

Citrus Section

Proc. Fla. State Hort. Soc. 118:1-3. 2005.

FRUIT AND JUICE QUALITY OF SEEDLESS PINEAPPLE ORANGES ON FOUR ROOTSTOCKS

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Additional index words. *Citrus sinensis*, irradiation, fruit quality, scion improvement

Abstract. Irradiation of seeds of 'Pineapple' orange resulted in the generation of several mutants with reduced seed count. In order to determine the horticultural characteristics of these mutants, trees of four numbered selections (10-8, 10-60, 10-97 and 10-98) were propagated on four rootstocks (Swingle, Carrizo, Cleopatra mandarin, and sour orange) and field trials were established at two locations in Florida (Lake and Osceola Counties). Data have been collected over five harvest seasons (1994, 1995, 1996, 2002, 2003) on fruit yield and juice quality (color, soluble solids, and total acidity). Although fruit of each selection ripened during the typical midseason of other pineapple oranges, selections differed in fruit and juice quality characteristics. Three of the selections produced fruit with very few seeds and many fruit had no seeds. The low seed count could make these selections much more valuable for the midseason fresh fruit market than the 'Pineapple' oranges that are presently available.

Seed content is an important component of consumer acceptability for fresh market citrus fruit. Many of the cultivars grown for the fresh market contain few seeds, however, many mandarin and some juice oranges contain numerous seeds (Soost and Roose, 1996). Since consumers prefer citrus fruit with few or no seeds, one objective of the USDA citrus breeding program is to develop seedless cultivars of citrus for the fresh market. Seedlessness is difficult to obtain by traditional breeding methods (Soost and Roose, 1996) but irradiation has proven to be useful for the development of seedless grapefruit (Henz, 1977) and holds promise for other citrus cultivars (Hearn, 1984, 1986).

Hearn (1984) reported on the development of seedless orange and grapefruit cultivars through seed irradiation. A number of seedless mutants of 'Pineapple' orange were identified but conclusions regarding the performance of these mutants could not be made based on observations of single-tree seedlings growing in close plantings. The objective of this work was to compare the fruit and juice quality characteristics

of four irradiated 'Pineapple' orange selections in replicated trials on multiple rootstocks and at multiple locations.

Materials and Methods

Two field experiments were established to evaluate the performance of four selections of irradiated 'Pineapple' orange. One experiment was located at the A.H. Whitmore Foundation Farm in Lake Co., FL. and the other was located on the property of a commercial cooperator in Osecola Co., FL. Budwood from 15-year old irradiated 'Pineapple' orange selections 10-8, 10-60, 10-97, and 10-98 from the USDA *Citrus* breeding program (Hearn, 1984) was grafted onto Swingle citrumelo (*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.), Carrizo citrange (*C. sinensis* (L.) Osb. × *P. trifoliata*.), Cleopatra mandarin (*C. reticulata* Blanco), or sour orange (*C. aurantium* L.) rootstocks. Two-year old budded trees were planted into the field in June 1990 at both the Lake Co. and Osceola Co. locations. At the Lake Co. location, trees on all four rootstocks were spaced 20 ft. × 15 ft. in a randomized complete block design of four-tree plots with four replications. At the Osceola Co. location, Swingle citrumelo was the only rootstock used in the trial. Trees were spaced 20 ft. × 15 ft. in a randomized complete block design of two-tree plots with four replications. At both locations, trees were maintained according to local standards for grove management.

Fruit were harvested in January/February of 1995, 1996, 2002, and 2003 at the Lake Co. site and in January/February of 1994, 1995 and 1997 at the Osceola Co. site. The number of seeds per fruit was determined on a sample of four fruit harvested in March of 1997 from each of the four rootstocks grown at the Lake Co. location. Average numbers of seeds per fruit were based on a pooled total of 16 fruit per selection. Fruit harvested in February 1995 from trees grown on Carrizo citrange at the Lake Co. location were measured to determine fruit diameter. Yield was estimated visually at the Lake Co. site. At the Osceola Co. site, yield was determined by harvesting fruit into standard field boxes. For both locations yield was expressed as the number of 90 lb. boxes per tree. Juice quality was determined following standard methods on a representative sample of fruit collected from each tree. Where possible, data were subjected to analysis of variance using PROC ANOVA (SAS Inst., Cary, NC) with mean separation by Duncan's multiple range test.

Results and Discussion

Fruit from irradiated 'Pineapple' orange selections 10-8, 10-60, and 10-98 were essentially seedless whereas fruit from irradiated selection 10-97 had seed counts typical of non-irradiated 'Pineapple' oranges (Tucker et al., 1993) (Table 1). These results were consistent with those reported by Hearn

We would like to thank Dr. Jack Hearn for developing the irradiated 'Pineapple' selections and establishing the field trials, Mr. Orie N. Lee for providing the grove land necessary for this experiment and collection of data, Dr. Bela Buslig for juice color analysis and Mr. Jim Baldwin for juice quality analysis.

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Table 1. Number of seeds per fruit and fruit diameter for four irradiated 'Pineapple' orange selections. Mean seed numbers were calculated from four fruit from each of four rootstocks at the Lake County location. Fruit diameter was measured on fruit grown on Carrizo citrange.

Selection	Seeds/fruit		Diameter (cm)
	Range	Means \pm se	
1-10-8	0-4	1.9 \pm 0.2	7.4
1-10-60	0-2	0.6 \pm 0.2	7.2
1-10-98	0-2	0.3 \pm 0.2	7.1
1-10-97	6-28	17.8 \pm 1.5	7.1

(1984) and indicate that the effects of irradiation on seediness are stable. There was no relationship between the number of seeds per fruit and fruit size (Table 1) as fruit of each selection averaged between 7.1 and 7.4 cm in diameter. The lack of correlation between seed number and fruit size contrasts with previous reports in which fruit size was positively correlated with the number of seeds per fruit (Cameron et al., 1960; Hearn and Reece, 1967). Fruit shape and peel characteristics of the irradiated selections were rated as good and stem end peel disruption (plugging) was not a problem (C. J. Hearn, pers. comm.).

Fruit yields (expressed as 90 lb. boxes per tree) of the four irradiated 'Pineapple' selections (Table 2) are comparable with reported yields for eight clones of 'Pineapple' oranges on twelve rootstocks over eight years (average 3.3 boxes per tree) (Bureau of Citrus Budwood Registration, 2005). Yields of the four irradiated 'Pineapple' selections followed a similar trend at both locations. Selection 10-8 produced the highest yield and the seedy 10-97 produced the lowest yield. The magnitude of the difference between the lowest and highest yielding selections was greater at Osceola Co. than at Lake Co. It has been suggested (Frost and Soost, 1968) that seedlessness is detrimental to the setting of fruit, so it was therefore surprising that the selections with reduced seed number would produce yields greater than the seedy selection. 'Pineapple' oranges are known to be susceptible to preharvest fruit drop (Tucker et al., 1993) and a major limitation of 'Pineapple' is its poor ability to store fruit on the tree (Young, 1986). Some observations suggest that the seedless mutants are less prone to fruit drop than the wild type 'Pineapple' orange (Mr. Orie Lee, pers. comm.). If the seedless selections are in fact less prone to fruit drop than the wild type 'Pineapple', this could be related to the lower yields produced by 10-97 compared to its seedy counter parts. Additional studies will be required to determine the susceptibility of the seedless selections to preharvest fruit drop.

Table 2. Yields of four irradiated 'Pineapple' orange selections at the Lake and Osceola County locations.

Selection	Boxes/tree	
	Lake	Osceola
1-10-8	3.8 a ^a	3.0 a
1-10-60	3.1 ab	2.8 a
1-10-98	2.7 ab	2.6 ab
1-10-97	2.6 b	1.8 b

^aValues within each column followed by unlike letters are significantly different by Duncan's multiple range test at $P < 0.05$.

Total soluble solids differed significantly among the four irradiated 'Pineapple' selections at both locations (Table 3). Harding et al. (1940) reported that 'Pineapple' oranges harvested in January or February from trees grown on rough lemon rootstock in central Florida averaged between 10.3 and 11.1 total soluble solids. Fruit of the seedy selection, 10-97, had significantly higher soluble solids than the reduced seeded selections at both Lake and Osceola Co. Neither total acidity nor the ratio of solids to acid differed significantly among the selections. In each case, total solids, total acid and ratio of solids to acid fell within the maturity standards as defined in the Florida Citrus Code (Florida Statutes, 2005). There was no effect of rootstock on total soluble solids, total acidity and solids acid ratio (data not shown).

At both locations, the yield of juice was lowest from 10-97, the seedy selection, and highest from 10-8 and 10-98 seedless selections (Table 4). At the Lake Co. site the yield of lbs. solids per box was significantly greater from 10-97 than the other selections, whereas at the Osceola Co. site there was no significant difference among the selections for lbs. solids per box.

Juice color scores for four irradiated 'Pineapple' orange selections are presented in Table 5. Although no statistical analysis of the data was possible, all juice color numbers were high enough (color number 32-35) to be classified as reasonably good (not as good as USDA OJ6, but not yellow). Most of the juice color scores (color number 36-40) would be classified as good (equal to or better than USDA OJ6) according to US Standards for grades of orange juice (USDA, AMS, 1983). The overall average for each selection, based on one year of data from Lake Co. and two years of data from Osceola Co., exceeded CN 36 which would be classified as good.

In summary, three seedless 'Pineapple' orange selections resulting from seed irradiation produced fruit with acceptable quality. Yields of the seedless 'Pineapple' selections aver-

Table 3. Average total soluble solids (TSS), total acid (TA), and solids-acids ratio (S/A) for four selections of irradiated 'Pineapple' sweet orange from trees on four rootstocks averaged over 5 seasons at the Lake and Osceola County locations.

Scion	TSS (%)		TA (%)		S/A	
	Lake	Osceola	Lake	Osceola	Lake	Osceola
1-10-8	10.7 bc ^a	10.9 c	0.92 b	0.90	11.8	13.3
1-10-60	10.4 c	11.4 ab	0.86 c	0.89	12.1	12.9
1-10-98	11.0 b	11.0 bc	0.95 a	0.86	11.5	12.8
1-10-97	11.5 a	11.8 a	0.95 a	0.87	12.0	12.7

^aValues within each column followed by unlike letters are significantly different by Duncan's multiple range test at $P < 0.05$. No letters within a column indicates no significant differences among treatments.

Table 4. Yields of juice and lbs. solids for four irradiated 'Pineapple' orange selections grown at the Lake and Osceola County locations on Carrizo and Swingle rootstocks.

Selection	Percent juice		Pound solids/box	
	Lake (Carrizo)	Osceola (Swingle)	Lake (Carrizo)	Osceola (Swingle)
1-10-8	60.3 a ^z	59.3 a	6.7 b	6.4
1-10-60	60.0 ab	61.5 a	6.5 b	6.4
1-10-98	57.0 b	59.7 a	6.4 b	6.4
1-10-97	58.7 b	55.5 b	7.4 a	6.5

^zValues within each column followed by unlike letters are significantly different by Duncan's multiple range test at $P < 0.05$. No letters within a column indicates no significant differences among treatments.

aged 2.6 to 3.8 90 lb. boxes per tree which is comparable for reported yields for 'Pineapple' oranges (Bureau of Citrus Budwood Registration, 2005). Total soluble solids (10.4-

Table 5. Juice color number (CN) values for four irradiated 'Pineapple' orange selections at the Lake and Osceola County locations averaged over 3 years.

Selection	Osceola (1993)	Lake		Average
		(1994)	(1995)	
----- CN -----				
1-10-8	35.7	36.7	37.1	36.5
1-10-60	35.5	37.2	37.1	36.6
1-10-98	35.3	37.3	36.8	36.5
1-10-97	34.5	36.4	36.5	36.5

11.8%) were similar to previously published results (Harding et al., 1940) and color numbers (ave. 36.5) indicated the juice was acceptable. Seedlessness should make these selections more attractive as a fresh market fruit than is standard 'Pineapple'. In addition, should the seedless selections prove to be less prone to preharvest fruit drop than the standard 'Pineapple', this would be another positive effect of modifications from irradiation.

Literature Cited

- Bureau of Citrus Budwood Registration. 2005. <http://www.doacs.state.fl.us/pi/budwood/yields.html#mid>
- Cameron, J. W., D. Cole, and E. M. Nauer. 1960. fruit size in relation to seed number in the Valencia orange and some other citrus varieties. *Proc. Amer. Soc. Hort. Sci.* 76:170-180.
- Florida Statutes, 2005. Ch. 601, Florida Citrus Code, <http://www.leg.state.fl.us/statutes>.
- Frost, H. B. and R. K. Soost. 1968. Seed reproduction: development of gametes and embryos. In *The Citrus Industry*, Vol. II. W. Reuther, L. D. Batchelor, and H. J. Webber (eds.), Univ. of Calif.
- Harding, P. L., J. R. Winston, and D. F. Fisher. 1940. Seasonal Changes in Florida Oranges, USDA Tech. Bul. No. 753.
- Hearn, C. J. 1984. Development of seedless orange and grapefruit cultivars through seed irradiation. *J. Amer. Soc. Hort. Sci.* 109:270-273.
- Hearn, C. J. 1986. Development of seedless grapefruit cultivars through budwood irradiation. *J. Amer. Soc. Hort. Sci.* 11:304-306.
- Hearn, C. J. and P. C. Reece. 1967. Pollination needs of Page, Lee, Nova and Robinson citrus hybrids. *Citrus Ind.* 48:19-23.
- Henz, R. A. 1977. Mutation breeding and the development of the 'Star Ruby' grapefruit. *Proc. Int. Soc. Citricult.* 2:582-585.
- Soost, R. K. and M. L. Roose. 1996. Citrus. In *Fruit Breeding*, Vol. I: Tree and Tropical Fruits, edited by Jules Janick and James N. Moore. John Wiley and Sons. pp. 257-323.
- Tucker, D. P. H., C. J. Hearn, and C. O. Youtsey. 1993. Florida citrus varieties. Fla. Coop. Extension Service.
- Young, R. H. 1986. Fresh Fruit cultivars. In *Fresh Citrus Fruits*. W. F. Wardowski, S. Nagy, and W. Grierson, Avi Publishing Co., Ch. 5, pp. 102-126.