Effects of Canopy Position on Quality, Photosynthesis and Mineral Nutrition of Four Citrus Varieties

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ABSTRACT

Quality, leaf gas exchange and mineral content of fruit from internal tree canopies were compared with those from external canopy positions in 4 citrus varities: 'Kinnow' mandarin; 'Redblush' grapefruit; 'Valencia' orange; and 'Lisbon' lemon. Fruit weight, total juice per fruit, peel fresh and dry weight, and rind thickness of fruit from internal canopies of all 4 varieties were significantly higher compared with external fruit. Mandarin, grapefruit, and orange fruit from external canopies had higher soluble solids and specific gravity. Leaves from internal canopy had higher photosynthesis than those of external canopy in all varieties. Fruit from internal canopies of all varieties had generally higher peel concentrations (%dry weight) of N, P and K due to a dilution effect, while the opposite condition existed in mandarin when these elements were expressed on a percent fresh weight basis. Peel Mg and S from external fruit were higher in all varieties, expressed as percentages of either dry weight or fresh weight. Nitrogen content of mandarin and orange juice and calcium content of grapefruit and lemon juice from external fruit were significantly higher, compared to those from internal canopy fruit. Eliminating fruit quality and mineral variations resulting from canopy positions is recommended by the means of cultural practices.

INTRODUCTION

Large fruit size, high soluble solids, high soluble solids to acid ratio and thin rind are considered desirable quality parameters in citrus fruit. A few studies have reported variations in juice soluble solids in relation to canopy position in orange (3, 4) and grapefruit (5). However, no comprehensive effort has been made to characterize the effects of canopy position on peel thickness, internal quality, and mineral content of fruit of various citrus varieties. Thus, the objectives of this study were to compare the quality, gas exchange and mineral differences between fruit from external canopy positions with those from internal positions for four commercially important citrus species (mandarin, grapefruit, orange, and lemon). This study could provide information that could be used to design optimal harvesting strategies to reduce the expense of sorting fruit for fresh market or juicing.

MATERIALS AND METHODS

Experimental trees were planted on sandy-loam soil at the University of Arizona, Yuma Mesa Experiment Station in 1970. The important commercial varieties -- citrus, 'Kinnow' mandarin, 'Redblush' grapefruit, 'Valencia' orange, and 'Lisbon' lemon budded on rough lemon (C. jambhiri Lush) rootstock -- were chosen for the experiment.

Tree spacing was 6.74 x 6.74 m; nitrogen was applied annually at the rate of 0.5- 1.3 kg per tree, depending on the age of trees. Irrigation was applied by flooding, and all cultural practices were standard. Ten trees per variety were randomly chosen for sampling. Ten fruit were picked randomly from each canopy position site (10 fruit from internal and 10 fruit from external) of each of 10 trees, and washed.

Each fruit was cut in half; peel thickness was measured on 2 sides of each half by an electronic digital caliper. Subsequently, fruit were peeled, and determinations were made for peel fresh weight, peel dry weight (oven dried at 70° C) and percent dry weight. Fruit juice, soluble solids, total acids, solid/acid ratio, and specific gravity were measured. Dried peel samples were ground to pass a 20 - mesh screen. Peel and juice samples were analyzed for total nitrogen by automated Micro Kjehdal, and for P, K, Ca, S, Mg, Mn, B, Fe, Cu, Zn and Sr by the use of Inductive Coupled Argon Plasma, by Jones method (2).

RESULTS AND DISCUSSION

Fruit Quality and Leaf Gas Exchange

Fruit weight, juice volume, peel fresh and dry weight, and rind thickness of internal fruit were significantly higher, compared to external fruit, in all citrus varieties (Table 1). Except for lemon, the percent dry matter of peel from external fruit were higher compared to internal (Table 1), indicating a lower water content in the peels of external fruit. Other than 'Valencia' orange, no significant differences was found in percentage (w/w) of juice relative to canopy positions (Table 1).

Soluble solids of fruit from external canopies of mandarin, grapefruit, and orange were significantly higher compared to internal fruit (Table 1). As a result of the higher concentration of soluble solids, specific gravities of juice from external fruit of these citrus varieties were also higher than internal fruit (Table 1). Higher soluble solids in the fruit of external canopies is perhaps due to 2 factors: 1) higher CO_2 assimilation rates (Table 2), higher leaf to fruit ratio, and efficient transport of photosynthetic products to fruit in external canopy positions; and/or 2) fruit from internal canopy positions are closer to the main limbs (main xylem tissues) and may receive more water, resulting in more dilution in soluble solids compared to external fruit.

No significant differences in soluble solids were observed in lemon, relative to canopy position (Table 1). Overall, soluble solids were 50 to 60% lower in lemon compared to other 3 varieties (Table 1), whereas CO_2 assimilation rates were twice as great for lemon (Table 2). The lower soluble solids in lemon is probably due to a greater portion of assimilation partitioned into acid (Table 1). Titratable acid of fruit from external canopies of mandarin and grapefruit were higher compared to internal fruit; the opposite condition existed for lemon (Table 1). However, soluble solids/acid ratios of external fruit were higher than those of internal fruit in grapefruit, orange, and lemon; the opposite condition was observed for mandarin (Table 1).

No difference was observed for transpiration or stomatal conductance between internal and external canopy positions of mandarin, grapefruit, or orange. However, transpiration of internal leaves of lemon were significantly reduced by low stomatal conductance (Table 2). The extremely low stomatal conductance observed in lemon leaves from internal canopies is probably related to reduced mesophyll capacity for CO_2 assimilation (Table 2).

Fruit Mineral Nutrient Status

Internal fruit of grapefruit and lemon had significantly higher peel concentrations (% d.wt.) of N, P, and K compared to external fruit; however, mandarin had only higher N (% d.wt.) in internal fruit (Table 3). Since the total peel dry weight per fruit from internal canopies was greater, compared to external (Table 1), the total amount of peel N, P, and K in internal fruit was also higher (Table 3). The lower percentage of these elements (on a % d. wt. basis) in the external fruit could be due to the presence of a higher percentage of dry matter (Table 1), resulting in more dilution of minerals as reported by Fallahi, etal. (1).

Table 1. Influence of location of fruit in a canopy on citrus fruit quality.

Citrus Variety	Location of fruit	Fruit wt (g)	Juice volume (ml/fruit)	% Juice by wt.	Juice specific gravity (g)	Soluble solids (°Brix)	% acid in the juice	Solids to acid ratio	Peel fresh wt (g/fruit)	Peel dry wt (g/fruit)	Peel Percent dry wt	Rind Thickness (mm)
	Internal	185	55	31.4	1.058	14.71	0.73	20.3	39.4	10.3	26.9	2.89
Mandarin	External	93	27	31.1	1.080	18.81	1.17	16.2	22.1	8.1	36.7	2.54
	Significance[z]	**	**	N.S.	**	**	**	**	**	*	**	*
	Internal	608	221	37.9	1.038	10.40	1.35	7.72	196.3	35.3	20.0	7.01
Grapefruit	External	388	140	36.9	1.044	11.42	1.47	7.84	127.1	28.5	22.7	5.71
	Significance	**	**	N.S.	*	**	**	N.S.	**	**	**	**
	Internal	267	95	37.1	1.041	11.52	0.67	17.1	65.0	19.2	28.8	5.11
Orange	External	172	58	34.6	1.049	13.56	0.66	20.5	41.3	13.5	32.2	4.15
	Significance	**	**	**	**	**	N.S.	**	**	**	**	**
	Internal	255	76	30.4	1.020	5.51	2.23	2.47	95.7	12.4	13.0	5.65
Lemon	External	195	56	29.3	1.021	5.55	2.08	2.66	74.1	10.4	14.1	5.02
	Significance	**	*	N.S.	N.S.	N.S.	**	**	*	*	N.S.	*

[z] Each quality parameter of fruit from inside of each citrus canapy is significantly different than that of outside at 5% if shown by *; at 1% if shown by **; and not significant if shown by N.S. Significance is evaluated with a t test.

Table 2. Gas exchange characteristics of leaves from internal and external canopies of citrus varieties. Data were taken at ambient CO_2 concentrations of 394.4 and at a mean temperature of 20.03 +/-1.7 °C. Light intensity (umol s^{-1} m^{-2} PPF) for internal canopy positions ranged between: 9 and 108 for Valencia; 6 and 142 for Mandarin; 5 and 65 for Grapefruit; and 8 and 164 for Lemon, whereas PPF for external canopies ranged between 913 and 1211.

Citrus Variety	Location of Fruit	CO_2 Assimilation (umol m^{-2} s^{-1})	Transpiration (mmol m^{-2} s^{-1})	Stomatal Conductance (mmol m^{-2} s^{-1})
	Internal	1.11	0.95	75.4
Mandarin	External	4.87	0.79	66.5
	Significance[z]	**	N.S.	N.S.
	Internal	1.35	0.88	62.1
Grapefruit	External	5.22	0.75	59.9
	Significance	**	N.S.	N.S.
	Internal	1.10	1.06	80.1
Orange	External	5.04	0.89	75.2
	Significance	**	N.S.	N.S.
	Internal	0.53	0.45	21.9
Lemon	External	9.09	1.79	93.8
	Significance	**	**	**

[z]Significant differences between internal and external canopy means are indicated as follows: * = 5%; ** = 1%; N.S. = not significant at the 5% level.

Dilution effects were evident in mandarin. The external fruit had lower levels of N, P, and K compared to internal fruit (when expressed on a dry weight basis); however, external fruit had significantly higher levels of these minerals when expressed on a 100 g fresh weight basis (Table 4). This observation leads us to suggest that more attention should be given to dilution effects when interpreting results of mineral analysis on a dry weight basis. Clearly, more studies are needed to determine wether expression of minerals on a fresh or dry weight basis would better correlate with peel-related quality parameters and/or disorders.

Peel Mg and S concentrations (% d. wt.) from external fruit of all varieties were generally higher, compared to internal fruit (Table 3). These differences were even larger when these minerals were expressed on a 100 g fresh weight basis (Table 4). Mandarin fruit from external canopies had significantly higher concentrations of Ca and Sr in their peels compared to internal fruit (Table 3). The reason for a higher accumulation of these minerals in the peels of external fruit is not understood.

Juice Ca, S, and Al concentrations in external fruit were significantly higher compared to internal fruit in grapefruit and lemon (Table 5). The higher juice Ca in the external fruit could have an important dietary value, particularly in grapefruit. Orange and mandarin juice N was higher in fruit from external canopies (Table 5). These elements could be transported from the leaves to fruit with organic compound, i.e. sugars and acids. Phloem translocation of these elements to external fruit may be greater than transport to internal fruit as was indicated by the greater amount of soluble solids and acids in the external fruit (Table 1).

CONCLUSIONS

Information from this study leads us to suggest that a packing house might reduce sorting time by harvesting fruit from external canopy positions separately from internal fruit. We also suggest that differences in mineral content and quality of fruit within a citrus canopy might be reduced by cultural practices such as pruning and training. Training and pruning citrus trees in the same way as an open-center decidious fruit tree, or training citrus on dwarf rootstocks to an open-trellis design might facilitate more uniform light penetration and photosynthate distribution among the fruit. We suggest that these types of cultural practices might be be possible with citrus varieties; they should be evaluated as a means for reducing variability of fruit quality and nutrient status due to canopy position.

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Table 3. Effects of location of fruit in a canopy on the mineral concentration of citrus peels.

Citrus Variety	Location of fruit	Mineral											
		N (% dry wt.)	P (ppm)	K (ppm)	Ca (ppm)	S (ppm)	Mg (ppm)	Mn (ppm)	B (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Sr (ppm)
Mandarin	Internal	1.11	67.7	1259	581	61	67.4	0.305	2.32	1.17	0.45	0.50	6.57
	External	0.95	62.2	1241	1633	89	69.1	0.370	2.52	1.82	0.65	0.45	9.22
	Significance[z]	*	N.S.	N.S.	*	**	*	N.S.	N.S.	N.S.	N.S.	N.S.	**
Grapefruit	Internal	0.91	82.7	1406	1123	71	85.2	0.330	2.77	1.15	0.37	0.42	7.87
	External	0.85	68.2	1298	1488	80	89.9	0.350	2.95	1.04	0.40	0.40	7.97
	Significance[z]	*	*	**	N.S.	*	N.S.	N.S.	*	**	N.S.	N.S.	N.S.
Orange	Internal	0.92	76.7	1095	690	52.9	80.4	0.288	2.25	0.97	0.32	0.27	7.35
	External	0.91	72.5	1055	683	59.6	82.1	0.300	2.32	1.00	0.35	0.32	7.35
	Significance[z]	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Lemon	Internal	1.38	92.8	1864	1215	46.1	68.5	0.323	2.80	2.37	0.52	0.67	8.90
	External	1.09	68.2	1591	887	47.8	84.8	0.390	2.97	2.20	0.62	0.42	10.12
	Significance[z]	*	*	*	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[z] Each mineral value of fruit peel from inside of each citrus canopy is significantly different than that of outside at 5% if shown by *; at 1% if shown by ** and no significance is shown by N.S. Significance is evaluated with a t test.

Table 4. Effects of canopy position on peel mineral and percent fresh weight mineral content.

Citrus Variety		Mineral											
		N		P		K		Ca		Mg		S	
		mg/100 g Peel Fresh Wt	Total mg/Peel	mg/100 g Peel Fresh Wt	Total mg/Peel	mg/100g Peel Fresh Wt	Total mg/Peel	mg/100 g Peel Fresh Wt	Total mg/Peel	mg/100 g Peel Fresh Wt	Total mg/Peel	mg/100 g Peel Fresh Wt	Total mg/Peel
Mandarin	Internal	281	125	1.66	.737	33.2	14.8	13.3	5.97	1.88	.679	1.67	.657
	External	344	81	2.15	.508	46.6	10.9	78.6	18.7	3.24	.813	3.25	.801
	Significance	*	*	**	N.S.	**	N.S.	*	*	**	N.S.	**	N.S.
Grapefruit	Internal	182	360	1.65	3.26	28	55	22	44	1.71	3.35	1.42	2.78
	External	196	234	1.56	1.87	30	36	34	41	1.91	2.27	1.83	2.17
	Significance	N.S.	**	*	*	**	**	N.S.	N.S.	*	**	*	*
Orange	Internal	287	174	2.27	1.37	33.7	20.7	21.4	13.1	2.49	1.52	1.64	1.00
	External	297	124	2.50	1.04	34.2	14.3	22.2	9.3	2.68	1.12	1.95	.814
	Significance	N.S.	**	N.S.	N.S.	N.S.	**	N.S.	**	N.S.	**	N.S.	*
Lemon	Internal	175	179	1.17	1.21	23.8	24.1	15.8	15.8	.884	.889	.596	.600
	External	158	113	.97	.70	22.8	16.1	12.2	9.10	1.21	.361	.684	.489
	Significance	N.S.	*	N.S.	*	N.S.	**	N.S.	N.S.	*	*	N.S.	N.S.

[z] Each value is significantly different at the 5% level if shown by *; at 1% if shown by **; and not significant if shown by N.S.

Significance is evaluated with a t test.

Table 5. Effects of location of fruit in a canopy on the mineral composition of citrus fruit juice.

Citrus Variety	Location of Fruits	Mineral N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	S (ppm)	Mg (ppm)	Fe (ppm)	Zn (ppm)	Al (ppm)
	Internal	340	20.8	874	11.4	17.7	18.0	0.15	0.1	2.0
Mandarin	External	425	13.3	988	11.3	14.3	17.7	0.10	0.1	1.5
	Significance[z]	*	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	Internal	280	66.9	1016	30.3	28.0	55.7	0.40	0.18	5.2
Grapefruit	External	286	71.8	1078	40.0	33.5	74.0	0.45	0.22	6.5
	Significance[z]	N.S.	N.S.	N.S.	*	**	*	N.S.	N.S.	*
	Internal	354	80.3	1352	15.4	35.3	26.1	0.25	0.15	3.9
Orange	External	456	89.2	1298	14.5	30.3	39.8	0.20	0.17	3.3
	Significance[z]	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	Internal	142	33.0	487	32.0	12.1	52.1	0.37	0.22	7.7
Lemon	External	127	31.0	569	52.0	14.0	56.2	0.37	0.42	9.1
	Significance[z]	N.S.	N.S.	*	*	*	*	N.S.	N.S.	*

[z] Each mineral value of fruit juice from inside of each citrus canapy is significantly different than that of outside at 5% if shown by *; at 1% if shown by ** and not significance if shown by N.S. Significance is evaluated with a t test.