the biological nature of the crop. "Valencia" orange trees "set" many times the number of fruit required for a normal crop. Most of this fruit drops during the first month following bloom (Fig. 4) but some drop continues throughout the growing season. The number that drops depends on the physiological condition of the trees and climatic conditions. It might be hypothesized that if some of the young fruit were removed by mechanical or other means the loss would be compensated for by fruit staying on the tree that normally would have dropped. The end effect would be reflected by subsequent yields. The poor correlation obtained between young fruit removal and subsequent yield reduction offers some support to this hypothesis.

Changes in young fruit weight and detachment force are the main properties affecting the selective removal of mature oranges with shakers since these properties for mature fruit change very little during the season. These properties have opposing effects on selection. The increase in detachment force aids selection by hindering removal of young fruit. The increase in weight aids in removal of young fruit, thus hindering selection. Consequently, a ratio of detachment force to weight of the young fruit (F/W) would be expected to indicate the ease of removal of young fruit, thus inversely reflecting the ease of selection assuming uniform conditions. Fig. 7 shows how F/W of young fruit varies over one season for detachment forces determined at 0, 45 and 90-deg angles of detachment.

Decreasing the detachment force differential of young and mature fruit should increase the ease of selection. This could be done either by reducing the detachment force of mature fruit or by increasing it for young fruit. One prospective approach of accomplishing this is by developing and abscission chemical to stimulate the natural loosening process in mature fruit without affecting the young fruit. However, the optimum chemical would be one that would decrease the detachment force of mature fruit and increase it for the young fruit. Presently plant physiologists are considering this possibility.

Stripper and spindle fruit removal mechanisms have been tried for the selective removal of mature "Valencia" oranges. Lenker (1970) reported on the development of an auger picking head for selectively harvesting fresh market oranges. Since these mechanisms depend on the differential in fruit diameter between young and mature fruit, it would seem that good selection could be obtained. However, in practice limbs and leaves are stripped through a sized opening with the young fruit. This material restricts the opening causing some young fruit to be removed with the mature fruit. The possibility of young fruit removal increases as the differential in diameter of young and mature fruit decreases over the harvest season.

CONCLUSION

The differentials in diameter and weight of young and mature fruit are possible criteria for selective removal of "Valencia" oranges. Changes in the number of young fruit and their properties result in increasingly less efficient selection by mechanical means as the season progresses. Shaker harvest devices are influenced by changes in young fruit weight and detachment force. Stripper devices are influenced by the change in the young fruit size. About May 15 or when young fruit is 22 mm in diameter, several changes begin to occur in young fruit which have a marked influence on selective harvest with limb shakers. The fruit weight begins to increase rapidly; the detachment force continues a steady increase and the fruit droppages approaches zero. A result of harvesting after this date is a sharp decrease in subsequent yields. It is prior to this date that shakers have their greatest potential for selective harvest.

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