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GROWTH CONDITIONS AFFECT SHEEPNOSING IN GRAPEFRUIT

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Abstract. **Tree growth and/or environmental conditions that cause grapefruit (*Citrus paradisi* Macf.) to develop an abnormally elongated, sheepnosed shape are not well understood. We manipulated early season fruit growth by modifying tree canopy temperature in grapefruit blocks in the Central Ridge and Indian River regions of Florida to determine growth effects on fruit shape. Elevating early season temperature in tree canopies by placing clear plastic tents over trees from before bloom (February) until July, increased the percentage of sheepnosed fruit above that of the uncovered control trees both areas and in four different grapefruit cultivars. Covering trees over the same period with 50% shade cloth tended to re-**

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duce the percentage of sheepnosed fruit. Overall, fruit became flatter as the season progressed but in the Indian River area, sheepnosing tended to increase between October and January. On the Ridge, there were no differences in the percentage of sheepnosed fruit among the different grapefruit cultivars. In another experiment on the Ridge evaluating the effect of nitrogen (N) fertilizer rate on fruit shape, 'Ruby Red' trees previously fertilized with 250 lb N/acre per year had more sheepnosed fruit (14%) than trees that received 100 lb N/acre per year (3%). If we can understand the interactions between determinants of fruit growth, fruit size, and fruit shape, we should be able to minimize sheepnosing problems and increase packout.

Sheepnosing or stem end taper, is a commercially important shape disorder of grapefruit that are destined for the fresh market. In Florida, misshaped fruit that are eliminated at the packinghouse are predominantly sheepnosed and these defects can represent up to ~20% of packout (Miller and Burns, 1992). Sheepnosing was among the top five causes of elimination in four of the past seven seasons (Ritenour et al., 2003). Sheepnosed fruit are pyriform (pear shaped) and often have thick, puffy rinds. This disorder results from excessive growth in the top hemisphere and albedo tissue of fruit. Sheepnosed shape is more common in relatively large fruit and in fruit from young, vigorous nucellar trees (Soost et al., 1965). Thus, high growth rates increase the incidence of sheepnosed fruit. Excessive growth in the peel can begin very early in the season soon after petal fall as sheepnosing apparently begins at the base of the flower pistil (Gibson, 1975). Fruit elongation, but not necessarily sheepnosing, is more severe in fruit grown under high temperatures (Richardson et al., 1997) or under large variations in daily maximum and minimum temperatures (Wutscher, 1976). This supports observations that late bloom fruit which expand during relatively warm late spring conditions, tend to become more sheepnosed. Elongated fruit are more common when grown at low humidity (Cohen et al., 1972; Reuter, 1973). Sheepnosing has been reported to be more severe in trees growing in sandy soil than in those growing in silt loam (Gibson, 1975). The percentage of sheepnosed fruit can be affected by regional climate and rootstock but year to year variations make drawing conclusions difficult (Patil, 2001). All of the above growth conditions can impact tree water status and fruit growth. There is much confusion in the literature about sheepnosing as the underlying cause(s) of misshaped fruit is not fully understood (Sauls, 1998). A major problem is that the citrus industry does not have an effective method for predicting the severity of sheepnosing that will develop in a citrus grove.

Although there are grapefruit blocks in which sheepnosed fruit are a perennial problem, year to year variations in packout reveal that causes of sheepnosing can be complex. There is a well-known inverse relationship between yield and average fruit size (Davies and Albrigo, 1994). In the east coast Indian River (IR) area of Florida, packouts of red cultivars continue to be significantly higher than those for white grapefruit but tree age does not appear to be the primary reason (Ritenour et al., 2003). In addition, packouts in the IR area tend to decrease as the season progresses and fruit continue to grow. The shape of citrons apparently is determined relatively late in their development such that changes in fruit shape are susceptible to tree age, vigor, and the number and location of seeds in the fruit (Goldschmidt, 1976). Thus, fruit shape is not always determined early in fruit development. Sheepnosing can be worse in light cropping years than in heavy cropping years (Gibson, 1975). If crop load is indeed a contributing factor determining fruit shape, interactions between crop load and other fruit shape-controlling environmental factors adds confusion about causes of sheepnosing.

We tested the hypotheses (Ho) that high temperatures and nitrogen rates support rapid, early fruit development and may increase the frequency of misshapen fruit. Sheepnosed grapefruit shape are often asymmetrical as one half of the top of a fruit is often more elongated that the other half (Sauls, 1998). An asymmetric growth of grapefruit peel can be induced by a localized application of the plant growth regulator gibberellin (Goldschmidt, 1983). Since seeds are a source of plant growth regulators, we also tested the hypothesis that differences in the numbers of seeds in fruit sections may be related to the observed differences in fruit shape.

Materials and Methods

Experiment 1. Canopy temperature effects on fruit quality. This study was conducted at a Central Ridge location in Lake Alfred, and also at an IR location near Ft. Pierce. The Ridge experiment used 4 cultivars of 15-year-old grapefruit (*Citrus paradisi* Macf.) trees on Swingle citrumelo rootstock. The cultivars were 'Marsh Seedless', 'Ruby Red', 'Ray Ruby', and 'Flame'. The IR trees were 14-year-old 'Ruby Red' trees on Swingle citrumelo rootstock. On 1 Feb. 2002, three replicate trees of each cultivar were either covered with a clear plastic tent, covered with 50% shade cloth or left uncovered as a control treatment. Covers were removed for one week at full bloom (15-22 Mar.) and then recovered until 1 July. Fruit drop per tree was evaluated by periodically counting green fruit under each tree during April-May and leaf and air temperatures under the covers and were monitored using fine wire thermocouples (copper-constantan) linked to a data logger (21X, Campbell Scientific, Logan, Utah). Fruit growth and fruit height/width (H/W) ratio over time were evaluated by measuring fruit H and W periodically from March until November. About 30 fruit from each tree were sampled for juice quality analysis in December and the shape of 30 fruit from both north and south canopy positions from each cultivar X cover treatment combination were visually rated as flat, round, or sheepnosed. Data were analyzed for significant differences using a factorial design analysis of variance (AOV) with cultivar, cover treatment and canopy position as the main effects, and Duncan's Multiple Range Test (DMRT) at $P < 0.05$.

In order to get insights into shape characteristics and seed number inside fruit, 20 Marsh grapefruit from each shape class, flat, round, or sheepnosed, were sectioned longitudinally and the surface area of the peel and visible juice sections were measured. Surface areas of fruit hemispheres and juice sections were calculated using elliptical formulae and the percentage of peel surface area was calculated by difference. Sheepnosed fruit were cut longitudinally through the longest polar diameter so that asymmetric fruit could be separated into large and small halves and their dimensions and seed numbers determined. All fruit were harvested in Mar. 2003. Data were analyzed by an AOV and DMRT using fruit shape in a completely random design.

Experiment 2. N rate effects on fruit quality. This field experiment was initiated in 1997 near Lake Alfred, using 16-year-old 'Ruby Red' grapefruit on Carrizo citrange rootstock. The soil type was a Candler fine sand; trees were irrigated with under the tree micro-irrigation with one emitter per tree. The treatments included 100 or 250 lb N per acre per year as dry granular broadcast applications equally split three times per year. Treatments had been in place for 5 years since 1998. Six-month-old spring flush leaves were sampled 8 July 2002 for leaf N. Fruit yield and quality measurements were made at harvest in Nov. 2002. The yield was measured in boxes from two to four trees per plot. Fruit were analyzed for juice quality, size, and shape as above. Data were tested for significant differences using a factorial AOV and DMRT with fertilizer rate as the main treatment.

Results

Experiment 1. There were no significant differences in yield, fruit size, or juice percentage content attributable to grapefruit cultivar (Table 1). There were only small differences in juice quality as 'Marsh' had a slightly lower Brix to acid (B/A) ratio than the other cultivars. All fruit had more flattened than round shape (H/W < 1) and 'Ruby Red' had a slightly lower H/W ratio. Overall, the percentage of sheepnosed fruit was relatively low varying between 5% and 8% across cultivars. There were no significant differences in fruit quality and shape attributable to canopy position. Although the covers tended to reduce yield, these decreases were not significant. The clear plastic covers over tree canopies early in the season clearly elevated temperatures during the early season (Fig. 1a) and reduced fruit drop (Fig. 1b). The lower fruit drop associated with the covered treatment may have been related to their lower yield (Table 1). Differences in yield were likely reflected in the larger fruit from tree under plastic than from open trees. Fruit that had developed under the plastic had a lower juice percentage and were more elongated than fruit from the shade or open treatments. In addition, the plastic covers increased the percentage sheepnosed fruit three fold. The shade treatment tended to reduce the percentage of sheepnosed fruit below that of the open controls but these differences were not significant. In general, all fruit were elongated (H/W > 1) early in the season, became round by mid-June and flattened by harvest in November (Fig. 2). From May until November, fruit from under the clear plastic treatment had the greatest H/W ratio.

Fruit shape results from the IR experiment were similar in that fruit were near round (H/W ~ 1) in mid-June with H/W ratios decreasing by harvest in Jan. 2003 (Table 2). From June through January, fruit that were previously under plastic covers were more elongated and had about twice the sheepnosing relative to fruit from the uncovered control trees. Fruit from the previous shade cloth treatment again had about half the percentage sheepnosed fruit as the open control but this difference was not significant. Previously shaded fruit were the most flattened as they had the smallest H/W ratio. Canopy position did not affect fruit H/W ratio but fruit from the southern canopy exposure were consistently more sheepnosed than fruit from the north positions. Fruit shape tended to deteriorate between October and January as the percentage of sheepnosed fruit increased during that period in all treatments.

Since fruit to be sectioned were previously classified by shape (flat, round, or sheepnosed), fruit height, H/W ratio, and longitudinal section surface area increased as their classification went from flat, to round, to sheepnosed (Table 3). Although the visible surface area of the juice sections in the larger fruit hemisphere were consistently larger than those from the smaller hemisphere, these differences were not significant. There was no difference in the percentage of the peel area in larger vs. smaller hemisphere regardless of shape. Thus, both the peel and sections contribute to fruit asymmetry. There were consistently more seeds in the large hemispheres than in the small hemispheres in all three shapes but these differences were not significant. Overall, there were fewer seeds in sheepnosed fruit than in flat or round fruit.

Experiment 2. Grapefruit in the N rate experiment showed an alternate bearing pattern which tended to obscure any meaningful yield response of grapefruit to fertilizer rate during the 5 years (Schumann, unpublished results). Although there was no yield or average fruit size response to fertilizer in 2002, there were significant increases in grapefruit juice content, brix/acid ratio, and total solids per box for the higher rate of fertilizer (Table 3). There was no effect of N rate on fruit H/W ratio but fruit from high N trees had more than four times the percentage of sheepnosed fruit than those from low N trees.

Discussion

We tried to develop early (postbloom) measurements that could be used to predict fruit shape at harvest and subsequent postharvest storage quality. Although sheepnosed fruit tend

Table 1. Effects of grapefruit variety, canopy position (N or S facing), shade cloth, or plastic covers over tree canopies from February through June on treatment means of yield, average fruit weight, juice quality, fruit height/width (H/W) ratio, and percentage sheepnosed (% S-nose) fruit in the Ridge Experiment. There were three replicate trees in each cover treatment and 30 fruit rated from each canopy position of each variety.

Treatment	Yield (Bx/Tr)	Fruit Wt. (g/fruit)	Juice (%)	B/A ratio	H/W ratio	% S-nose
Marsh	3.1 ns[z]	354 ns	59 ns	8.44 b	0.91 a	5.9 ns
Ruby Red	3.0	357	59	8.78 a	0.90 b	6.9
Ray Ruby	2.6	348	59	8.97 a	0.90 ab	8.3
Flame	3.1	366	58	8.94 a	0.91 a	7.4
North	—	352 ns	59 ns	8.73 ns	0.90 b	6.3 ns
South	—	360	58	8.84	0.91 a	8.0
Open control	3.4 ns	349 b	59 a	8.69 b	0.90 b	4.2 b
Shade	2.7	344 b	60 a	8.97 a	0.89 c	2.4 b
Plastic	2.8	378 a	57 b	8.70 b	0.92 a	14.0 a

[z]Column means within a group followed by dissimilar letters differ significantly at P < 0.05 as tested by Duncan's Multiple Range Test.
ns = non-significantly different.

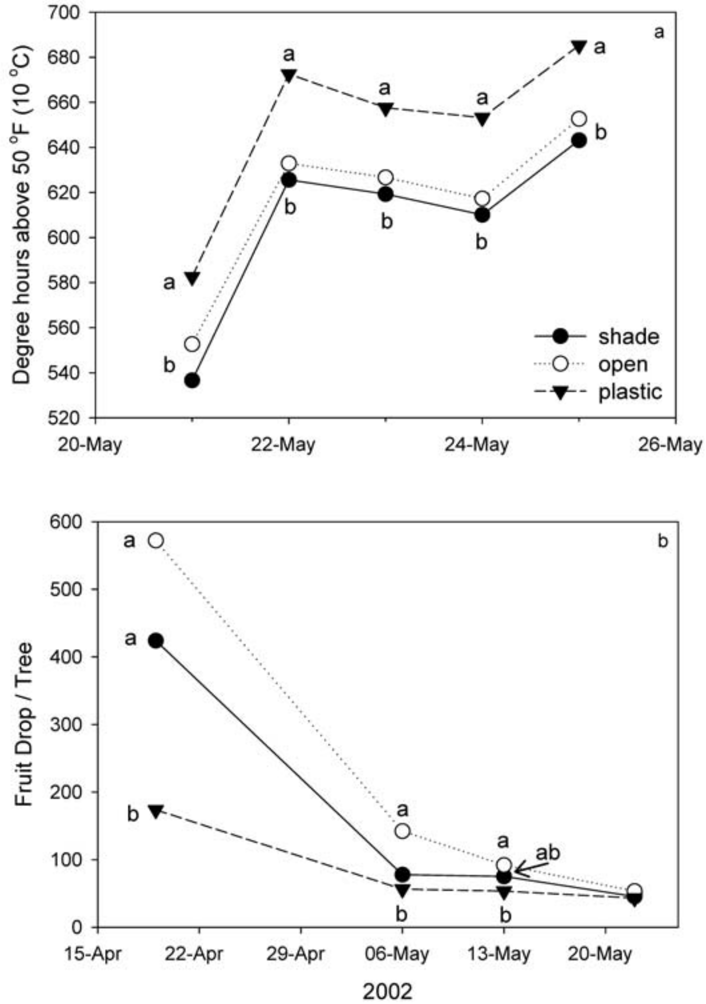

Fig. 1. Effects of clear plastic, 50% shade covers or open canopy (control) treatment on a) degree hours above 10 °C (50 °F) in tree canopies for 5 representative days in May 2002 (n = 3 trees per treatment) and b) the number of fruit drop per tree during April and May 2002 (n = 12 trees per treatment). Symbols associated with dissimilar letters differ significantly at P < 0.05 as tested by Duncan's Multiple Range Test.

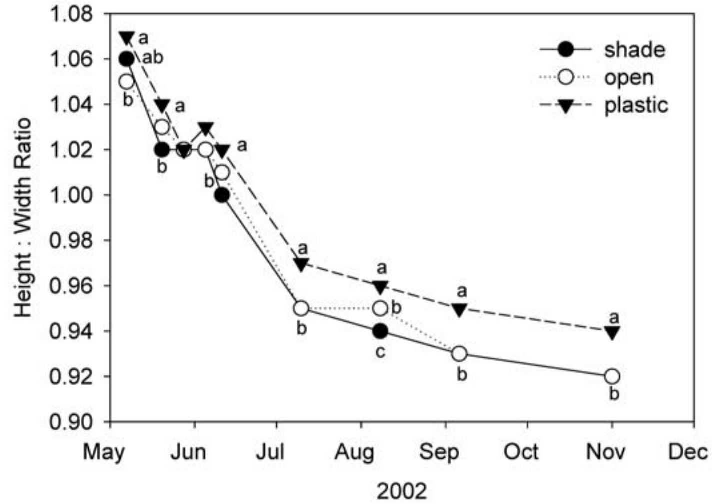

Fig. 2. Effects of clear plastic, 50% shade covers or the open canopy (control) treatment on fruit height/width ratio from May until Nov. 2002. There were 20 to 40 fruit measured on each of 12 trees in each treatment. Symbols associated with dissimilar letters differ significantly at P < 0.05 as tested by Duncan's Multiple Range Test.

to be relatively large, coarse, and elongated along the vertical axis (prolate), not all sheepnosed fruit had a large (> 1) H/W ratio. In fact, the average H/W ratio of sheepnosed fruit was always less than one. Therefore, even sheepnosed fruit tended to be flattened at the top and bottom. Fruit shape was thereafter evaluated qualitatively by rating fruit as either flat, round, or sheepnosed.

Interactions between sheepnosed shape, crop load, alternate bearing, and other year-to-year variations in fruit quality make drawing conclusions from one year's data problematic. Nonetheless, we increased sheepnosing using high N and high temperature. The early season plastic cover treatments have recently been repeated at both the Ridge and IR locations with similar results (data not shown). Thus, we are confident that elevated temperatures and humidity before and after bloom leads to grapefruit developing a larger percentage of sheepnosed shape. In addition, results through time in the Indian River area, support the idea that sheepnosing increases late in the season (Ritenour et al., 2003). More recently developed grapefruit cultivars ('Flame' and 'Ray Ruby') tended to be more elongated than 'Marsh seedless' and 'Ruby Red' but there were no significant effects of scion cultivar, rootstock, or can-

Table 2. Effects clear plastic covers or 50% shade cloth over tree canopies from February through June and of canopy position on treatment means fruit of fruit height/width (H/W) ratio and percentage sheepnosed (% S-nose) shape of 'Ruby Red' grapefruit in the Ft. Pierce experiment. There were 30 fruit rated from each canopy position of six replicate trees in each cover treatment.

	12-Jun-02	29-Jul-02		22-Oct-02		13-Jan-03	
Treatment	H/W Ratio	H/W Ratio	% S-Nose	H/W Ratio	% S-Nose	H/W Ratio	% S-Nose
Plastic	1.00 a[z]	1.02 a	33.47 a	0.94 a	26.69 a	0.93 a	29.31 a
Open Control	0.98 b	0.93 b	16.60 b	0.91 b	9.05 b	0.90 b	15.81 b
Shade	0.96 c	0.91 b	7.64 b	0.89 c	3.19 b	0.89 c	8.05 b
	12-Jun-02	29-Jul-02		22-Oct-02		13-Jan-03	
Position	H/W Ratio	H/W Ratio	% S-Nose	H/W Ratio	% S-Nose	H/W Ratio	% S-Nose
North	0.98 ns	0.97 ns	12.91 b	0.91 ns	8.14 b	0.90 ns	13.54
South	0.98	0.94	25.56 a	0.92	17.81 a	0.91	21.91

[z]Column means within a group followed by dissimilar letters differ significantly at P < 0.05 as tested by Duncan's Multiple Range Test.
ns = non-significantly different.

Table 3. Fruit height (Frt. H), H/W ratio, longitudinal surface area (SA) of juice sections or total fruit, percentages of surface area of peel, and number of seeds in large (Lg) and small (Sm) fruit hemispheres (hemi.) of flat, round, and sheepnosed 'Marsh seedless' grapefruit from the Ridge experiment. There were 20 fruit rated and sectioned in each shape class.

			Section SA		Fruit SA				Number of seeds		
Fruit shape	Frt. H (mm)	H/W ratio	Sm hemi. (cm^2)	Lg hemi. (cm^2)	Sm hemi. (cm^2)	Lg hemi. (cm^2)	Sm hemi. % peel	Lg hemi. % peel	Lg sec.	Sm sec.	Total seeds
Flat	80.1 c[z]	0.82 b	42.5 b	44.1 b	60.5 b	62.7 b	29.8 b	29.8 b	2.7 ns	2.5 a	5.1 a
Round	85.9 b	0.87 a	44.5 ab	46.3 b	65.7 b	67.2 b	32.2 b	31.4 b	1.8	1.6 ab	3.8 ab
Sheep	96.1 a	0.89 a	46.9 a	49.5 a	79.7 a	83.9 a	39.8 a	40.1 a	2.0	1.4 b	3.3 b

[z]Column means within a group followed by dissimilar letters differ significantly at $P < 0.05$ as tested by Duncan's Multiple Range Test.
ns = non-significantly different.

Table 4. Effects of N rate on leaf and fruit N content, fruit yield, fruit size, juice quality, fruit height/width (H/W) ratio and percentage sheepnosed (%S-nose) 'Ruby Red' grapefruit on the Ridge. There were 60 fruit rated from six replicate trees fertilized at the high and low rates of N.

N rate (lb/Ac)	Leaf N (%)	Fruit N (%)	Yield Bx/Tr	Fruit wt. (g/fruit)	Juice (%)	B/A ratio	H/W ratio	% S-nose
100	2.44 b[z]	0.91 ns	5.1 ns	525 ns	49.7 b	8.41 b	0.93 ns	3.2 b
250	2.66 a	0.94	4.5	478	53.0 a	9.16 a	0.92	14.7 a

[z]Column means within a group followed by dissimilar letters differ significantly at $P < 0.05$ as tested by Duncan's Multiple Range Test.
ns = non-significantly different.

opy position on sheepnosing. It is interesting to note that we also reduced crop load and increased fruit size by the high temperature and relative humidity under the clear plastic treatment. Thus, it is possible that not only the high temperatures (and relative humidities) in the early season, but also the reduced yield played a role in enhancing sheepnosed shape. In the high vs low N treatments where crop load was not affected, high N increased sheepnosing. Recently, Sauls (2004) suggested that growers could reduce fertilizer N applications to reduce sheepnosing as soon as crop loads were known to be small. Our data support that suggestion.

Since there were fewer seeds in sheepnosed fruit than in flat or round fruit, we have no data to support the hypothesis that differences in the numbers of seeds in fruit may be related to the observed differences in fruit shape. Although the number of seeds in larger hemisphere of fruit was consistently greater than in the smaller hemisphere, these differences were not significant. Thus, the presence of seeds was apparently not a sufficient source of plant growth regulators or of greater growth demands that contributed to sheepnosing.

Ultimately, using methods to decrease sheepnosing in grapefruit, should lead towards the development of cultural practices to manage sheepnosing and misshapen fruit within a grove. At the very least, through understanding how field treatments affect fruit growth and the mechanism(s) by which sheepnosing occurs, we will be able to determine the onset of misshaped fruit as early as possible. Decisions to target crops for the fresh or processed market could be made early in the season to allow the diversion of resources to groves with a high predicted packout. Modified management practices may increase packout and returns to growers. For example, growers could use this information to alter management strategies such as reduced nitrogen rates when crop loads are low.

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