Subtropical Plant Science, 50: 15-19.1998

Comparisons of Fruit Shape of 'Rio Red' and 'Henderson' Grapefruit, *Citrus paradisi* Macf., in Texas

Julian W. Sauls

Texas Agricultural Extension Service, 2401 East Highway 83, Weslaco, TX 78596

ABSTRACT

Fruit shape of 'Rio Red' and 'Henderson' grapefruit (Citrus paradisi Macf.) was determined during January through March, 1998, in seven-year-old orchards located about 8.6 km (5.3 miles) apart near Santa Rosa in Cameron County, Texas, using the ratio of equatorial to polar diameter as the measure of fruit shape. The fruit of both cultivars was more oblate with increased fruit size. 'Rio Red' grapefruit in each commercial size were rounder than that of 'Henderson'. The shape of the largest and most oblate 'Rio Red' fruit was comparable to that of the smallest and least oblate 'Henderson' fruit.

RESUMEN

Se evaluó la forma de la fruta de toronjas 'Rio Red' y 'Henderson' durante el período de enero a marzo de 1998 en huertas de 7 años localizadas a una distancia entre ellas de aproximadamente 8.6 km (5.3 millas) cerca de Santa Rosa en el condado de Cameron, Texas. La forma de la fruta se determinó usando la relación del diámetro ecuatorial al polar. La fruta de ambos cultivares fue más aplastada en los polos a medida que se incrementó su tamaño. Las toronjas del cultivar 'Rio Red' fueron más redondas que las del cultivar 'Henderson' en las dos localidades. La forma más grande y más achatada en los polos de la fruta del cultivar 'Rio Red' fue comparable a la forma de la fruta más pequeña y menos achatada del cultivar 'Henderson'.

Sheepnosing is a term used in Texas and Florida to describe grapefruit (*Citrus paradisi* Macf.) which exhibits a snoutlike appearance at the stem end of the fruit; in California, the disorder is referred to as stem end taper. The malformation ranges from slight elongation of the stem end of the fruit, often accompanied by creased, depressed stem end, to prominently elongated, almost necked, stem end. Although other types of citrus can be affected, the disorder is more common and striking in the normally oblate-shaped grapefruit.

Sheepnosing is invariably associated with thick rind, coarse peel texture and puffiness of the fruit (Wutscher, 1976). Vigorously growing trees, especially nucellar lines, are more likely to exhibit sheepnosing (Soost et al., 1965) and it occurs more commonly on larger fruit (Nauer et al., 1975; Wutscher, 1976). Sheepnosing is also more common in inland growing areas than in coastal areas (Reuther, 1973; Wutscher,1976).

Historically, sheepnosing of grapefruit in Texas has been a sporadic problem that occurred in some orchards in certain years. During so-called sheepnose years, sheepnosed fruit could be found in all orchards, although the amount of sheepnosed fruit and degree of sheepnosing varied among orchards.

Since the advent of the 'Rio Red' cultivar (Hensz, 1985), sheepnosing has become considerably more important because of the fact that sheepnosing of 'Rio Red' has occurred every year-although older cultivars such as 'Henderson' and 'Ruby Red' grapefruit have only occasionally experienced sheepnosing during that time. Because 'Rio Red' accounts for approximately 70% of Texas grapefruit acreage (Findley and Waldrop, 1995), the industry is keenly interested in the problem, as severely sheepnosed grapefruit is eliminated from the fresh market, thereby increasing the oversupply of processed grapefruit juice and decreasing grower returns.

The causes of sheepnosing are not really known, being widely assumed to result from environmental stress such as dry climate, late bloom or warmer than normal temperatures during bloom and early fruit development. Conditions which support overly vigorous growth, such as nucellar budlines, young trees and excess nitrogen fertilization, exacerbate both the amount and severity of sheepnosing, especially in so-called sheepnose years (Soost et al., 1965).

In a comprehensive review of climatic effects on fruit shape, Reuther (1973) concluded that a more humid climate with smaller seasonal and diurnal amplitudes in temperature produces smoother texture, flatter shape and less prominent neck than does a drier climate with larger amplitudes in temperature variations. Although his review dealt mostly with oranges and mandarins, his Figure 9-11 contrasts a flat, very smooth-skinned 'Redblush' grapefruit from a cool, relatively humid coastal climate with a less oblate, coarse skinned fruit

from a hot, arid interior valley climate in California. While not sheepnosed, the latter fruit would be considered intermediate between normal oblate fruit and sheepnosed fruit. Nauer et al. (1975) reported larger, coarser and more elongated grapefruit, with thicker rind, from inland growing area of California.

Cohen et al. (1972) found a strong, negative correlation between pan evaporation (from April to October) and the shape of 'Marsh' grapefruit at eight locations in Israel, but other climatic factors such as relative humidity and temperature, including average daily maximum temperature (April to October), average daily minimum temperature (November to March) and occurrences of both high and low temperatures, were not correlated with fruit shape. Contrary to the evidence they presented, the authors concluded that "climatic conditions in the winter(s) prior to flowering are important in determining...fruit shape of grapefruit" and that those factors "are as important as, and probably even more so, than the conditions prevailing during the fruit-growing season". While this work has been cited with reference to sheepnosing, there is no reference by the authors to sheepnosing or even to abnormally shaped grapefruit. Indeed, the worst-shaped grapefruit reported in their work had an equatorial to polar diameter ratio of 1.10 while the best measured 1.22.

While thicker rind is invariably associated with sheepnosing, Cohen et al. (1972) reported a strong, but non-significant, negative correlation between fruit shape and rind thickness, i.e., rounder fruit tended to thicker rind. Rind thickness is affected by rootstock (Wutscher and Shull, 1972; 1975; Wutscher and Dube, 1977; Wutscher et al., 1975) and budline vigor (Maxwell et al., 1973) Smaller fruit were reported to have thinner rind (Nauer et al., 1975; Wutscher and Shull, 1975; Wutscher and Dube, 1977), but Wutscher et al. (1975) found no apparent correlation between rind thickness and fruit size. Soost et al. (1965) reported a high percentage of thick-peeled fruit, as well as stem end taper, but did not attempt to correlate the two.

Zekri (1995) reported that phosphorous deficiency in grapefruit results in a coarse, thick rind, and that excess potassium results in larger fruit with coarser rind. Hipp and Shull (1976) observed no influence of nitrogen, phosphorous or potassium on grapefruit shape, but reported that nitrogen levels resulted in thicker rind that was more prominent in later years on larger fruit.

Soost et al. (1965) reported (equatorial to polar diameter) ratios of 1.00 to 1.07 for 'Marsh' grapefruit over several seasons in California. In all cases, old budline produced flatter fruit shape than nucellar and old budline trees produced a lower percentage of fruit having stem end taper (sheepnosing). The percentages of fruit having stem end taper were 10 to 20 in the best year for fruit shape, ranging upward to 40 to 60% in other years. The authors claimed that the degree of stem end taper in the nucellar budline had decreased as the trees aged, but no data were presented.

Wutscher (1976) reported that grapefruit grown under constant 32° day, 7° night temperatures exhibited severe sheepnosing, with normal, oblate fruit being produced at 32° day, 24° night conditions. He also reported that fruit produced under 32° day, 30° night temperatures exhibited creased stem ends.

Wutscher's fruit shape data are flawed because the ratios were derived from circumferential rather than diametrical measurements, inasmuch as there can exist a wide range of diameters among spherical objects having the same circumference. The ratio reported for normal-shaped fruit was 1.00, which depicts a round fruit rather an the oblate fruit.

The fruit shown in his Fig. 2 (Wutscher, 1976) to demonstrate sheepnose resulting from the low night temperature regime, while obviously sheepnosed and elongated polarly, is far more elongated than fruit normally encountered in the field. By contrast, three of the fruit shown in his Fig. 1, which represent shapes resulting from the high night temperature regime, depict moderate sheepnosing as is currently of concern to the Texas citrus industry. Nonetheless, Wutscher's work showed that sheepnosing in grapefruit could be induced by a large amplitude (25° C) in diurnal temperature, which also resulted in increased peel thickness.

Sauls (1996) attempted to compare the departure from normal maximum, minimum and mean temperatures during prebloom and from bloom through final fruit set with the occurrence of sheepnosing in Texas. Both the 1989-90 and the 1995-96 seasons were considered to be sheepnose years, i.e., sheepnosing was common Valleywide on all grapefruit cultivars. In both seasons, all three temperature parameters were warmer than normal. In all other seasons since 1988-89, the temperature parameters were cooler than normal, with a couple of exceptions, yet sheepnosing has occurred in 'Rio Red' grapefruit every year, while it was hard to find in the other grapefruit cultivars.

Because off-bloom grapefruit invariably exhibits sheepnosing with coarse, thick skin and puffy fruit, even in coastal areas where there is relatively little diurnal temperature fluctuation (Wutscher, 1976), it seems apparent that climate during bloom and early fruit development has some importance in the development of sheepnosing. In some cases, a delayed bloom of only one to two weeks results in increased sheepnosing (R.E. Rouse, personal communication). The fact that 'Rio Red' exhibits sheepnosing every year in both Texas and Florida while other cultivars only rarely exhibit the condition (R.E. Rouse, personal communication) suggests that some factor or factors other than climate must be involved. During the last several years, I have observed that 'Rio Red' fruit invariably tends to be rounder than that of other cultivars. Because both sheepnosing and roundness of shape involve increased polar diameter in relation to equatorial diameter, this study was undertaken to ascertain and compare the shapes of 'Rio Red' and 'Henderson' grapefruit.

MATERIALS AND METHODS

During the 1997-98 season, both polar and equatorial diameters of 'Rio Red' and 'Henderson' grapefruit were measured from January through March, 1998. The 'Rio Red' orchard was planted at 4.57 x 7.62 m (15 x 25 feet) in 1991 and is under flood irrigation. The 'Henderson' orchard was set 3.81 x 7.31 m (12.5 x 24 feet) in 1991 and is under microsprayer irrigation. Both cultivars are growing on sour orange rootstock. The two orchards are situated about 8.6 km (5.3 miles) apart

Table 1. Fruit shape of 'Rio Red' and 'Henderson' grapefruit, as determined by the ratio of equatorial to polar diameter, during the 1997-98 season.

Equatorial diameter (cm)	Comparable packed size	Number of fruit	Equatorial: polar diameter[z] Rio Red	Henderson
8.6-9.0	56	130	1.072 a[y]	1.125 a
9.1-9.5	48	131	1.086 b	1.131 a
9.6-10.0	40	192	1.096 b	1.163 b
10.1-10.5	35	174	1.099 b	1.184 c
10.6-11.0	32	153	1.114 c	1.204 d
11.1-11.5	27	130	1.128 d	1.220 e
11.6-12.0	23	119	1.132 d	1.23S f
Mean			1.102	1.179
Significance: Cultivar			***	***

[z]A ratio of 1.000 indicates a round fruit; the greater the value above 1.000, the more oblate the fruit shape.
[y]Means followed by letters in common do not differ at the 0.05 level of probability.

near Santa Rosa in Cameron County, Texas, are under the same management and received the same fertilization, weed control and pest management during the season. The 'Rio Red' orchard received 114 mm (4.5 inches) of irrigation water in July, 1997, and rainfall totaling 950 mm (37.5 inches) from March through December, 1997. The 'Henderson' orchard received 110 mm (4.3 inches) of irrigation water during July and August and 742 mm (29.2 inches) of rainfall from March through December.

Measurements were made with a homemade caliper consisting of a horizontal base to which a metric ruler was affixed, with a rigid arm on one end of the base and a movable arm on the other. For equatorial diameter measurements, the blossom end of the fruit was centered, flat, on the horizontal part of the caliper, with one side against the stationary upright and the other side touching the sliding upright arm of the caliper. The fruit was then rotated on its polar axis to obtain the maximum equatorial diameter. For polar diameter measurements, the blossom end of the fruit was centered fiat against the stationary upright of the caliper, while the mobile upright was moved into contact with the stem end of the fruit. In this way, the movable upright contacted both sides of the button of uniform fruit or the highest side of lopsided fruit.

Measurements were determined to the nearest millimeter. The data were sorted by equatorial diameter, then grouped in 0.5 cm increments corresponding to the mid-range of the respective packed or "count" sizes. The range between minimum and maximum diameters of the packed or count sizes is sufficiently broad and overlapping that a fruit of mid-range diameter might also fit into both the next larger and the next smaller size.

Initially, all fruit from a tree were harvested and measured, except that fruit which exhibited severe sheepnosing was excluded. Severe sheepnosing was considered as fruit having a prominent stem-end protrusion and for which polar diameter was equal to or greater than equatorial diameter. As the season progressed, however, it became necessary to select both smaller and larger 'Rio Red' fruit and larger 'Henderson' fruit to obtain equal numbers of fruit in each size for each the two cultivars.

The data were subjected to statistical analysis by corresponding ring size. Means for the two cultivars were compared by T test, while Duncan's multiple range test was used to compare means within a cultivar (PC-SAS,1997).

RESULTS AND DISCUSSION

The ratio of equatorial to polar diameter of both 'Rio Red' and 'Henderson' grapefruit increased with increasing fruit size (Table 1), i.e., fruit shape was more oblate or flattened with increased size. Although this finding may seem contrary to reports (Nauer et at., 1975; Wutscher, 1976) and the popular belief that larger fruit tend to experience more sheepnosing, severely sheepnosed fruit were excluded from this study. In this regard, 87 of the first 856 'Rio Red' fruit harvested were rejected because of severe sheepnosing, after which point clean-tree harvesting was replaced by the selection of specific sizes only and no records were kept of exclusions. By contrast, no 'Henderson' fruit were rejected for sheepnosing since there was no sheepnosing in this cultivar in this orchard during the 1997-98 season.

For each size category, 'Rio Red' fruit was significantly rounder than 'Henderson' fruit, thereby verifying field observations. The shape of the largest and most oblate 'Rio Red' fruit (sizes 27 and 23) was equivalent to that of the smallest and roundest 'Henderson' fruit (sizes 56 and 48).

The highest ratio reported by Soost et al. (1965) for 'Marsh' grapefruit in California was 1.07, with 8.0 and 11.0% stem end taper, in 1964, which the authors considered to be a good year for fruit shape. The lowest ratio reported by Cohen et al. (1972) for 'Marsh' grapefruit in Israel was 1.10, with no reference to either sheepnose or stem end taper. In the present study, the average ratio for all 'Rio Red' fruit was 1.102. The average ratio for all 'Henderson' fruit was 1.179, which is equal to or better than the ratios reported for six of the eight locations in Israel.

While the review by Reuther (1973) concludes that grapefruit shape is more elongated polarly in drier climates with larger amplitudes in seasonal and diurnal temperature

variations, as did work by Soost et al. (1965) and Nauer et al. (1975), and while Cohen et al. (1972) found pan evaporation to be the only significant weather factor affecting grapefruit shape in different climatic zones in Israel, the differences in shape between 'Rio Red' and 'Henderson' grapefruit and between sizes within each cultivar in this study cannot be attributed to climatic causes. For the most part, the differences in fruit shape discussed in the literature occurred in different climatic zones of California, Israel or elsewhere. However, there is little information about year to year variations in fruit shape within the same climatic zone nor between cultivars within the same climatic zone.

The proximity of the two orchards in the present study does not support significant differences in climate as being responsible for differences in shape of the two cultivars. It could be argued that soil type, irrigation method and total rainfall were different between the two orchards, and that such differences may have affected fruit shape. However, soil type (and, by extension, nutrition) can be discounted because of the fact that sheepnosing occurs in 'Rio Red' orchards across the Valley every year and that when sheepnosing occurs on other grapefruit cultivars, it can be found across all citrus soils in the Valley.

The differences in irrigation system should not have been a factor in this study, as no irrigation was applied to either orchard until July, by which time ultimate fruit shape had already been determined (Bain, 1958; Olson, 1965; Young et al., 1969; Reuther, 1973; Wutscher, 1976). Rainfall from March 1 to June 24, 1997 totaled 447 mm (17.6 inches) at the 'Henderson' orchard and 509 mm (20.0 inches) at the 'Rio Red' orchard. Moreover, rainfall at either orchard occurred within 2 or 3 days of that at the other orchard.

In addition, 'Rio Red' trees which had been interplanted into a 'Ruby Red' orchard in 1990 (after the latter was buckhorned as the result of the December, 1989, freeze) exhibited a very high degree of sheepnosing in the 1995-96 season, i.e., more than half the fruit were observed to be sheepnosed. By contrast, the author observed only a few sheepnosed fruit on any of the rehabilitating 'Ruby Red' trees, which observation was also true of the adjacent 'Henderson' trees in the same orchard. Indeed, these observations by the author during what would be described as a sheepnose year precipitated the closer observation of 'Rio Red' fruit shape which led to the present study.

That 'Rio Red' grapefruit are rounder than 'Henderson' grapefruit is obvious. Because grapefruit sizing is based on equatorial diameter, the differences between cultivars and between sizes within each cultivar are due solely to differences in polar diameter. The basic roundness of 'Rio Red' grapefruit may not be the cause of its sheepnosing inasmuch as it does produce some oblate fruit. For example, the most oblate individual 'Rio Red' fruit in this study had ratios ranging from 1.17 (size 56) to 1.32 for sizes 27 and 23 (data not shown).

That both sheepnosed and oblate 'Rio Red' fruit occur on the same tree at the same time suggests that the controlling factor or factors are not related to climate, but have to be more specific to the individual tree, to individual branches or perhaps even to individual flower clusters or flowers. Soost et al. (1969) reported that inside fruit was less tapered (sheepnosed) and flatter than outside fruit and that outside fruit on the south side of the tree was more tapered than that on the north side of the tree. They also reported that nucellar grapefruit grow more rapidly and bear a greater percentage of fruit in the outer canopy, which leads to a higher incidence of stem end taper and rough peel.

Based upon the available literature and this study, plus years of observations and discussions with colleagues, it seems likely that some unknown factor or factors predispose individual fruit or clusters of fruit to sheepnosing. While such factors may themselves be affected by climate, it seems more likely that climatic factors during early fruit development affect the degree of expression of sheepnosing in those fruit.

The occurrence of slight lopsidedness of the stem end of some fruit was observed when the movable upright arm of the caliper did not touch both sides of the button when measuring polar diameter. The condition was noted as no more than a couple of millimeters in magnitude, being more common on rounder fruit in small and medium sizes of 'Rio Red' grapefruit-although no effort was made to quantify this observation. No reference to this slight anomaly of shape was encountered in the literature. Its apparent similarity to a very slight degree of sheepnosing, however, warrants further study.

LITERATURE CITED

Bain, J.M. 1958. Morphological, antomical, and physiological changes in the developing fruit of the Valencia orange, *Citrus sinensis* (L.) Osbeck. Austral. J. Bot. 6:1-24.

Cohen, A., J. Lomas and A. Rassi. 1972. Climatic effects on fruit shape and peel thickness in 'Marsh Seedless' grapefruit. J. Amer. Soc. Hort. Sci. 97(6):768-771.

Findley, D.S. and J.H. Waldrop. 1995. Texas citrus tree inventory. Texas Agri. Stat. Serv. Bul. 253(1). 12 pp.

Hensz, R.A. 1985. 'Rio Red', a new grapefruit with a deep-red color. J. Rio GrandeValley Hort. Soc. 38:75-76.

Hipp, B.W. and A.V. Shull. 1976. Influence of nitrogen, phosphorous and potassium on red grapefruit. J. Rio Grande Valley Hort. Soc. 30:65-72.

Maxwell, N.P., E.E. Burns and H.K. Wutscher. 1973. A comparison of three nucellar selections of red grapefruit with old budline Redblush. J. Amer. Soc. Hort. Sci. 98(1):116-118.

Nauer, E.M., J.H. Goodale, L.L. Summers and W. Reuther. 1975. Climate effects on grapefruit and lemons. Calif. Agr. 29(3):8-10.

PC-SAS. 1997. SAS Users Guide Statistics. SAS Institute, Cary, NC.

Reuther, W. 1973. Climate and citrus behavior. In: Walter Reuther (ed) The Citrus Industry Vol.III, Agricultural Publications, Univ. of Calif., Berkeley. pp.280-337.

Sauls, J.W. 1996. Sheepnose and temperature revisited. In: Valley Citrus Notes, Texas Agri. Ext. Serv. newsletter. 10 (4)4-5,7.

Soost, R.K., J.W. Cameron, R.H. Burnett and B. England. 1965. Fruit characters of nucellar Washington navel orange and Marsh grapefruit budlines. Calif. Citrograph 51(1): 3,18, 20,22,24.

Wutscher, H.K. 1976. Influence of night temperature and day length on fruit shape of grapefruit. J. Amer. Soc. Hort. Sci. 101(5):573-575.

Wutscher, H.K. and A.V. Shull. 1972. Performance of 13 citrus cultivars as rootstocks for grapefruit. J. Amer. Soc. Hort. Sci. 97(6):778-781.

Wutscher, H.K. and A.V. Shull. 1975. Yield, fruit quality, growth and leaf nutrient levels of 14-year-old grapefruit, *Citrus paradisi* Macf., trees on 21 rootstocks. J. Amer. Soc. Hort. Sci. 100(3):290-294.

Wutscher, H.K. and D. Dube. 1977. Performance of young nucellar grapefruit on 20 rootstocks. J. Amer. Soc. Hort. Sc. 102(3): 267-270.

Wutscher, H.K., N.P. Maxwell and A. V. Shull. 1975. Performance of nucellar grapefruit, Citrus paradisi Macf., on 13 rootstocks in south Texas. J. Amer. Soc. Hort. Sci. 100(1)48-51.

Zekri, M. 1995. Nutritional deficiencies in citrus trees: nitrogen, phosphorous and potassium. Citrus Ind. 76(8):58-61.