

Pruning and Skirting Affect Canopy Microclimate, Yields, and Fruit Quality of 'Orlando' Tangelo

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Abstract. Pruning and skirting (removal of low-hanging limbs) effects on canopy temperature, relative humidity (RH), and fruit yield and quality of 'Orlando' tangelo trees (*Citrus paradisi* Macf. x *Citrus reticulata* Blanco) on 'Carrizo' citrange rootstock [*Poncirus trifoliata* (L.) Raf. x *Citrus sinensis* (L.) Osb.] were studied at the Univ. of Florida Fifield Farm in Gainesville, Fla., in 1996–97. In the first season, treatments consisted of skirted and non-skirted trees. In the second season, two skirting (skirted and non-skirted) and three pruning (gable-top, flat-top, and non-pruned) treatments were evaluated. Neither RH nor air temperature was affected in the lower canopy by any treatment. However, temperature in the upper canopy of flat-topped trees was higher than that in gable-topped or non-pruned trees, and reached >45 °C during spring and summer. Fruit number and yield were decreased by pruning and skirting in one season. Skirted, gable-topped trees had the lowest yields, followed by skirted, flat-topped and non-skirted, gable-topped trees. All other treatments produced yields similar to those of non-skirted, non-pruned trees. Pruning increased the percentage of large fruit and reduced the percentage of small fruit. Skirting and pruning had no effect on blemish incidence with the exception of wind scar, which was higher in skirted than in non-skirted trees in the first season. During both seasons the main causes of packout reduction were rust mite and wind scar damage. Regardless of treatment, rust mite damage was much higher in the lower than in the upper canopy because of lower average temperatures and higher RH. Pruning effects on fruit quality were similar to those reported previously, but skirting had no effect on most fruit quality factors.

'Orlando' is the most widely planted tangelo in Florida (Commercial Citrus Tree Inventory, 1998). In 1996–97, prices for fresh tangelos were much higher than those for processing fruit (Citrus Summary, 1997–98), but a low percentage of the crop was marketed fresh because of poor external fruit quality. Fruit size, peel color, and blemish incidence are the main factors that determine fresh fruit quality. Poor appearance can substantially reduce packout and net returns to the grower. Total soluble solids (TSS), titratable acidity (TA), ratio of TSS:TA, and juice content also are important for consumer preference and acceptance.

Mechanical pruning and skirting are widely used to control tree size and improve fruit quality, but their effects on yields have been inconsistent. Hedging and topping 'Ruby Red'

grapefruit (*C. paradisi* Macf.) (Fucik, 1977) and hedging 'Valencia' orange [*C. sinensis* (L.) Osb.] trees (Bevington and Bacon, 1976) reduced yields the first year after pruning, but increased yields in subsequent seasons. Annual topping of oranges and satsuma mandarins (*C. unshiu* Marc.) reduced yields in the two subsequent seasons after pruning (Whitney et al., 1983). In contrast, hedging one side of satsuma mandarins (Iwagaki, 1981) and two sides of several citrus cultivars (Raciti et al., 1981) and 'Valencia' orange trees (Fucik, 1982) did not affect yields. Similarly, skirting navel orange (El-Zeftawi, 1976) and lemon (*C. limon* Burm. f.) trees (Phillips et al., 1990) did not affect yields.

Pruning also has had variable effects on internal and external fruit quality. Internal quality of satsuma mandarin was not affected by hedging and topping every 3 years (Iwagaki and Ideta, 1977). Similarly, hedging did not affect internal quality of several citrus cultivars in Italy (Raciti et al., 1981) or of 'Valencia' oranges in Cuba (Leyva et al., 1987). Topping height had only minor effects on fruit size, color, and juice content of oranges grown on 'Rusk' citrange [*P. trifoliata* (L.) Raf. x *C. sinensis* (L.) Osb.] rootstock; however, when trees were grown on a more vigorous rootstock ['Milam' (*C. jambhiri* Lush.)], topping

at the lower height produced poor quality fruit (Wheaton et al., 1995). Hedged and topped 'Valencia' orange trees (Leyva et al., 1987; Raciti et al., 1981) had less incidence of fruit with wind scar than did non-pruned trees.

The effects of pruning on fruit size are variable. Topping and light pruning of mandarins increased fruit size (Gilfillan, 1995; Zaragoza and Alonso, 1981; Zaragoza et al., 1992). Similarly, 'Hamlin' orange trees hedged at a 30° angle had larger fruits than trees hedged at 10° (Phillips, 1972). In contrast, neither hand nor mechanical pruning increased fruit diameter of 'Washington' navel orange (Zaragoza and Alonso, 1981). Topping and hedging reduced fruit size of lemons (Francis et al., 1975) and mandarins because more fruit were set on the non-pruned sides (Raciti et al., 1981). No difference in fruit size was found in orange trees hedged on both sides (Wheaton et al., 1984).

Skirting also has variable effects on fruit quality. Skirting improved orange fruit quality by reducing fruit contact with the soil, thus decreasing damage from soilborne organisms (El-Zeftawi, 1975). Skirted lemon trees also had less incidence of fruit infected with brown rot [*Phytophthora citrophthora* (R.E. Sm. and E.H. Sm.) Leonian] than did fruit from non-skirted trees; however, packout was similar (Phillips et al., 1990). Skirting did not affect fruit diameter, yield, juice content, TSS, or TA of navel oranges in Australia (El-Zeftawi, 1976). Many growers assume that pruning and skirting affect the microclimate in the tree, but data are lacking to support this viewpoint.

Mechanical topping, hedging, and skirting are used extensively in Florida citrus groves to control tree size and facilitate spraying and harvesting. However, little is known about the effects of skirting and pruning on the tree canopy microclimate, incidence of blemishes, fruit size, packout, and internal fruit quality of 'Orlando' tangelo. Our first objective was to evaluate the effects of pruning and skirting on RH and temperature in different positions of the canopy during the season. The second objective was to determine their effects on fruit quality, size distribution, and packout and to determine if these factors are related to tree microclimate.

Materials and Methods

Expt. 1, 1996. 'Orlando' tangelo trees on 'Carrizo' citrange rootstock were planted at the Univ. of Florida Fifield Farm in Apr. 1990. Trees were spaced at 5.0 m within and 6.0 m between rows in a north–south orientation. They were cross-pollinated by 'Robinson' tangerine [(*C. paradisi* Macf. x *C. reticulata* Blanco) x *C. reticulata* Blanco] and 'Ambersweet' orange [(*C. reticulata* Blanco x (*C. paradisi* Macf. x *C. reticulata* Blanco)) x *C. sinensis* (L.) Osb.] trees planted on either side of the 'Orlando' rows. Soil type was an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paludults). Trees were irrigated weekly with 180° microsprinklers at 60 L·h⁻¹ and 1.6 kg 10N–4.3P–8.3K fertilizer was applied in March and June. Weeds

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were controlled using glyphosate [*N*-(phosphomethyl)glycine] as needed. Citrus oil (FC-435) was applied in July at 12 L·ha⁻¹ to control greasy spot fungus (*Mycosphaerella citri* Whiteside) and rust mites (*Phyllocoptruta oleivora* Ashm.).

'Orlando' tangelo trees were skirted with a hand-held hedger in Mar. 1996 at 0.9 m above ground level, or remained non-skirted. Treatments consisted of seven, single-tree replicates of skirted and non-skirted trees arranged in a completely randomized design. During harvesting, the trees were divided into three main sections based on the distance from the soil level: 0–1.2 m (bottom), 1.21–2.2 m (middle), and 2.21 m and above (top). These sections were further subdivided into four quadrants: northeast, southeast, northwest, and southwest. Mature fruit from each of the 12 sections were harvested separately during the second week of Dec. 1996. Fruit were sized in the packinghouse using a roller-sizer into the following commercial categories (fruit equatorial diameters are in parentheses): 80 (74.0–76.2 mm), 100 (72.4–74.0 mm), 125 (63.5–72.4 mm), 163 (57.2–63.5), and >163 (diameter <57.2 mm). The primary cause of damage for each fruit was evaluated visually. Fruit were classified as U.S. No. 1 (<1/3 of the peel surface area blemished), or as eliminations.

The data for all variables were subjected to analyses of variance. Variables that did not show a normal distribution after plotting the residual against the predicted value were transformed as appropriate. For total fruit number and overall fruit size distribution, the data were analyzed as a factorial experiment. Before analysis, values for total fruit number and overall fruit size distribution were transformed by square-root or arcsin, respectively. Fruit size distribution was reported as a percentage of the total fruit number. Fruit size distribution, packout, and percentage of blemishes within the different sections of the canopy were analyzed as a split-plot experiment in which the main plot consisted of the tree and the sub-plots as sections and quadrants within each tree.

Expt. 2, 1997. A different set of 'Orlando' tangelo trees was selected in Feb. 1997 from the same grove for the second year of the study. Trees ranged from 3.8 to 4.0 m in height and had begun growing together in the row. Trees were irrigated based on soil water depletion (SWD) using a neutron probe. Water was applied at 1/3 SWD from January to June and at 2/3 SWD the rest of the year (Koo, 1963) using 180° microsprinklers at 60 L·h⁻¹. Trees were irrigated to bring the soil back to field capacity (≈4 h). Fertilization, weed, and pest control were performed as in 1996.

Forty-eight uniform trees were selected with individual trees serving as experimental units. Treatments were arranged in a completely randomized design as a 2 × 3 factorial experiment consisting of two skirting treatments (skirted or non-skirted) and three pruning treatments (gable-top, flat-top, or non-pruned). Therefore, each treatment combination was applied to eight single-tree replicates.

Trees were skirted and pruned during the

first 2 weeks of Mar. 1997 using hand trimmers and chain saws. Trees were skirted by removing all branches 0.9 m above soil level. Pruning was done in two ways. In the first treatment, trees were pruned on the east and west sides by non-selectively cutting ≈1.0 m deep into the canopy and topping at a 2.8-m height, producing a square-shaped (flat-top) tree. In a second treatment, trees also were pruned on the east and west sides but were topped at an angle of 30° on both sides, producing a gabled-shaped (gable-top) tree. The peak of the gable was at a 3.7-m height, and the shoulder height was 2.8 m above ground level. All foliage and branches smaller than ≈2.5 cm in diameter were removed. The third group of trees was not pruned.

One relative humidity (RH) and one temperature Hobo-Datalogger (Onset Computer Corp., Pocasset, Mass.) was placed in each of three different trees and remained there throughout the year. The dataloggers were programmed to take measurements every 15 min. From April to October, four positions in the canopy from three of the six treatment combinations (skirted, gable-top; skirted, flat-top; non-skirted, non-pruned) were selected based on height in the canopy and distance from the trunk. The four height/distance positions included: 2.8/0.8 m, 1.1/0.8 m, 2.8/1.4 m, and 1.1/1.4 m. The sensors were placed for 2 to 3 d in the same position in each treatment until the measurements were completed and then were moved to the next group of treatments. Temperature and RH were measured at four dates during the study.

Eighteen trees (three trees per treatment combination) were harvested 2–9 Dec. 1997. Trees were divided into the three main sections and four quadrants as described for the 1996 season. Each of the quadrants was further subdivided into two sections, inside (the region from the trunk outward to 1.0 m into the canopy) and outside (the region 1.1 m from the trunk to the outside of the canopy). Thus, each tree was divided into 24 sections that were harvested and evaluated separately. Another group of 12 trees (two trees per treatment combination) was harvested 10–13 Dec. 1997. Trees were divided into the three main sec-

tions as described previously (top, middle, and bottom). The remaining 18 trees (three trees per treatment combination) were harvested 14–18 Dec. without dividing the tree into sections. Not all of the 48 trees could be harvested in sections because of limitations in time and manpower. However, yield and fruit-size distribution data were collected for all 48 trees.

Fruit from each of the sections were weighed and then sized and graded as described in the 1996 season. For the first group of 18 trees, inside and outside fruit from the different quadrants of the same main section (top, middle, or bottom) were combined in separate groups and a sample of 10 fruit was taken. Thus, six samples were taken per tree: top-inside, top-outside, middle-inside, middle-outside, bottom-inside, and bottom-outside.

The combined sample of 10 fruit was evaluated for peel color and firmness. Color was measured using a Chroma Meter CR-300 Colorimeter (Minolta Osaka 541, Japan) and expressed as L*C*H (L = lightness, C = Chroma, and H = Hue angle). The Hue angle (H) was used as the most accurate indicator of color (McGuire, 1992). Three readings were taken around the equator of each fruit for a total of 30 measurements per sample. Firmness was measured using an AccuForce III gauge (Ametek, Mansfield and Green Prod., Largo, Fla.). Two measurements were made per fruit at the equator. The 10 fruit were weighed and juiced using a standard juicer. Juice was then weighed and expressed as percentage of total fruit weight. A few drops of juice were placed in a Reichert 10430 hand-held refractometer (Buffalo, N.Y.) to determine Brix. The TA was measured by titrating 25 mL of juice with 1.0 N NaOH using phenolphthalein as an indicator. Percent anhydrous citric acid was calculated according to Wardowski (1991).

Total yield, percent packout, and fruit-size distribution were calculated as described in 1996. The data for all variables were subjected to analyses of variance. For total fruit number, overall fruit-size distribution, packout, and blemish incidence, the data were analyzed in the same way as described in the previous season. The data for fruit quality were ana-

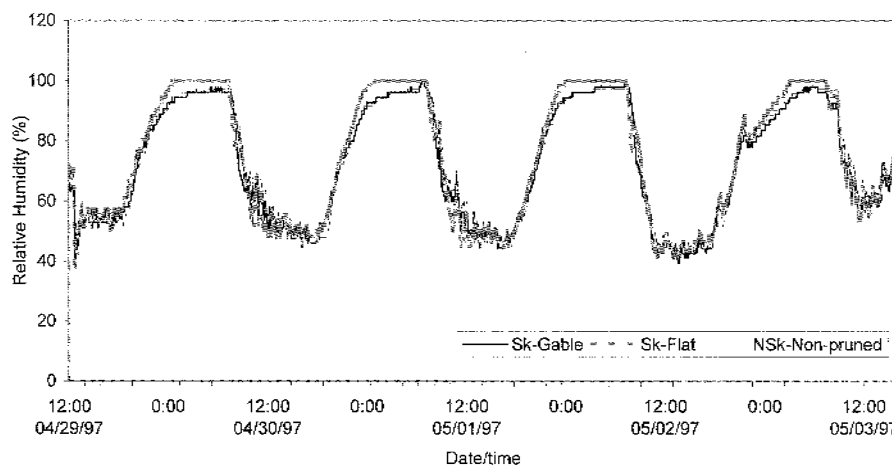


Fig. 1. Effects of pruning and skirting on relative humidity of the bottom-inside of the canopy for 'Orlando' tangelo trees in Apr. and May 1997. SK = skirted; NSK = non-skirted.

lyzed as a split-plot experiment in which the main plot was tree and the sub-plots were sections and positions in the canopy. To evaluate the effect of position and section on fruit quality, values for position and section were grouped independently of treatment after initial analysis and then were analyzed separately. All analyses were performed using the SAS 6.11 statistical software (SAS Institute, Cary, N.C.).

Results and Discussion

Canopy microclimate. The data presented (Figs. 1 and 2) are representative of four measurements taken throughout the season at different locations in the tree. The results were the same in every instance. Large diurnal fluctuations in RH occurred during spring (Fig. 1) and late summer (Fig. 2) for both skirted and non-skirted trees. The RH in the bottom-inside canopy decreased to $\approx 50\%$ during the day and increased to 100% at night, as expected (Fig. 1). No consistent differences in RH were found in the lower canopy between skirted and non-skirted trees or pruned and non-pruned trees on any of the measurement dates. Moreover, skirting and pruning did not affect RH in the upper inside part of the canopy in spring (data not shown) or summer (Fig. 2). Furthermore, RH was similar in the top-inside of gable, flat-topped trees, and of non-pruned trees on all dates. The diurnal fluctuation in RH was generally greater in the upper than in the lower portion of the canopy. This is contrary to the notion that skirting and pruning decrease RH in the canopy. The high RH found in Florida for most of the season was the same inside and outside the canopy (data not shown).

Similarly, skirting and pruning did not affect air temperature in the lower portion of the canopy (Fig. 3). In spring, air temperature in the bottom-inside canopy ranged from 31 °C day/13 °C night and was not affected by skirting (Fig. 3). During summer, air temperature reached 37 °C day/20 °C night (data not shown).

In contrast, pruning increased air temperature in the upper part of the canopy (Fig. 4). Air temperatures in the top-outside canopy in flat-topped trees were higher than in gable-topped and non-pruned trees. During spring (Fig. 4) and summer (data not shown), the temperature in the top of flat-topped trees reached 45 °C and was 10 °C higher than in gable-topped and non-pruned trees. During late summer, flat-topped trees occasionally experienced high air temperatures in the upper canopy, although temperatures were not very different from those of non-pruned trees, probably due to regrowth and canopy reestablishment (data not shown).

Daito et al. (1980) also found that diurnal changes in air temperature were affected by training system. Air temperatures changed rapidly in the tops on the south and east sides of the canopy in open center trees, while for trees grown in hedgerows the changes were more rapid on the east side during the morning and less rapid on the west side. In this study, changes in air temperature in the upper canopy of flat-topped trees resembled those

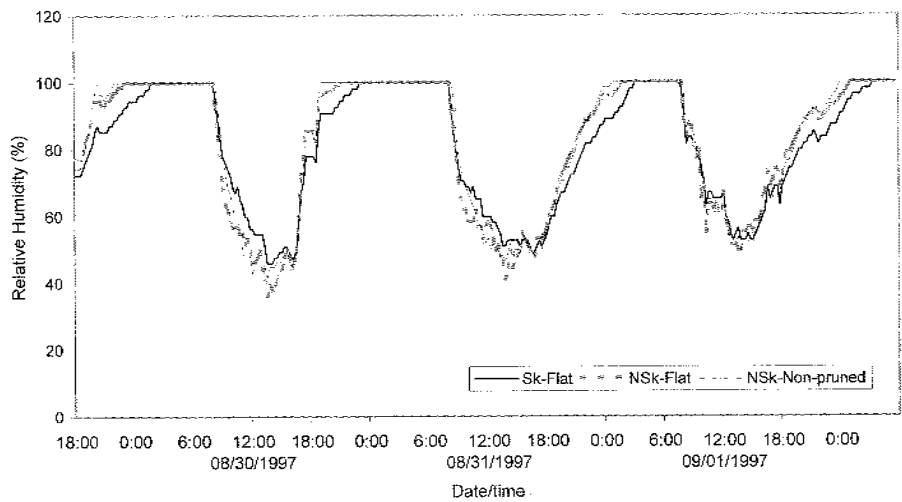


Fig. 2. Effects of pruning and skirting on relative humidity of the top-inside of the canopy for 'Orlando' tangelo trees in Aug. and Sept. 1997. SK = skirted; NSK = non-skirted.

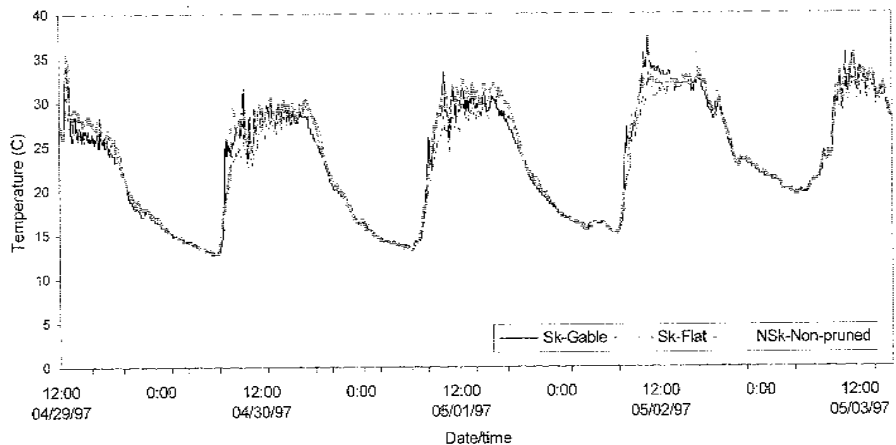


Fig. 3. Effects of pruning and skirting on air temperature of the bottom-inside of the canopy for 'Orlando' tangelo trees in Apr. and May 1997. SK = skirted; NSK = non-skirted.

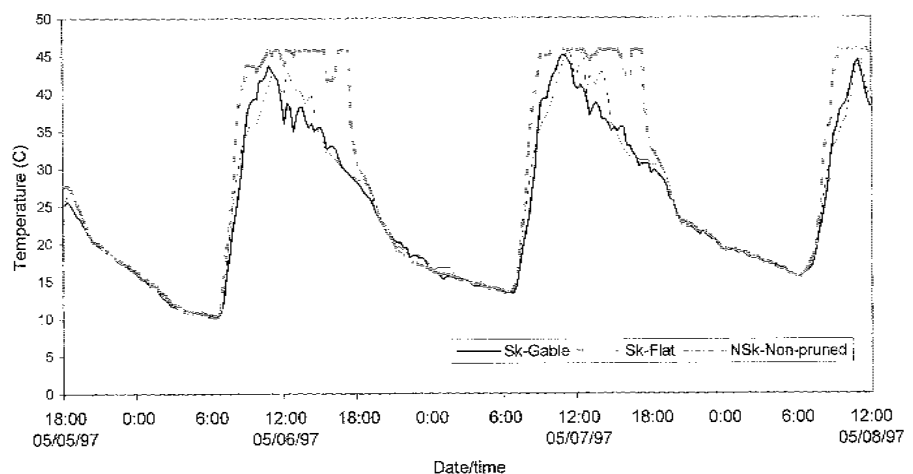


Fig. 4. Effects of pruning and skirting on air temperature of the top-outside of the canopy for 'Orlando' tangelo trees in May 1997. SK = skirted; NSK = non-skirted.

in trees trained to an open center.

Yield and fruit size distribution. Skirting did not affect total fruit number per tree or fruit-size distribution significantly in 1996 (data not shown). Skirted and non-skirted trees produced an average of 508 and 604 fruit per tree, respectively. In 1997, both pruning and skirting significantly reduced yields (Table 1). The overall mean fruit number and weight were statistically greater ($P \leq 0.06$) for non-skirted than for skirted trees. Gable-topping significantly reduced yields in non-skirted, but not skirted trees, flat-topping did not. However, in non-skirted, flat-topped trees yields were not reduced. Therefore, although no interaction was detected at the 5% level, there appears to be one when examining the data using multiple t tests. Often interaction is not detected because of insufficient replication, but this greatly increases a chance of type 2 error (Bancroft, 1968). Phillips et al. (1990) also found that skirting slightly reduced yields of 'Valencia' orange trees 2 years after skirting. Conversely, skirting lemon trees at 45 cm above soil level did not decrease yield.

Fruit-size distribution in 1997 was affected by pruning but not by skirting (Table 1). Regardless of skirting treatment, gable- and flat-topping treatments had $\approx 30\%$ of their fruit in the largest size category, while the non-pruned trees had only 26% (skirted) or 12.3% (non-skirted) of their fruit in that size category. Non-skirted, non-pruned (control) trees had the lowest percentage (19.5%) of 100 size fruit. The highest percentage of fruit size 125 occurred in non-skirted, non-pruned trees, while the lowest percentage of fruit of that size category was from skirted, gable- and flat-topped trees and non-skirted, flat-topped trees. Non-skirted, non-pruned trees had a higher percentage of fruit size 163 than skirted and non-skirted, gable-topped trees or non-skirted, flat-topped trees. Non-skirted, non-pruned trees had a higher percentage of small fruit size (>163) than all other treatments with the exception of skirted, flat-topped trees. Thus, pruning substantially increased the percentage of fruit of large sizes (100 and 80) and generally reduced the amount of small fruit (>163).

Fruit number and total fruit weight were lower in skirted, gable-topped, skirted, flat-topped and non-skirted, gable-topped trees than in non-skirted, non-pruned (control) trees. This may be attributable to differences in the severity of pruning. Pruning was most severe for the skirted, gable-topped trees followed by skirted, flat-topped trees. In both treatments a large amount of canopy was removed from the sides, top, and bottom of the tree. Pruning did not reduce fruit number or weight in non-skirted, flat-topped trees, indicating that although pruning was considerable, the lower part of the canopy had many fruit. In citrus, fruit are produced mainly on shoots that are at least 1 year old and located primarily in the outer meter of the canopy. Thus, as pruning became more severe, more fruit were removed and yields were reduced. These results agree with those of Bevington and Bacon (1976), who found that moderate hedging to form a

truncate triangle at a 20° angle reduced yield by 18%, while severe vertical hedging reduced yield by 39%.

The reduction in fruit number by skirting in the second experiment was not translated into an increase in fruit size for the remaining fruit. El-Zeftawi (1976) also reported that skirting of navel orange during spring reduced yields in the subsequent season, but that fruit diameter and weight were not changed. Similarly, Fucik (1978) observed that average fruit weight was not changed after removing fruit from the bottom portion of mature grapefruit trees.

The more severe pruning treatments, on the other hand, increased fruit size by shifting the proportions of fruit in the largest and smallest fruit size categories. Gilfillan (1995) also reported that pruning substantially increased fruit size and decreased the number of small fruit. Oren (1988) observed that more large fruit were obtained following hedging and topping of 'Clementine' mandarins. Simi-

larly, Zaragoza et al. (1992) found a slight increase in fruit size of 'Clausellina' orange pruned moderately to severely during fruit set and June drop. Phillips (1972) observed that fruit became larger as hedging angles increased in the first years after hedging. Fruit size distribution was not changed in this study for skirted, flat-topped trees, even though total fruit number was reduced substantially. Certainly, cultivar and growing conditions may account for some of the differences in pruning response in this and other studies.

Thus, the data suggest that a pruning treatment that results in at least a 30% reduction in fruit number is necessary to affect fruit size distribution in 'Orlando' tangelo trees in Florida (Table 1). Similarly, Moss et al. (1981) suggested that removing between one-third and one-half of the immature fruits by hand thinning substantially increased fruit size of 'Valencia' oranges. In contrast, Zaragoza et al. (1992) in Spain found that removing 66%

Table 1. Effects of pruning and skirting on fruit number, total fruit weight, and fruit-size distribution for 8-year-old 'Orlando' tangelo trees, 1997. Trees were harvested in Dec. 1997, $n = 8$ trees.^z

Skirting/pruning treatment	Fruit/tree (no.) ^x	Total fruit wt (kg)	Percentage ^y of fruit in size category:				
			>163 ^w	163	125	100	80
Skirted							
Gable-topped	522 b	109 b	4.1 b	18.8 b	18.7 b	25.3 a	33.0 a
Flat-topped	604 b	119 b	7.3 ab	22.4 ab	18.6 b	22.4 a	29.3 a
Non-pruned	703 ab	143 ab	5.4 b	22.6 ab	20.7 ab	25.4 a	25.8 a
Mean	610	124					
Non-skirted							
Gable-topped	612 b	128 b	3.5 b	19.7 b	18.7 b	28.0 a	30.0 a
Flat-topped	696 ab	144 ab	6.3 b	20.2 b	19.3 ab	26.0 a	28.1 a
Non-pruned	994 a	185 a	13.0 a	32.2 a	23.0 a	19.5 b	12.3 b
Mean	767	152					
Skirting (S)	*v	*v	NS	NS	NS	NS	NS
Pruning (P)	**	**	**	*v	*v	NS	**
S \times P	NS	NS	NS	NS	NS	**	NS

^zMean separation among all treatments within columns by multiple t tests. Means followed by the same letter within a column do not differ at $P \leq 0.05$.

^yValues transformed to square roots before analysis.

^xValues transformed to arcsin before analysis.

^wValues represent number of fruit per standard 19.2-kg carton.

^v $P \leq 0.06$

ns, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Table 2. Effects of skirting and section of tree on packout (% U.S. No. 1) and blemish incidence for 7-year-old 'Orlando' tangelo trees harvested in Dec. 1996, $n = 7$ trees.

Section ^x	U.S. No. 1 (%) ^z	Blemish incidence (%) ^{z,y}					
		RM	SC	Mech	Plug	WS ^w	Other
<i>Non-Skirted</i>							
Bottom	51.3 c ^v	20.2 a	0.6 b	1.1 b	6.1 a	8.0 b	12.6 a
Middle	65.4 b	10.8 b	1.3 b	2.2 ab	6.2 a	4.8 c	9.3 a
Top	79.9 a	2.1 c	2.0 a	3.0 a	7.2 a	2.8 d	3.0 b
<i>Skirted</i>							
Bottom	36.4 c	18.2 a	0.6 b	1.6 a	7.8 b	21.0 a	11.0 a
Middle	57.6 b	6.5 b	2.1 b	2.1 a	14.0 a	9.0 b	5.2 a
Top	78.9 a	0.9 c	1.8 a	3.1 a	9.7 a	3.5 cd	2.1 b
Skirting (Sk)	NS	NS	NS	NS	NS	**	NS
Section (Se)	**	**	**	**	NS	**	**
Sk \times Se	NS	NS	NS	NS	**	**	NS

^zValues for packout and blemish incidence were transformed using arcsin transformation before analysis. ^yRM = rust mite damage; SC = scale damage; Mech = mechanical damage; Plug = plugging; Other = other insect damage, creasing, misshapen, and green-colored fruit.

^xBottom, middle, and top = fruit harvested from 0–1.2 m, 1.21–2.2 m, and 2.3 m and higher, respectively.

^wMean separation for wind scar damage was for the entire column because of a significant interaction.

^vMean separation among canopy sections within skirting treatments by multiple t tests ($P \leq 0.05$). Transformed arcsin values were used for mean separation.

ns, ** Nonsignificant or significant at $P \leq 0.01$, respectively.

of 'Clausellina' mandarin fruit by hand thinning increased fruit size, while removing 33% of the fruit had no effect.

Packout and blemish incidence. Skirting did not affect percentage of packout or blemish incidence, with the exception of increasing wind scar damage in 1996 in the lower portion of the canopy (Table 2). Similarly, neither skirting nor pruning had a significant effect on percent packout in 1997 (data not shown). Location in the canopy, however, had a significant effect on packout and blemish incidence independent of pruning or skirting treatments (Tables 2 and 3). The highest packout was obtained from fruit harvested from the top, followed by the middle and bottom portions of the canopy, respectively.

Skirting did not improve packout from the bottom part of the canopy, as proposed by Russell (1968). In both seasons, the main causes for reduced packout in the lower canopy were rust mite and wind scar damage. The high incidence of wind scar in the bottom of skirted trees was probably due to increased air movement in the lower canopy. For all treatments, air temperatures were consistently higher in the upper than in the lower canopy, which may account for the lower rust mite incidence. Allen and McCoy (1979) found that low temperatures in the north and south bottom quadrants of the canopy of 'Valencia' orange trees were associated with high rust mite densities, whereas the south top quadrant had the lowest populations. Since skirting did not reduce RH in the lower canopy, rust mite incidence would be expected to be similar for skirted and non-skirted trees. High RH favors the increase in population of immature stages of rust mite (Hobza and Jeppson, 1974; Pratt, 1957).

Wind scar incidence was similar for all pruning treatments (data not shown), suggesting that the regrowth produced after pruning protected the fruit from windscarring. These results differ from those of Burns et al. (1977, 1979) who reported that the regrowth produced by pruned trees gave more protection to the fruit than the normal growth flush from non-pruned trees in reducing wind scar incidence.

Section and position in the canopy, on the other hand, had a significant effect on internal fruit quality (Table 4). Juice content was lowest in fruit from the top-outside of the canopy. Fruit located in the top had the highest Brix, whereas TA content varied little among locations. The Brix : TA ratio was highest in top-outside fruit and lowest in fruit located in the bottom and middle-inside of the tree. The effects of location in the tree on fruit quality are well-documented and not surprising. Similar results were obtained for oranges (Sites and Reitz, 1949) and grapefruit (Syvertsen and Albrigo, 1980).

Section and position in the canopy also had a significant effect on external fruit quality (Table 4). Fruit in the bottom and middle sections were firmer than those located in the top. The greatest Hue (H) value, which indicates the greenest color, was found in fruit from the bottom-inside of the canopy, while the lowest H was obtained in fruit from the top

Table 3. Effects of source of fruit (section of the canopy) on packout (% U.S. No. 1) and blemish incidence for 8-year-old 'Orlando' tangelo trees harvested in Dec. 1997, n = 48 trees.

Section of the canopy ^x	U.S. No. 1 (%) ^y	Blemish incidence (%) ^{z,y}					
		RM	Scale	Mech	Plug	WS	Other
Bottom	58.8 c ^w	13.9 a	2.0 b	1.2 b	8.0 a	14.4 a	1.8 b
Middle	64.7 b	9.0 b	3.7 a	1.5 a	8.8 a	9.8 b	2.2 a
Top	71.0 a	2.6 c	4.3 a	1.0 b	9.0 a	9.8 b	2.4 a

^xValues for packout and blemishes were transformed by arcsin transformation before analysis.

^yRM = rust mite damage; SC = scale damage; Mech = mechanical damage; Plug = plugging; Other = other insect damage, creasing, misshapen.

^zBottom, middle, and top = fruits harvested from 0–1.2 m, 1.21–2.2 m, and 2.3 m and above, respectively.

^wMean separation within columns by multiple *t* tests ($P \leq 0.01$). Transformed arcsin values were used for mean separation.

Table 4. Effect of fruit location in the canopy on external and internal fruit quality factors of 8-year-old 'Orlando' tangelo trees harvested in Dec. 1997, n = 18 trees. Ten fruit per sample per section and position/tree were used.^z

Canopy position ^z	Fruit quality factor					
	Juice (%)	Brix (%)	TA (%)	Ratio Brix : TA	Firmness (N)	Color (h)
	<i>Inside</i>					
Bottom	51.0 a ^y	8.0 c	0.76 a	10.6 c	4.4 a	73.3 a
Middle	50.3 a	8.2 c	0.72 ab	11.4 c	4.3 a	69.7 b
Top	49.7 a	9.1 a	0.69 bc	13.3 b	4.0 b	66.1 cd
	<i>Outside</i>					
Bottom	49.4 a	8.5 b	0.68 bc	12.7 b	4.1 b	69.3 b
Middle	48.9 a	8.6 b	0.69 bc	12.6 b	4.1 b	67.3 c
Top	46.1 b	9.2 a	0.65 c	14.5 a	3.9 c	65.6 d
Position (P)	**	**	**	**	**	**
Section (S)	*	**	**	**	**	**
S × P	NS	NS	NS	NS	NS	NS

^zBottom, middle, and top = fruit harvested from 0–1.2 m, 1.21–2.2 m, and 2.3 m and above, respectively. Inside = region from the trunk outward to 1.0 m into the canopy. Outside = region 1.1 m from the trunk to the outside of the canopy.

^yMean separation within columns by multiple *t* tests. $P \leq 0.05$.

^{ns, *, **}Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

of the canopy. Again, these same trends were observed by Sites and Reitz (1949) and Iwagaki et al. (1976).

The differences in RH between upper and lower portions of the canopy influenced external fruit quality and, to some extent, internal quality. Rust mite incidence was increased in the lower canopy where RH was high. In addition, juice content was lower (Table 4) in the top-outside of the tree where RH was low, than in the rest of the canopy. However, fruit located in the top-inside of the canopy had juice content similar to that of fruit from other locations. This suggests that although the upper canopy had lower RH compared to the lower canopy, the differences in RH between top-inside and other canopy locations were not high enough to influence juice content. In general, fruit produced in semiarid climates, such as California, tend to produce fruit with a thicker peel and lower juice content than those in climates with high RH, like Florida (Reuther, 1988). However, the overall seasonal differences in RH between California and Florida are very large compared with the differences within canopy locations in this study.

The lack of effects of pruning and skirting on fruit quality is in agreement with several other studies worldwide. El-Zeftawi (1976) observed that skirting did not improve internal quality of navel oranges in Australia, and Raciti et al. (1981) found no effect of skirting

on internal quality of several cultivars in Italy. Iwagaki and Ideta (1977), Leyva et al. (1987), and Phillips (1972) also found no difference in internal fruit quality of hedged over non-hedged citrus trees. On the contrary, hedging on two or four sides plus topping of 30- and 45-year-old grapefruit trees improved fruit quality 2 years after pruning, but this was attributable to the great severity of pruning in their study (Kretschman and Jutras, 1962).

Fruit from the interior and lower canopy had similar Brix and TA regardless of pruning treatment. In contrast, Daito et al. (1981) observed that fruit from the lower and interior canopy of trees trained as an open center and in hedgerows had slightly lower Brix and TA than non-pruned trees. Hedging and topping in this study consisted of nonselective removal of all foliage and branches, while training to an open center consisted of removal of branches by manual pruning to open the canopy and improve light penetration. Therefore, the extent of pruning may influence its effect on fruit quality.

In summary, pruning generally improved fruit size and decreased yields of 'Orlando' tangelo trees in Florida. Skirting had no effect on canopy temperature and RH, generally decreased yields, and did not improve fruit internal or external quality. The combination of pruning and skirting also decreased yields and improved fruit size but generally did not affect fruit quality.

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