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CANOPY HEDGING, TOPPING, AND SKIRTING EFFECTS ON YIELD AND FRUIT QUALITY OF VALENCIA ORANGES

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Abstract. **A 5-year hedging, topping, and skirting experiment was conducted in 9-year-old Rohde Red Valencia (*Citrus sinensis* L. Osbeck.) orange on Carrizo citrange (*C. sinensis* × *P. trifoliate*) rootstock to investigate their effect on yield and fruit quality. Spring hedging resulted in higher juice brix than did fall hedging, but there were no consistent differences in yield. Compared to flat topping at 15 ft, flat topping at 12 ft reduced juice brix and pound solids/box, but yield was not consistently reduced. Angle topping resulted in consistently higher yield than did flat topping. Compared to no skirting, skirting at 20 and 36 inches high had no consistent effects on yield and fruit quality.**

Those in the business of growing and producing Florida citrus have always sought methods of maximizing returns from their plantings. In the 1960s, growers began planting higher density (more trees per acre) groves in hopes of achieving early returns on their investment and higher yields. Planting more trees/acre and the pressure from harvesters to reduce tree height, however, required growers to adopt hedging and topping of canopies as methods of tree size control. More recently, raising the height of the lower canopy (skirting) has become more common to make under-canopy cultural practices more efficient (e.g., the maintenance of microsprinkler irrigation systems). Skirting also improves the packout of fresh fruit and provides sufficient clearance for efficient operation of catchframe-type mechanical harvesting systems (Whitney et al., 2003).

Many growers found that planting higher density groves, while producing high yields and returns before the planting was 10 years of age, resulted in significant problems after the tree canopies had filled their allotted volumes and formed a hedgerow. Tree size was controlled with hedging and topping and yield per acre often declined. Whereas most hedging cuts are normally made at or near the same location or surface on the canopy, some growers have felt that "rejuvenation" hedging may stimulate the tree to produce more fruit. Rejuvenation hedging makes a more severe cut (deeper into the canopy to larger limb sizes) in year one, and then in subsequent years moves the cut toward the outer canopy to the original hedging surface. We have demonstrated (Wheaton et al., 1984, 1995) that topping trees, particularly the more vigorous scion/rootstock combinations, will cause significant yield reductions where significant regrowth (4 to 6 ft) occurs. We also demonstrated that good production could be maintained with higher density plantings if tree topping was minimized, but fruit production generally shifted toward the tree top because of shading and crowding effects (Whitney and Wheaton, 1984). Furthermore, manual harvesters disliked hedgerows because of difficulties associated with moving ladders and fruit across the row. Various cross hedging strategies to make manual harvesting easier were shown to reduce yield compared to the hedgerow (Wheaton et al., 1984). To answer grower concerns with "problem groves using current tree size control methods," we began to investigate hedging, topping, and skirting practices to determine their effects on yield and fruit quality.

Materials and Methods

An experiment was initiated in the fall of 1995 in a portion of a 70-acre grove near Arcadia, Fla. with trees spaced 25 × 15 ft on two row beds. The trees were 9-year-old Rohde Red Valencia (*Citrus sinensis* L. Osbeck) on Carrizo (*C. sinensis* × *P. trifoliate*) rootstock with microsprinkler irrigation. The trees had not been previously topped, averaged 15 ft in height, and had been hedged annually at an 8 ft middle width and 10 degrees on the side of the canopy. For the 70-acre grove, the grower's records showed the yield had peaked (562 boxes/acre) for the harvest in 1993 at 7 year old, and had then declined in yield each of the two subsequent seasons to 385 boxes/acre in 1995.

All hedging, topping, and skirting treatments were initiated in the fall of 1995 and the spring of 1996 and continued through the fall of 2000 and spring of 2001 (Table 1). Timing of hedging and topping treatments was considered to investigate lengthening the time period normally allocated for this activity and potentially reducing its cost. Hedging and topping has historically been done in the late winter and spring after early midseason harvest, and are done mainly by contract operators with expensive machinery. Fall hedging and topping, if severe cuts are made, can make the trees more susceptible to freeze damage, but it lengthens the time period

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for this activity to be accomplished. Thus, the demand for this specialized and expensive machinery can be spread over a longer period of time during the year and reduce costs. Both angle (gable top) and flat topping are being done in the industry, but angle topping conforms more closely to the natural canopy shape and is more expensive because of increased machinery time (more trips through the grove with machinery). The treatments were selected to investigate the effects of timing (Treatments 1, 2, 4) and severity (Treatments 1-4) of hedging, the timing (Treatments 1, 6, 7, 8), severity (Treatments 1, 5-9), and style (Treatments 12, 13) of topping, and the severity (Treatments 10, 11) of skirting. As indicated in the footnote of Table 1, the rejuvenation hedging treatment (no. 3) was initiated in the bed top middle in the spring of 1996 and the ditch middle in the spring of 1998. Within the fall and spring time period, hedging and topping treatments were done at the same time, and the spring treatments were done prior to harvest. Each plot or experimental unit had 16 trees, four rows wide by four trees long, and data were collected on the four center trees. The experiment was a randomized complete block design with five replications. Treatments 1-11 were located in a contiguous area of the 70-acre grove while Treatments 12 and 13 were located in a separate, adjoining contiguous area. Inadvertently, yield and fruit quality data were not collected in 1996. However, yield data were collected for 5 year (1997-2001) by weighing the manually harvested fruit from each plot. When trees were missing from the plots in the later years of the experiment, fruit was weighed from the existing trees in the plots, and boxes/acre and lb solids/acre yields were extrapolated from boxes per existing tree yields at 116 trees per acre. Fruit quality data were also measured during the 5 year by taking a 30 lb sample from each plot yield during harvest and analyzing it at the Lake Alfred CREC using commercial equipment.

Throughout the experiment, a total of 160 lb of nitrogen per acre was applied annually in four split applications. All other production practices, except for the hedging, topping, and skirting treatments in this experiment, were determined and applied uniformly across treatments by the grower. All data were analyzed by the GLM procedures in SAS (SAS Institute, Cary, NC). The main dependent variables considered in the analyses were boxes/acre, lb solids/acre, percent juice, brix, lb solids/box, acid, ratio, and weight of individual fruit.

Results

Grower records showed the average yield in 1996 was 407 boxes/acre in the 70-acre grove where the experiment was conducted. The yield in the experiment from 1997 to 2001 averaged 642, 256, 302, 134, and 351 boxes/acre, respectively. In the January-February period prior to the 1997 and 2001 harvests, temperatures were low enough on several mornings to cause leaf burn on young flush growth resulting from the 1996 and 2000 fall hedging and topping cuts.

Hedging effects. For most of the hedging cuts, except for the "rejuvenation" cut of Treatment 3, the amount of foliage removed was minimal. The effects of spring vs. fall hedging (Treatment 1 vs. 2) were similar over the 5 year for most of the variables. The most consistent trend was for brix in which case spring hedging resulted in the highest value for four of the five seasons, and was significantly higher for 2 of the 5 year (Table 2). In the table, 5 year contrast means are shown and the individual years that the annual means were significantly different. SAS has a procedure that allows for the comparison of contrast means, each of which may include one or more treatment means. Contrast means for other variables were significantly different in some years but the differences were not consistent from year to year. Hedging in both the spring and the fall (Treatment 4) resulted in higher brix for 4 of the 5 years compared to the average brix of spring (Treatment 1) and fall (Treatment 2) hedging. Rejuvenation hedging (Treatment 3), compared to spring hedging (Treatment 1), showed no consistent differences with any of the variables. Overall, there were no significant differences between Treatments 1-4 on boxes/acre and lb solids/acre.

Topping effects. Comparing spring and fall flat topping (Treatments 1 and 6 vs. 7 and 8), fall topping resulted in higher box/acre yields all 5 years and higher lb solids/acre in 4 of the 5 years; the means associated with flat topping were significantly higher for 3 of the 5 years (Table 2). Contrast means for both variables were significantly higher for fall topping in 1999, 2000, and 2001. Over the 5-year period, flat topping at 12 ft (Treatments 6 and 7) consistently reduced brix and lb solids/box compared to flat topping at 15 ft (Treatments 1 and 8), but the weight of individual fruit was consistently heavier with 12 ft flat topping. Flat topping height did not have a consistent effect on boxes/acre or lb solids/acre, but the 5-year mean for both variables was highest for the 15 ft flat topping height, and the means for the 15 ft flat topping height were significantly higher in 1997. Comparing no topping (Treatment 5) to the four topping treatments (No. 1, 6, 7, and 8) showed minimal effects on all response variables. It should be remembered here that throughout this experiment, the 15 ft flat topping treatments cut very minimal foliage off the trees and was essentially the same as Treatment 5. Even the 12 ft flat topping treatments (6 and 7) caused very minimal regrowth. All of these observations indicated that 15 ft were near the maximum height most of the trees would grow without topping. Four out of 5 years, angle topping (Treatment 13) produced higher juice content and lb solids/box than did flat topping (Treatment 12). Consistently over the 5-year period, angle topping produced higher boxes/acre and lb solids/acre than did flat topping.

Skirting effects. As stated in Table 1, the skirting treatments were applied in the fall of 1995 and 1998. For all 5 years, the lower skirting height (20 inches, Treatment 10) consistently resulted in lower brix than the 36 inch skirting height, Treatment 11 (Table 2). However, in the last 4 of the 5 years, the lower skirting height gave the highest boxes/acre and lb solids/acre, with 1999 being the only year when the differences were statistically significant (lb solids/acre). The 5-year means of these two variables were also highest for the 20 inch skirting height. Comparing no skirting (Treatment 1) with skirting (average of Treatments 10 and 11), the brix associated with Treatment 1 was consistently higher for the 5 years than for Treatments 10 and 11. For 4 of the 5 years, and the 5-year means, boxes/acre and lb solids/acre were lower for no skirting, Treatment 1, but the differences were minimal.

Discussion

When this experiment was initiated in these 9-year-old trees, we expected the tree canopies to continue to increase in height, but this did not occur. Many of the trees never exceeded 15 ft in height during the experiment, and little or no foliage was removed at the 15 ft flat topping height. Tree mor-

Table 1. Treatments applied in experiment.

Treatment No.	Hedge[z]	Top[x]	Skirt[w]
1	Spring	Spring 15 ft flat	None
2	Fall	Spring 15 ft flat	None
3	Rejuvenation[y]	Spring 15 ft flat	None
4	Spring and fall	Spring 15 ft flat	None
5	Spring	None	None
6	Spring	Spring 12 ft flat	None
7	Spring	Fall 12 ft flat	None
8	Spring	Fall 15 ft flat	None
9	Spring	Spring 12 ft flat (3 years)	None
10	Spring	Spring 15 ft flat	20 inch @ dripline (fresh)
11	Spring	Spring 15 ft flat	36 inch @ dripline (processed)
12	Spring	Spring 14 ft flat	None
13	Spring	Spring angle (13 ft shoulder, 15 ft peak)	None

[z]All hedging treatments were applied annually and cut with side of canopy 10 degrees off vertical toward top of canopy. Except for Treatment No. 3, the middle width near the bottom of the tree canopy was cut at 8 ft.

[y]In the spring of the 1995-1996 through 1999-2000 seasons, bed top middle cut at 10, 9, 8, 8, and 8 ft, and ditch middle cut at 8, 8, 10, 9, and 8 ft, respectively.

[x]All topping treatments were applied annually except for Treatment 9 in which case the trees were topped in 1995-1996 and 1999-2000 seasons or 3 years between subsequent toppings.

[w]Skirting treatments applied in the fall of 1995 and 1998.

tality, thought to be mainly from blight and tristeza, was substantial in two of the five replications with only one or two of the four record trees remaining in some plots at the end of the experiment. Trees in the experiment were propagated using one of the first-released budline sources of 'Rohde Red Valencia.' Most of those sources were eventually discontinued because of problems with variation among the trees in yield, and occasional reversion of fruit from typical 'Rohde Red' to standard 'Valencia.' These factors appeared to minimize treatment effects and increased variability within treatments, thus imposing limitations on the interpretation of the results.

Regrowth following most of the hedging treatments was minimal as were hedging effects on any of the measured variables. Spring hedging generally resulted in higher juice brix, but no differences in boxes/acre and/or lb solids/acre. Freezing temperatures early in 1997 and 2001 killed some of the regrowth resulting from fall hedging in 1996 and 2000, but apparently had no detrimental effects on the trees or fruit.

Flat topping the trees at 12 ft resulted in minimal regrowth. As with fall hedging, some of the regrowth from fall topping in 1996 and 2000 was killed by freezing temperatures early in 1997 and 2001, but there were no detrimental effects on the measured variables. The trend was for fall topping to give 10% higher boxes/acre and lb solids/acre than spring topping. Compared with flat topping at 15 ft, flat topping at 12 ft resulted in consistently lower juice brix and lb solids/box and heavier fruit, but did not consistently lower boxes/acre and lb solids/acre. Reduced juice brix and lb solids/box with topping agrees with results from Wheaton et al. (1984). The minimal effects of the 12 ft topping heights on boxes/acre and lb solids/acre probably indicates that this treatment did not remove enough of the tree foliage to be significant. This statement is supported by the fact that the "no topping" treatment (No. 5) had minimal effects on most of the measured variables compared to the four topping treatments (No. 1, 6, 7, 8). Angle topping consistently gave an average of 10-15% higher boxes/acre and lb solids/acre than did flat topping. These results may appear inconsistent with the other topping results, but Treatments 12 and 13 were located in a different area of the grove than the other topping treatments.

The skirting results were somewhat contradictory. Skirting at 20 inches high consistently gave lower juice brix than did 36 inches high, but "no skirting" consistently gave lower juice brix than the average of the two skirting treatments. In addition for 4 of the 5 years, the 20 inch skirting height gave higher boxes/acre and lb solids/acre than did the 36 inch skirting height, but the average of these two treatments gave higher boxes/acre and lb solids/acre than did the "no skirting" treatment. The numbers of young fruit removed by the first skirting in the fall of 1995 were not measured. However, in the fall of 1998, the numbers removed/acre averaged 4640 (25 boxes/acre mature fruit equivalent based on 1999 fruit weights) for the 36 inch skirting height and 2550 (14 boxes/acre mature fruit equivalent) for the 20 inch skirting height. These numbers were not related to the differences in boxes/acre yields for the three treatments in 1999, which were 286, 349, and 279 for "no skirting," 20 inch skirt, and 36 inch skirt, respectively. The 5-year yield averages for these three treatments were 335, 372, and 328 boxes/acre, respectively.

Conclusions

1. Spring hedging resulted in higher juice brix than did fall hedging, but there were no consistent differences in the two with respect to boxes/acre and lb solids/acre.

2. Flat topping at 12 ft in trees which had reached a maximum natural growth height of approximately 15 ft consistently reduced juice brix and lb solids/box, but boxes/acre and lb solids/acre were not consistently reduced.

3. Compared with flat topping, angle topping consistently increased boxes/acre and lb solids/acre.

4. Skirting at 20 and 36 inches high, compared to no skirting, did not have a consistent effect on yield or fruit quality parameters.

Table 2. Five-year contrast treatment means and years the annual means were statistically significant.[z]

Contrast treatment mean comparisons	Juice by wt (%)	Juice acid (%)	Juice brix	Juice ratio	Lb solids per box	Lb solids per acre	Boxes per acre	Weight per fruit, lb
				Hedging				
1, spring 2, fall	58.19 58.11	0.62 0.61 1997*	12.62 12.35 1999+ 2001+	20.67 20.40 1997* 1999* 2001*	6.61 6.46	2193 2157	335 339	0.63 0.65 1997* 1999+
4, spring & fall 1 & 2, avg spring + fall	58.75 58.15	0.63 0.61 1999+	12.76 12.49 1999+ 2001**	20.73 20.54 2001*	6.75 6.54 2001**	2132 2176	319 337	0.63 0.64
1, spring 3, rejuvenation	58.19 58.26	0.62 0.61	12.62 12.52	20.67 20.68	6.61 6.56	2193 2249	335 342	0.63 0.64
				Topping				
1 & 6, avg spring flat 7 & 8, avg fall flat	58.30 57.64	0.62 0.62	12.58 12.45 1998*	20.61 20.36	6.60 6.47	1993 2271 1999* 2000+ 2001+	306 350 1999* 2000* 2001+	0.65 0.65
6 & 7, avg 12 ft flat 1 & 8, avg 15 ft flat	57.60 58.34 1998*	0.61 0.62 1997+	12.42 12.60	20.53 20.43 1997*	6.41 6.67 1999*	2011 2244 1997*	317 338 1997*	0.67 0.63 1997* 1999* 2001+
5, none 1, 6, 7, 8, avg all flat topping	58.79 57.97	0.62 0.62	12.63 12.51	20.57 20.48	6.69 6.54 1999+	2258 2132	342 328	0.63 0.65
13, angle 12, flat	57.63 56.10 1997+ 1998** 2000*	0.60 0.59	12.38 12.28	20.97 21.35	6.42 6.21 1998* 2000*	2337 1986 2001**	373 327 2001**	0.64 0.67
				Skirting				
10, 20 inch 11, 36 inch	58.73 58.36 1997* 2001+	0.61 0.63 1997+ 2001*	12.34 12.59 2001*	20.63 20.11 1997* 1999+	6.49 6.61 1997+	2397 2183 1999+	372 328	0.66 0.62 1997+
1, none 10 and 11, avg 20 and 36 inch	58.19 58.34 2001*	0.62 0.62	12.62 12.47	20.67 20.37 1999*	6.61 6.55	2193 2296	335 350	0.63 0.64

[z]Means significantly different at 10% level.
*Means significantly different at 5% level.
**Means significantly different at 1% level.

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