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TREE HEIGHT, FRUIT SIZE, AND FRUIT YIELD AFFECT MANUAL ORANGE HARVESTING RATES

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Abstract. **Orange harvesting rates were measured for 4 pairs of pickers in trees with heights from 12 to 18 ft, fruit sizes from 175 to 255/box, and fruit yields from 300 to 760 boxes/acre. Each picker used a conventional ladder and bag and emptied the harvested fruit into 10-box tubs. Average harvesting rates per picker ranged from 5.9 to 9.2 boxes/hr. A regression analysis of the data indicated a harvesting rate increase per picker of 1 box/hr for an approximate decrease of 6 ft in tree height, an increase of 200 boxes/acre in fruit yield, or an increase in fruit size equivalent to a reduction in count of 50 fruit/box.**

From the late 1950s through the early 1980s, harvesting was a major concern of the Florida citrus industry because of large crops, low labor availability, and low profit margins. A research program was pursued to investigate solutions and a considerable amount of information was developed on picking aids, mechanical harvesters, and abscission chemicals. The industry, however, failed to adopt the equipment and chemicals as a replacement for the manual (conventional) picker/ladder/bag method (Whitney and Harrell, 1989).

Since 1991, there have been renewed concerns about harvesting for the same reasons stated above (Whitney, 1995). The average cost of harvesting (tree to processing plant or packinghouse) almost equals the cost of production and is expected to escalate to $2.33/box of oranges by the 2002-03 season (Polopolus et al., 1993). Total Florida citrus production is expected to increase 48% to a record 362 million boxes in the decade ahead, and 75% of this will be oranges. These increases in production will require 10,000 additional pickers, and with foreign competition, are expected to depress on-tree fruit prices by 33%.

Since the early 1960s, Florida citrus growers have continued to plant and interset orange trees at higher densities to achieve high yields early and throughout the life of the tree. In 1980, the Lake Alfred Citrus Research and Education Center (CREC) initiated a cooperative experiment with the Coca Cola Company to investigate the management of orange trees planted at densities ranging from 150 to 360 trees/acre. One research objective in this experiment was to study effects of high-density planting variables on harvesting systems for processed oranges. Whitney et al. (1994) has discussed how various characteristics of this high-density grove may affect harvesting by manual means, with picking aids, and by machine.

The objective of the research reported in this paper was to quantify the effects of scion variety, rootstock, tree height, tree spacing, and other pertinent variables in this planting on the manual (conventional) harvesting rate.

Materials and Methods

Test site. The experimental orange grove used for the harvest tests has been described by Wheaton et al. (1986), Whitney et al. (1994), Wheaton et al. (1995), and Whitney et al. (1995). The trees were planted in 1980 on a 25-acre site in Polk County between Frostproof and Babson Park. Factors in

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the experiment are listed in Table 1. A multiple split plot design with 4 replications was used. Scion variety was the main plot factor followed by successively smaller subplot factors of tree height, between-row spacing, rootstock, and in-row spacing. There were 2 levels of each of the 5 factors for 32 factor combinations. Subplot 4 (Table 1) was the experimental unit and 4 rows × 7 trees with the center 10 trees (2 rows × 5 trees) designated for data collection.

'Hamlin' and 'Valencia' were the scion varieties representing early- and late- maturing oranges. Rusk citrange and Milam were chosen as moderately vigorous and vigorous rootstocks, respectively. Between-row spacings of 15 and 20 ft and in-row spacings of 8 and 15 ft gave 4 tree densities: 150, 200, 270, and 360 trees/acre. Tree heights of 12 and 18 ft were included as a treatment to determine if suitable fruit productivity could be achieved and maintained at lower heights to facilitate harvesting.

When the width and height of the tree row canopies reached containment size, they were maintained by hedging and topping. On the more vigorous canopies, hedging was initiated on the 15-ft row spacing in 1985 and the 20-ft row spacing in 1986; annual flat topping in the spring was initiated at 12 ft in 1987 and 18 ft in 1991. Hedging width was set at 6.5 ft until 1991 and 7 ft thereafter with a hedging angle of 7° from vertical toward the tree top. Beginning in 1991, the trees designated for the 12 ft height were flat topped twice (spring, fall) in an attempt to control regrowth and improve fruiting in the lower canopy of trees on the Milam rootstock. The trees designated for the 18-ft height were flat topped once in the spring.

Data collection. Data were collected during the 1993-94 season. To determine the harvest rates, 8 pickers (4 pairs) with 20-ft ladders and 90-lb fruit bags harvested the center 5 trees in the western row of each (tree row orientation north/south) experimental plot. Each pair of pickers harvested each of the 32 factor combinations, and placed the fruit in 10-box tubs (900 lb orange capacity). The time required for each pair to harvest each plot was recorded and fruit yield was determined by weighing.

On the 2 center plot trees, horizontal canopy diameter measurements were made near ground level in the in-row and across-row directions, and canopy height measurements were made. Tree canopy volume in each plot was calculated and based on the center tree canopy measurements and the assumption that the canopy naturally developed as one-half an ellipsoid according to the equation 1.

$$CV = (0.52)(H)(D_A)(D_I) \quad (1)$$

where CV = canopy volume, ft^3
H = canopy height, ft
D_A = horizontal canopy dimension across-row near ground level, ft
D_I = horizontal canopy dimension in-row near ground level, ft

Table 1. Experimental factors, plot designations, and levels of each factor.

Factor	Plot designation	Levels
Scion	Main	Hamlin orange Valencia orange
Tree height	Subplot 1	12 ft; 18 ft
Between-row spacing	Subplot 2	15 ft; 20 ft
Rootstock	Subplot 3	Rusk citrange (moderate vigor); Milam (vigorous)
In-row spacing	Subplot 4 (experimental unit)	8 ft; 15 ft

Modifications of canopy shape (and thus volume) by tree topping, hedging between rows, and merging canopies in row were based on these modifications of the ellipsoid shape.

Weight cropping efficiency in each plot was calculated by dividing the fruit yield (weight) by the canopy volume. Number cropping efficiency in each plot was calculated by dividing the weight cropping efficiency by the average fruit weight, which was determined from a sample of 50 to 80 fruit (~30 lb) taken from each plot. The weight and diameter of individual fruit in the sample were also measured and used to calculate the apparent specific gravities of individual fruit.

All data were statistically analyzed using SAS GLM procedures (SAS, 1985). Significant differences, where stated, refer to the 5% level of significance.

Results and Discussion

Average harvest rate. The average harvest rate of the individual pickers was expressed in two ways in each plot. First, the box harvest rate (BHR) was defined as the boxes/hr (1 field box = 90 lb). Second, the number harvest rate (NHR) was calculated by multiplying the BHR by the average number of fruit/box as calculated from the fruit sample. (See the nomenclature at the end of the article for definitions of terms, abbreviations, and units). The NHR (number of fruit/hr or fruit/hr) was calculated because the average fruit size varied considerably (153 to 270 fruit/box) among individual plots, and thus would affect the BHR, assuming each picker picked similar numbers of fruit per unit time. If this assumption is valid, then the NHR is independent of fruit size and may indicate how factors such as tree geometry and the number cropping efficiency (which may be confounded with fruit size) affect the rate at which the picker harvests individual fruit.

The average BHR values of the 4 pairs of pickers were 6.2, 6.6, 8.6, and 8.7 boxes/hr with an overall average of 7.6 boxes/hr. The rates varied by 41% from low to high, and because the 2 lowest and 2 highest rates were at either end of the spectrum, data from the 2 lowest and 2 highest pairs were pooled and designated as SLOW and FAST, respectively. Including the SLOW and FAST pickers in the statistical analysis as a class in the model statement of the GLM required that the harvest rate data be analyzed as a fractioned factorial because the SLOW and FAST pickers each harvested only 64 of the 128 plots. Both the BHR and NHR of the SLOW and FAST pickers were significantly different, averaging 6.4 and 8.7 boxes/hr, and 1421 and 1869 fruit/hr.

Fruit yield vs. fruit size. Although pickers generally prefer trees with higher yields to achieve higher BHR values, the average fruit size tends to be inversely related to fruit yield, boxes/acre. Wheaton and Stewart (1973) showed a similar relationship. Fig. 1 shows the relationship between fruit size and yield in this planting. (In each of the figures in this article, the 'best fit', least squares linear, exponential, logarithmic, or power regression line is shown. The mean values of each of the 32 factor combinations, averaged over 4 replications, are the rootstock/tree height combinations and were used to calculate the regression line. The statistical significance of the R^2 values in the figures and elsewhere in the text

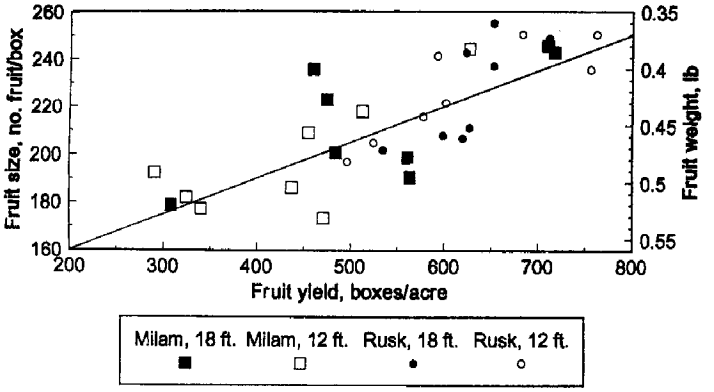

Figure 1. Fruit size (left ordinate) expressed as number of fruit per box versus fruit yield. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = 131 + 0.15(X). R^2 = 0.63**. The right ordinate shows the fruit weight corresponding to the fruit size on the left ordinate.

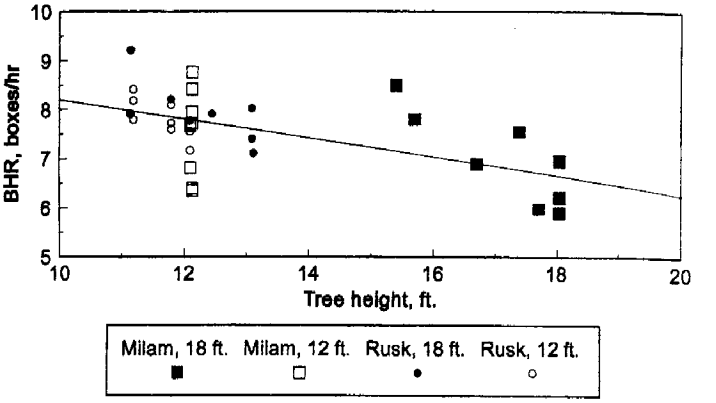

Figure 2. Box harvest rate (BHR) versus tree height. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = 10.1 - 0.19(X). R^2 = 0.32**.

is indicated by *0.05 and **0.01). Fruit size varied from 174 to 255 fruit/box while fruit yield varied from 300 to 760 boxes/acre. The NHR for the smaller fruit (255 fruit/box) would have to be 47% higher than for the larger fruit (174 fruit/box) to maintain a given BHR.

Factor effects on BHR. In-row tree spacing was the only experimental factor which had a significant effect on BHR, being 7.2 and 8 boxes/hr in the 8- and 15-ft in-row spacings, respectively. Some of the reasons for this were the fruit yield and the weight cropping efficiency were significantly higher for the 15-ft in-row spacing (see Table 2). There was also a significant rootstock × in-row interaction for BHR. Further examination of the data (Table 2) indicated the lower BHR at the 8-ft spacing was mainly due to the Milam (vigorous) rootstock, and probably resulted because of the low fruit yields and weight cropping efficiencies of the rootstock. The changes of the BHR with in-row spacing were similar for the SLOW and FAST pickers, and there was no statistical interaction between the two.

One would normally expect BHR to be reduced with increased tree height, but the tree height factor (12 vs. 18 ft) in this study did not have a significant effect on BHR, for several reasons. First, the average heights of the trees designated as 12 and 18 ft were actually 11.8 and 14.8 ft, respectively, because the trees on the Rusk rootstock and designated for the 18 ft height averaged only 12.1 ft (see Fig. 2). Therefore, 75% of the trees were approximately 12.1 ft high, and the remaining 25% averaged 17.1 ft high. Fig. 2 shows the range of BHR values for both the shorter trees (7.7 boxes/hr average) on the left and the taller trees (7.0 boxes/hr average) on the right. The linear regression line shows a decrease of 1 box/hr in BHR for each 5-ft increase in tree height, or a decrease of 0.9 boxes/hr from the shorter to the taller trees. The 7 lowest BHR values (< 6.9 boxes/hr) occurred in the Milam rootstock trees: 3 in the shorter trees (Milam, 12 ft) and 4 in the taller trees (Milam, 18 ft). These 7 low BHR values also occurred in the trees with the lowest weight cropping efficiencies as shown in Fig. 3, and these also were the Milam rootstock trees at the 8-ft in-row spacing. These data shown in Fig. 3 suggested the BHR increased with weight cropping efficiency up to a value between 0.2 and 0.25 lb/ft^3, and then became asymptotic at about 7.8 boxes/hr (the regression curve is not asymptotic). In the lower left quadrant of Fig. 3 below a weight cropping efficiency of 0.14 lb/ft^3, the 7 low BHR values discussed above averaged 6.4 boxes/hr or 19% less than 7.8 boxes/hr. However, in Fig. 3 it should be noted the 3 low values of BHR at weight cropping efficiencies above 0.3 resulted because of small fruit sizes at high fruit yields as discussed in Fig. 1.

The relationship between BHR and fruit yield is shown in Fig. 4, and the 7 low BHR values are in the lower left quadrant at a fruit yield of less than 500 boxes/acre. These data suggested BHR peaked between 500 and 600 boxes/acre, and then decreased somewhat as fruit yield increased to 770 boxes/acre, mainly because of the reductions in fruit size at the highest fruit yields (Fig. 1).

Overall, there was no relationship between BHR and fruit size (Fig. 5). However, if only the Rusk rootstock trees are considered in Fig. 5, the trend is for BHR to increase with increasing fruit size, perhaps because these trees were very similar in height and fruiting characteristics compared with the Milam rootstock trees. Again, the 7 low BHR values discussed above occurred across the range of fruit sizes, and illustrate with Fig. 3 and 4 that larger fruit sizes may not increase BHR if weight cropping efficiencies and fruit yields are low.

Table 2. BHR, fruit yield, and weight cropping efficiency values of rootstock × in-row spacing levels.*

	Rusk rootstock			Milam rootstock			Averages		
In-row spacing, ft	BHR, boxes/hr	Fruit yield, boxes/acre	Weight cropping efficiency, lb/ft^3	BHR, boxes/hr	Fruit yield, boxes/acre	Weight cropping efficiency, lb/ft^3	BHR, boxes/hr	Fruit yield, boxes/acre	Weight cropping efficiency, lb/ft^3
8.00	7.70	640.00	0.26	6.60	392.00	0.12	7.20	516.00	0.19
15.00	8.00	612.00	0.34	7.90	575.00	0.20	8.00	594.00	0.27
Avgs.	7.90	626.00	0.30	7.30	484.00	0.16	7.60	555.00	0.23

*See Nomenclature for definitions.

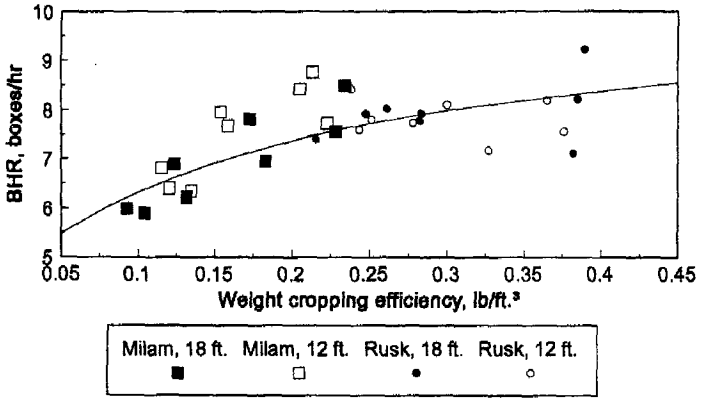

Figure 3. Box harvest rate (BHR) versus weight cropping efficiency. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = 9.6 + 1.35[ln(X)]. R^2 = 0.48**.

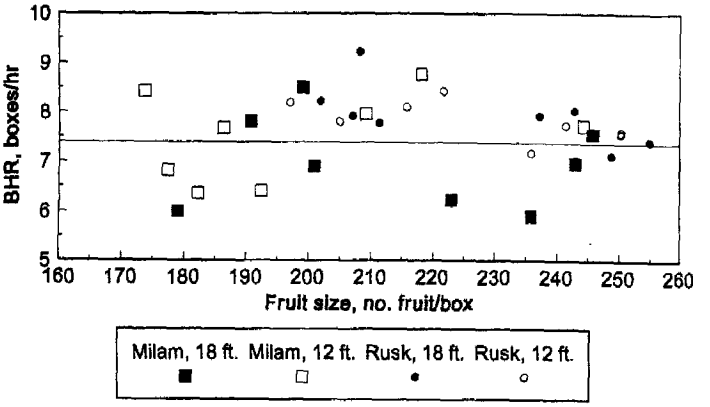

Figure 5. Box harvest rate (BHR) versus fruit size expressed as number of fruit per box. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = 7.45 + 0.0004(X). R^2 = 0.0002.

Factor effects on NHR. Scion variety had a significant effect on NHR as values were 1743 fruit/hr for Hamlin and 1546 fruit/hr for Valencia. In Hamlin, fruit size was significantly less (234 vs. 196 fruit/box) and number cropping efficiency was higher, 0.61 compared to 0.50 fruit/ft³ for Valencia. Fig. 6 shows a fairly good relationship between NHR and number cropping efficiency. The 7 low NHR values in the lower left quadrant of the figure averaged 1271 fruit/hr with an average number fruiting density of 0.26 fruit/ft³ and occurred in the same plots as the 7 low BHR values discussed above in Fig. 2 through 5. The data in Fig. 6 suggested NHR increases with number cropping efficiency up to a value of 0.5 to 0.7 fruit/ft³, and then becomes asymptotic at a value of about 1800 fruit/hr (not illustrated by regression line). The 7 low NHR values were 29% less than 1800 fruit/hr and in fruit yields of less than 500 boxes/acre, as mentioned above for the 7 low BHR values. Since fruit yield is a more commonly known variable, Fig. 7 shows its relationship with NHR, and the results are similar as one might expect to that with the number cropping efficiency.

The NHR of the Rusk rootstock averaged 1786 fruit/hr and was significantly higher than the NHR of the Milam rootstock at 1504 fruit/hr. In this case, the number cropping efficiency of the Rusk rootstock was more than double that of the Milam rootstock, 0.76 vs. 0.37 fruit/ft³. In addition, for the Rusk rootstock, fruit yield was significantly higher, and fruit size and tree height were significantly lower.

The NHR at the 20-ft between-row spacing was significantly greater than at the 15-ft between-row spacing (1692 vs. 1597 fruit/hr). The higher NHR at the wider between-row spacing was probably increased by the significantly smaller fruit size (218 vs. 209 fruit/box), but the significantly lower number cropping efficiency (0.52 vs. 0.58 fruit/ft³) would normally have decreased the NHR. In this case, one possible explanation that a lower number cropping efficiency would not decrease the NHR if the fruit is concentrated more in the outer portion of the tree canopy volume where it is nearer and more accessible to the picker. The number cropping efficiency only measures an average throughout the canopy volume, and even though the canopy volume/acre was 20% greater for the 20-ft between-row spacing (data not shown), the fruit yields (boxes/acre) were similar and number cropping efficiencies in the outer portions of the tree canopies could have been similar.

As with BHR, the NHR at the 15-ft in-row spacing was significantly higher than at the 8-ft in-row spacing, 1745 vs. 1545 fruit/hr. The number cropping efficiency was likewise significantly greater for the wider in-row spacing, 0.65 vs. 0.45 fruit/ft³. A significant in-row spacing × rootstock interaction resulted, as it did with BHR, because the NHR in the Rusk rootstock changed little (1770 to 1802 fruit/hr) with in-row spacing, while it increased markedly (1320 to 1687 fruit/hr)

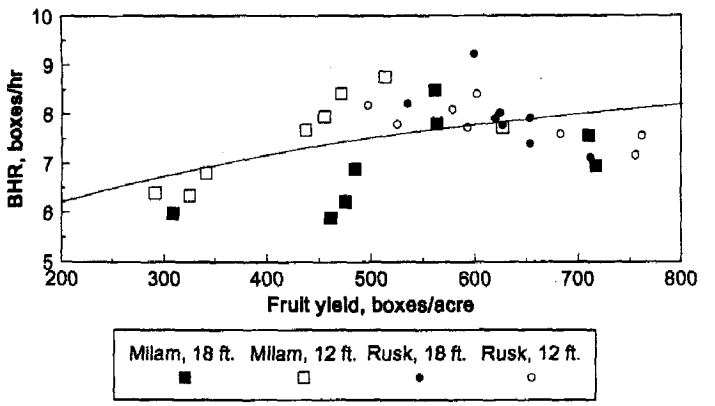

Figure 4. Box harvest rate (BHR) versus fruit yield. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = - 1.3 + 1.42[ln(X)]. R^2 = 0.20*.

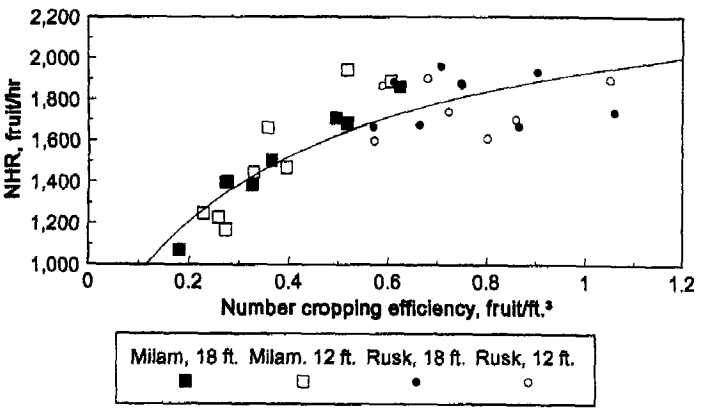

Figure 6. Number harvest rate (NHR) versus number cropping efficiency. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is Y = 1936 + 441[ln(X)]. R^2 = 0.71**.

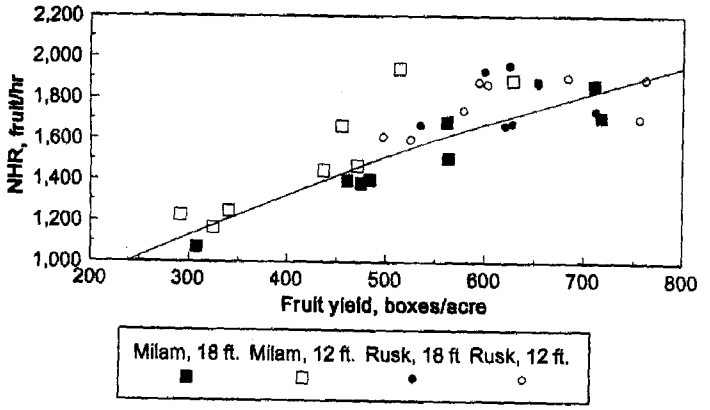

Figure 7. Number harvest rate (NHR) versus fruit yield. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is $\ln(Y) = 3.9 + 0.55[\ln(X)]$. $R^2 = 0.75^{**}$.

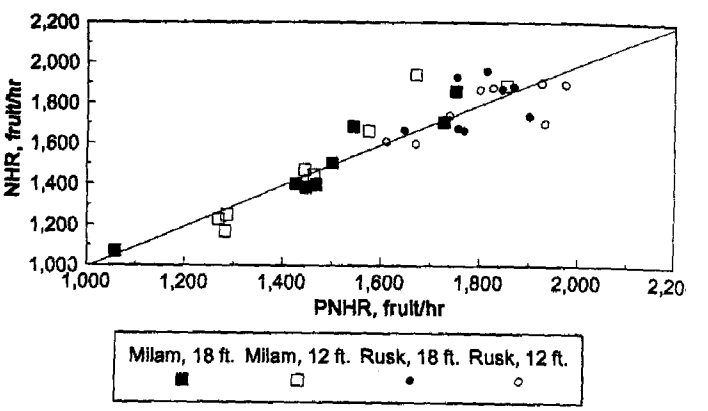

Figure 9. NHR versus PNHR. Each point is the average of 4 replication for a rootstock/tree height combination. The least squares regression line i $Y = 0.99(X)$. $R^2 = 0.84^{**}$.

from the 8 to the 15-ft in-row spacing in the Milam rootstock. Similarly, the number cropping efficiency of the Rusk rootstock increased from 0.66 to 0.86 fruit/ft^3 with increasing in-row spacing and that of the Milam rootstock increased from 0.27 to 0.47 fruit/ft^3. As discussed above, number cropping efficiencies of 0.43 to 0.57 fruit/ft^3 and greater resulted in similar NHR values, and the 7 low NHR values corresponded to an average number cropping efficiency of 0.26 fruit/ft^3.

Fig. 8 shows that, overall, NHR was inversely related to fruit size, and the 7 lower NHR values occurred across the range of fruit sizes. If only the Rusk rootstock trees (very similar in height and fruiting characteristics) are considered in Fig. 8, NHR changes little with fruit size.

Predicting harvest rates. Variables that could be readily measured in the field were considered for predicting harvesting rates. These were fruit yield (Y) in boxes/acre, fruit size (S) expressed as number of fruit/90-lb box, and tree height (H) in feet. A multiple regression analysis relating these 3 variables to the measured NHR values resulted in the predicted number harvest rate (PNHR)

$$PNHR = -630 + 544[\ln(Y)] - 151{,}531/(S) - 32.9(H) \quad (2)$$

$R^2 = 0.84^{**}$ Standard error of PNHR estimate = 106 fruit/hr

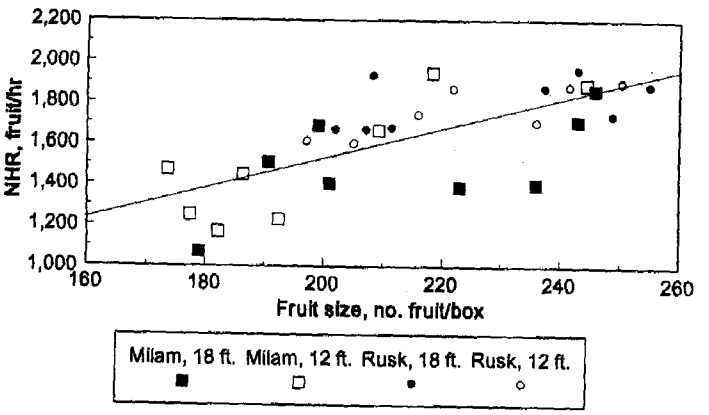

Figure 8. Number harvest rate (NHR) versus fruit size expressed as number of fruit per box. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is $Y = 66 + 7.3(X)$. $R^2 = 0.54^{**}$.

Fig. 9 shows the PNHR values from equation 2 plotted against the actual NHR values measured in this study. A linear regression analysis of these data resulted in

$$NHR = 0.999(PNHR) \quad (3)$$

$R^2 = 0.84^{**}$

A multiple regression analysis relating these variables to the measured BHR values yielded equation 4 for the predicted weight harvest rate (PBHR)

$$PBHR = -12.2 + 2.8[\ln(Y)] + 890/(S) - 0.15(H) \quad (4)$$

$R^2 = 0.62^{**}$ Standard error of PBHR estimate = 0.52 boxes/hr

As one might expect, the respective coefficients in equation 4 were approximately 1/200th of those in equation 2 or the average number of fruit/box in this study was about 200. Further analyses of the data resulted in a better fit for PBHR than equation 4 by dividing equation 2 by the number of fruit/box, which is a logical relationship, and resulted in equation 5

$$PBHR = (PNHR)/(S) = -630/(S) + 544[\ln(Y)]/(S) - 151{,}531/(S^2) - 32.9(H)/(S) \quad (5)$$

$R^2 = 0.68^{**}$ Standard error of PBHR estimate = 0.47 boxes/hr

Fig. 10 is a plot of the PBHR values from equation 5 and the actual BHR values measured in this study. A linear regression analysis of the data with a zero intercept resulted in

$$BHR = 0.999(PBHR) \quad (6)$$

$R^2 = 0.68^{**}$

Although the fit for PBHR (equation 5) was not as good as for PNHR (equation 2), it did indicate that PBHR increased with increasing fruit yield and size (decreasing number of fruit/box) and decreasing tree height in the same way that BHR was affected by these variables.

Consider the approximate range of variable values in this study: fruit size 174 to 255 fruit/box, fruit yield 300 to 760 boxes/acre, and tree height 12 to 18 ft. Table 3 shows the effects of these ranges on PBHR. The minimum and maximum PBHR values were 5.0 and 9.8 boxes/hr. In the top third of the table, PBHR changes or increases 0.8 to 2.0 boxes/hr when fruit size increases from 255 to 174 fruit/box at the 4 combinations of end-range values for fruit yield and tree

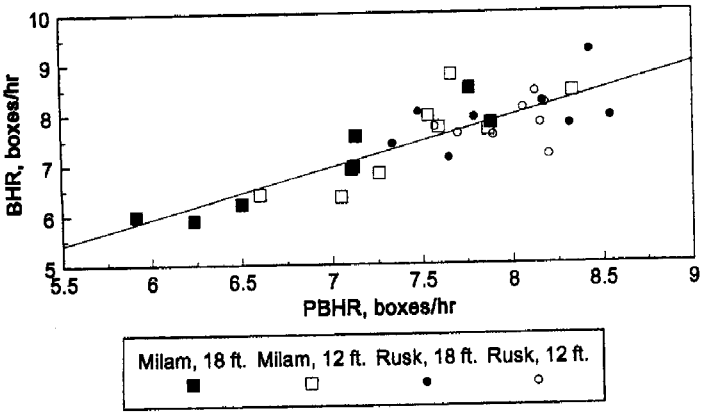

Figure 10. BHR versus PBHR. Each point is the average of 4 replications for a rootstock/tree height combination. The least squares regression line is $Y = 0.99(X)$. $R^2 = 0.68^{**}$.

height. Similarly, in the middle third of the table, PBHR changes or increases 2.0 to 2.9 boxes/hr when fruit yield increases from 300 to 760 boxes/acre at the 4 combinations of end-range values for fruit size and tree height. Finally, in the bottom third of the table, PBHR changes or decreases 0.8 to 1.1 boxes/hr when tree height increases from 12 to 18 ft at the 4 combinations of end-range values of fruit size and fruit yield.

Most of the mature Florida orange trees are similar to the trees on Milam rootstock in this study. At maturity, they are at least 18 ft tall. Assuming fruit size decreases (number of fruit/box increases) with increasing fruit yields as shown in Fig. 1, and fruit yield increases from 300 to 760 boxes/acre, fruit size will decrease from 180 to 250 fruit/box, and the PBHR will increase from 5.7 to 7.1 or 1.4 boxes/hr as predicted by equation 5. This is a 24% increase in PBHR. If the higher yielding trees are reduced to a 12-ft height, the PBHR increases to 7.9 boxes/hr or a 38% increase over 5.7 boxes/hr. This is a 2.2 boxes/hr increase. Reducing only the height of the high-yielding trees increases the PBHR 0.8 boxes/hr or 11%.

Thus, this study shows that high fruit yields on short trees can increase the PBHR more than 1/3 compared with low fruit yields on tall trees, or reducing the height of high-yielding trees by 6 ft can increase the PBHR by 11%. Further, this study gives a basis to estimate PBHR using 3 variables (fruit size, fruit yield, and tree height) which are measurable in the field.

Table 3. The effects of ranges in fruit size, fruit yield, and tree height on PBHR as predicted by equation 5.*

Fruit size, no. of fruit/box	Fruit yield, boxes/acre	Tree height, ft	PBHR, boxes/hr
255 to 174	300	12	5.8 to 6.9 (+ 1.1)
255 to 174	300	18	5.0 to 5.8 (+ 0.8)
255 to 174	760	12	7.8 to 9.8 (+ 2.0)
255 to 174	760	18	7.0 to 8.7 (+ 1.7)
255	300 to 760	12	5.8 to 7.8 (+ 2.0)
255	300 to 760	18	5.0 to 7.0 (+ 2.0)
174	300 to 760	12	6.9 to 9.8 (+ 2.9)
174	300 to 760	18	5.8 to 8.7 (+ 2.9)
255	300	12 to 18	5.8 to 5.0 (- 0.8)
174	300	12 to 18	6.9 to 5.8 (- 1.1)
255	760	12 to 18	7.8 to 7.0 (- 0.8)
174	760	12 to 18	9.8 to 8.7 (- 1.1)

*See Nomenclature for definitions.

In applying the information from this study to Florida orange harvesting, it should be remembered the harvesting rates measured were based on weight boxes. In actual practice, however, pickers are credited with the boxes harvested in the grove by bulk volume or the number of filled containers, such as the 10-box (900 lb) tub. This credit is an estimate and is usually adjusted up or down based on how this estimate compares with the actual weight determined at the processing plant. One of the main factors which contributes to the difference between the box estimate based on bulk volume and weight boxes is the apparent specific gravity of the individual fruit. In this study, the apparent specific gravity of the fruit varied from 0.87 to 0.93 or about 7%, and this would probably cause a 7% difference in the harvested boxes estimated by bulk volume and by weight. However, whether or not apparent specific gravity information is available, the PBHR values given by equation 5 should be useful in determining the relative effect of fruit yield, fruit size, and tree height on conventional harvesting rates.

Caution is advised in using equation 5 to estimate harvesting rates on orange trees and fruiting characteristics outside the physical limits existing in this study. In addition, this study was conducted on uniform-sized trees within each plot and caution should be used in applying equation 5 in groves with nonuniform tree size and fruiting characteristics.

Conclusions

The box harvest rate of conventional pickers in Florida oranges was predicted in uniform grove conditions with 3 variables: fruit yield, fruit size, and tree height. The ranges of values for the 3 variables were: fruit yield, 300 to 760 boxes/acre; fruit size, 255 to 174 fruit/box; and tree height, 12 to 18 ft Using multiple regression analyses, the equation for the predicted box harvest rate per picker accounted for 68% of the variability in the box harvest rate, which had an overall average value of 7.6 boxes/hr. Predicted box harvest rate increased with increasing fruit yield and fruit size, and decreasing tree height. Fruit size was inversely related to fruit yield. When the fruit yield of 18-ft trees increased from 300 to 760 boxes/acre, fruit size decreased from 180 to 250 fruit/box, and predicted box harvest rate increased from 5.7 to 7.1 boxes/hr. Reducing the tree height of the 760 boxes/acre trees from 18 to 12 ft increased the predicted box harvest rate to 7.9 boxes/hr. Thus, the predicted box harvest rate in the shorter, higher-yielding trees was greater by 2.1 boxes/hr or 38% greater than in the taller, lower-yielding trees.

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Nomenclature

1. BHR — box harvest rate per picker, expressed as number of boxes (90 lb/box by weight) of fruit harvested per hr or boxes/hr.
2. H — tree height, ft.
3. NHR — number harvest rate per picker, expressed as number of fruit harvested per hr or fruit/hr.
4. PBHR — predicted box harvest rate per picker, expressed as the number of boxes (90 lb/box by weight) of fruit harvested per hr or boxes/hr.
5. PNHR — predicted number harvest rate per picker, expressed as number of fruit harvested per hr or fruit/hr.
6. S — fruit size, expressed as number of fruit per 90-lb box, and was calculated by dividing 90 by the average fruit weight in lb from the fruit samples.
7. Y — fruit yield per unit area, expressed as boxes/acre.
8. Number cropping efficiency is the average number of fruit per unit canopy volume expressed as fruit/ft^3.
9. Weight cropping efficiency is the weight of fruit per unit canopy volume expressed as lb/ft^3.

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CITRUS PRODUCTION DECISIONS MAY BE AIDED BY NETWORK RESOURCES[1]

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Additional index words. Email, e-mail, E-mail, electronic mail, telecommunications, Internet, networks, DISC.

Abstract. **A series of experiences with electronic mail [e-mail] as a replacement for conventional mail, telephone communications and commuting to meetings is described with the intent that readers will be encouraged to choose e-mail more frequently and use it more effectively. E-mail was used extensively to put together a research proposal involving a team with members at remote locations which was presented to the Florida Citrus Production Research Advisory Council [FCPRAC]. The proposal described the flow of weather information through existing communication networks and into models of the activity of weather sensitive pests and stresses of Citrus. Although the proposal was not funded, the effectiveness of e-mail in fostering such collaborative efforts led to the contemplation of a Citrus Production Model which features a weather information front end and an interpretive back end with the middle a stack of weather sensitive pest and stress models. The purpose of the back end is to protect the user from being overwhelmed with the information that is expected to flow from such models. It is hoped that the model will be able to learn things about the user that will make it more efficient. The remaining experiences have to do with the introduction of e-mail into the FSHS Board of Directors communications, and a possibility of its use to interface members of the Board with advisors in the Horticultural Industries in regard to the selection of papers. The selection of papers of higher industry interest is expected to make it easier to attract both new members and better papers.**

The purpose of this report is to describe several situations in which electronic mail [e-mail] played a productive role in deliberations that impact citrus production decisions and decisions within the Florida State Horticultural Society [FSHS]. It is hoped that these experiences inspire some readers to experiment with e-mail in their communications with FSHS, other growers and perhaps with sources of weather information. The intention is to convince the reader to become more proficient with this means of communication by using it.

Experience confirms that effective use of the communications method increases with use (Elmer-DeWitt, 1995; Pike, 1995). There are more users every day and this increases the opportunity to substitute e-mail for telephone, FAX, or snail mail [as the e-mail enthusiasts refer to conventional mail] (Swerdlow et al., 1995; Rogers, 1995). Increased use of the network is forecasted rather convincingly by leaders in the microcomputer revolution (Elmer-DeWitt, 1995). One reason is that it is friction free (Gates, 1995).

Last year a delightful experience with the use of e-mail in distance education was described to the Society (Martsolf, 1994a). That experience occurred in conjunction with several experiences described here and all of these grew from experiences over the past 15 years with the networking of weather information, and especially satellite images (Martsolf, 1994b).

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