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CHANGES FOLLOWING THE FREEZE OF JANUARY, 1977 IN THE QUALITY OF FRUIT AND FOLIAGE INJURY FROM TWELVE CITRUS STOCK-SCION COMBINATIONS[1]

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Abstract. **Fruit were tested for juice quality in November, 1976 and in February, 1977 after the freeze of January 18-20, 1977 from 'Pineapple' orange and 'Marsh' grapefruit trees planted in shallow-tilled, deep-tilled and deep-tilled plus heavily limed plots on Trifoliate orange, Carrizo citrange, Cleopatra mandarin, rough lemon, sour orange, and Rangpur lime rootstocks. Lower juice, less acid and higher solids/acid ratio in individual fruit were found on fruit harvested from both scions on all rootstocks in February. Fruit on certain rootstocks were less affected than those on other rootstocks. Fruit from trees planted on the deep-tilled, heavily limed-plots generally were higher in quality than fruit from trees on plots receiving shallow-tilled or deep-tilled without deep incorporation of lime treatments.**

The freeze of January 18-20, 1977 ranks as one of the worst over south Florida in this century (1). On the morning of January 20, 1977 temperatures at the weather station at the Soil-Water-Atmosphere-Plant (SWAP) relations drainage site near Fort Pierce, fell below 26°F and remained below this temperature for nearly seven hours. Minimum temperature recorded on this date at this site was 22°F. Compared to the freeze of 1962, when only minor damage was sustained in the Indian River area, damage to citrus trees and fruit was considerably more severe in January, 1977. A survey of groves in the Indian River area disclosed considerable variations in cold damage; contributing factors included citrus variety, rootstock, topographic position of grove, cultural practices and soil type. Some of the differences in damage appeared to be associated with non-uniform movement of cold air through the groves. Groves adequately irrigated sustained less fruit damage than groves not adequately irrigated (5). Groves flooded with artesian water and/or drainage water shortly before and during the freeze had less severe freeze damage when compared to adjacent or nearby groves that were not flooded. Generally, groves on finer textured soils were injured less than those planted on coarse textured soils.

Historically, variations that occur in juice quality of 'Pineapple' oranges in non-freeze years have been well documented in previous studies (7) and similar information on juice quality is also available for 'Marsh' grapefruit on an annual basis (4). Therefore, it appears reasonable to assume that the extreme departures encountered in freeze years from the normal year variations in juice quality are the result of freeze injury.

Studies on freeze induced changes in juice quality of 'Valencia' oranges in Florida after the 1962 freeze were presented by Rasmussen, et al (10). To document the influence of environmental factors and cultural practices on freeze damage on a fairly large number of scion and rootstock combinations, fruit samples were taken after the freeze from trees in the SWAP drainage site and the trees were ranked for relative foliage and twig injury. Since fruit samples had been taken for juice quality analysis in November, 1976, resampling in February two weeks after the freeze provided a rare opportunity to study changes in fruit quality that may have been induced by the cold.

The quality of the juice of grapefruit and oranges before and following the January, 1977 freeze is reported and related to soil tillage treatments and to twig and foliage injury of the trees.

Methods and Materials

'Marsh' grapefruit and 'Pineapple' orange fruit were collected February 7-9, 1977 from the plots in the SWAP drainage experiment (8) near Fort Pierce, Florida. Growth and yield responses from the 12 citrus scion-rootstock combinations in this experiment were recently reported (2). The February sampling period was about 2 weeks after the freeze of January 18-20, 1977. Four replications, each containing 2 trees each of the 12 rootstock-scion combinations, were sampled in each of the 9 tillage plots at the SWAP site. Forty fruit were collected for each sample. Similar samples had been taken from the same plots on November 29-30, 1976.

Soluble solids, % juice, % titratable acid and fruit weight were determined by previously published methods (9). In addition to the fruit quality determinations, the trees from which fruit were sampled were ranked for relative freeze injury on January 25, 1977. The evaluations included extent of twig and leaf damage and relative loss of foliage. All evaluations were based on inspection of all 4 sides of each tree rated.

Results

Juice content. The average loss of juice from 'Pineapple' oranges on the 6 rootstocks following the freeze was 9.5 percentage points representing a 16.5% change in juice content. Average juice losses from oranges on 'Rangpur' and rough lemon stocks were significantly greater, (4.5 percentage points or 8.2% higher) than the average juice losses for the other 4 stocks (Table 1). It is recognized that the juice loss due to the freeze may have been slightly less than calculated, since Harding, et al (7) showed in his studies that the juice content of 'Pineapple' oranges normally decreases 1 or 2 percentage points from mid-November through mid-February. Differences in juice content between November and February in this study, however, ranged up to values over 12 percentage points representing a 22% change in juice content (Table 1).

Juice losses from 'Marsh' grapefruit attributable to the freeze were considerably less than for 'Pineapple' oranges and the differences in losses of grapefruit juice that could be attributed to differences in rootstocks were not statistically significant. However, it should be noted that before the freeze, grapefruit on sour orange had significantly higher juice content than grapefruit on Trifoliate orange. The freeze may have narrowed the range in juice content among the various grapefruit rootstock combinations.

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Table 1. Effect of tillage treatments and January, 1977 freeze on quality of 'Marsh' grapefruit and 'Pineapple' orange on six rootstocks.

	Soluble solids ° Brix		Acidity %		Ratio Brix-Acid		Juice % by weight		Juice % loss	Fruit weight gms/fruit		Relative leaf injury[y]
Treatment	Before freeze	After freeze	Before freeze	After freeze	Before freeze	After freeze	Before freeze	After freeze		Before freeze	After freeze	After freeze
					Marsh grapefruit							
Tillage												
ST	8.79b[z]	8.67a	1.11a	0.99a	7.90a	8.80a	53.63b	48.86b	4.78b	404b	422a	0.74a
DT	8.88a	8.58a	1.18a	1.00a	7.65a	8.61a	53.28b	48.47b	4.81b	420a	435a	0.71a
DTL	8.99a	8.70a	1.17a	0.98a	7.72a	8.92a	54.97a	50.84a	4.13a	410b	425a	0.73a
Rootstock												
Carrizo	8.97ab	8.81a	1.12a	0.99a	8.00a	8.94a	53.11cd	49.08a	4.03a	420ab	434abc	0.87b
Cleopatra	8.98ab	8.77a	1.15a	1.01a	7.82a	8.66a	53.60bcd	50.33a	3.07a	401cde	403d	0.50c
Rangpur	8.67c	8.12a	1.11a	0.94a	7.78a	8.63a	55.14ab	50.05a	5.09a	420a	437ab	0.60c
rough lemon	8.46c	8.44a	1.14a	0.96a	7.44a	8.86a	54.18abc	48.45a	5.73a	416abcd	423abcd	0.56c
sour orange	9.04ab	9.16a	1.23a	1.05a	7.51a	8.67a	55.45a	51.29a	4.16a	414abcd	450a	0.50c
Trifoliate	9.21a	8.58a	1.16a	0.98a	7.99a	8.88a	52.27d	47.13a	5.14a	397e	416bcd	1.27a
					Pineapple orange							
Tillage												
ST	10.52a	10.52b	0.85a	0.57b	12.45a	18.45a	57.75a	47.68b	10.07a	210a	202a	0.80a
DT	10.59a	10.68b	0.86a	0.58b	12.43a	18.44a	57.27a	47.39b	9.88ab	207a	212a	0.66a
DTL	10.60a	11.32a	0.86a	0.64a	12.39a	17.97a	57.91a	49.42a	8.49b	214a	208a	0.84a
Rootstock												
Carrizo	10.83ab	11.23abc	0.87abc	0.63abc	12.48ab	18.12bcd	57.54a	50.47a	7.08a	211a	217a	0.77b
Cleopatra	10.54bcd	10.69cd	0.84abcd	0.58bcd	12.58ab	18.43b	58.28a	49.05a	9.23a	205a	196a	0.49c
Rangpur	10.14de	10.01de	0.78d	0.50e	13.06a	20.09a	55.76a	43.66b	12.11b	218a	209a	0.82b
rough lemon	10.01e	9.75e	0.83abcd	0.56cd	12.11b	17.51cd	57.45a	44.62b	12.83b	214a	211a	0.70b
sour orange	10.79abc	11.74a	0.90ab	0.65ab	12.05b	18.21bc	58.59a	50.85a	7.74a	209a	200a	0.55bc
Trifoliate	11.10a	11.62ab	0.91a	0.67a	12.19b	17.39e	58.22a	50.34a	7.88a	203a	210a	1.28a

[z]Treatment means followed by the same letter within columns are not significantly different at the 5% level (Duncan's multiple range test).
[y]Leaf injury ratings: 0 = no visible foliage damage, 1 = mild foliage injury, 2 = moderate foliage injury and 3 = severe foliage injury.

Tillage treatments influenced juice losses in fruit sampled from both scions. Juice loss from 'Pineapple' oranges from surface tilled (ST) plots was 1.6 percentage points higher than from deep tilled with lime (DTL) plots. There were no statistical differences in juice loss in fruit sampled from the deep tilled (DT) plots as compared to either ST or DTL fruit. Tillage treatments affected juice losses in the grapefruit scion-stock combinations (Table 1). In this case losses of juice from fruit sampled from ST and DT plots were both significantly greater than from the DTL plots.

Soluble Solids. After the January freeze soluble solids decreased slightly in the juice of grapefruit in five of the six rootstocks (Table 1). The one exception was sour orange where a slight increase in soluble solids was detected. Before the January freeze grapefruit on 'Rangpur' and rough lemon rooted trees had significantly less soluble solids than the other four combinations. Grapefruit on Trifoliate produced the highest soluble solids, but the amount of these solids was not statistically different from that produced by sour orange, 'Cleopatra' and 'Carrizo'.

Significant differences among the soluble solids of grapefruit samples taken before the freeze were related to the tillage treatments. Fruit produced in DT and DTL plots had significantly higher soluble solids than fruit from the ST areas (Table 1). Differences in soluble solids in grapefruit juice from the various rootstocks after the freeze were not significant.

Before the freeze tillage treatments did not have a significant effect on soluble solids in 'Pineapple' oranges. After the freeze soluble solids were significantly higher in fruit from the DTL plots than from ST and DT plots. Before the freeze oranges from rough lemon and 'Rangpur' rootstocks had significantly lower soluble solids than the other rootstocks (Table 1). 'Pineapple' on Trifoliate had significantly more soluble solids than 'Pineapple' on the other stocks except on sour orange and Carrizo. 'Pineapple' on sour orange, rough lemon and Rangpur had less solids after the freeze than before the freeze. After the freeze 'Pineapple' on sour orange still had significantly more solids than 'Pineapple' on the other rootstocks except Trifoliate and Carrizo. After the freeze 'Pineapple' on 3 of the 6 rootstocks increased in soluble solids while three decreased.

Acid Content. The acid content of the grapefruit was not affected appreciably by tillage or rootstock. In all cases acidity decreased in samples taken after the freeze, however, the decrease was not greater than normally expected for grapefruit during this time period (4).

The acid content of the juice from oranges was affected by tillage and rootstocks. After the freeze acid content of fruit from ST and DT soil treatments were significantly lower than acid content from DTL treatment. Juice from fruit on Rangpur sampled before the freeze was significantly lower in acid than fruit from Carrizo, sour orange and Trifoliate. Except for being consistently lower after the freeze, the differences between rootstocks with respect to acid content of fruit both before and after the freeze were nearly identical (Table 1).

The solids/acid ratio increased markedly in the orange juice following the freeze. 'Pineapple' on Rangpur produced juice with the highest ratio both before and after the freeze. Although the solids/acid ratio in grapefruit juice increased between samplings, the amount of increase was comparable to that expected in a non-freeze year (4).

Fruit Weight. The average weight in grams of the 40-fruit sample of 'Pineapple' oranges was not influenced by either tillage or rootstocks, nor were orange weights materially changed by the January freeze. Grapefruit weights were influenced by both tillage and rootstocks, and although fruit were heavier after the freeze, no significant differences were observed. Grapefruit sampled before the freeze from DTL and ST were heavier than fruit from DT plots. This difference was not significant after the freeze.

Grapefruit weights varied among rootstocks both before and after the freeze (Table 1). The pre-freeze samples showed fruit from trees on Trifoliate were lighter than fruit from trees on Rangpur and Carrizo stocks, with remainder of stocks producing fruit intermediate in weight. In general, fruit were heavier after the freeze, with sour orange producing the heaviest grapefruit and Cleopatra producing the lightest.

Foliage Injury. Freeze damage to orange and grapefruit foliage was influenced by rootstocks but not by tillage. Foliage injury sustained by trees on Trifoliate stock was greater than the damage sustained by both scions on the other stocks (Table 1). Scions on sour orange and 'Cleopatra' suffered the least amount of foliage injury (Table 1).

Discussion

The most important results obtained in this study were the significant losses of juice sustained by orange fruit on Rangpur and rough lemon stocks following the freeze. The % loss of the orange juice was negatively correlated ($r = -0.72^{**}$) with the soluble solids in the juice following the freeze. This indicates that fruit containing higher soluble solids were injured less by the freeze and, therefore, lost less juice than fruit with lower soluble solids. Presumably, the higher solids acted to depress the freezing point which allowed the fruit to endure lower temperatures without injury for longer time periods. The % loss of grapefruit juice was also negatively correlated with the soluble solids in the fruit following the freeze ($r = -0.16^{*}$), but the correlation was much lower than for oranges, probably because of the better freeze protection afforded the grapefruit by their thicker rinds.

Deep tillage and particularly deep tillage plus deep incorporation of dolomitic limestone influenced several juice quality factors for both scions. For grapefruit, deep tillage was associated with highest soluble solids and highest % juice before the freeze. After the freeze more juice persisted in grapefruit from plots receiving the DTL treatment. The greater amount of juice after the freeze can be partly explained by DTL fruit having a higher juice percentage initially. However, since juice loss was significantly less for grapefruit from DTL plots than from DT and ST plots, it appears that the DTL treatment afforded some additional protection against loss of juice by freeze injury.

Soluble solids and acid content were significantly higher while juice loss was significantly lower in the orange juice from DTL at the February sampling. There were no significant differences in juice content due to tillage in November. Juice loss after the freeze was significantly less in oranges in DTL than in ST. These facts indicate that a higher level of juice quality was maintained in fruit from trees planted on the DTL treated plots than in fruit from ST and DT treatments. Two reasons for less freeze damage to fruit from DTL plots are readily apparent. First, the citrus trees in DTL plots were larger than in DT and ST plots (2), therefore, more heat was retained within the canopy and within the larger trunk and branches, and therefore, less freeze damage would be expected in fruit in this treatment. Secondly, since DT fruit, especially 'Pineapple' oranges, fared slightly better than ST fruit with regard to loss of juice from the freezing temperatures, it is likely that increased soil moisture in the deep-tilled plots (6), helped reduce freeze damage to the fruit by allowing heat stored in the deeper layers to be transferred to the soil surface and into the air more rapidly than in the drier shallow tilled plots (3).

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