Chapter 5

DIFFERENCES IN FRUIT CHEMICAL CHARACTERISTICS IN TWO NON-ADJUNCT ORCHARDS

Abstract

Two non-adjunct orchards of similar character were compared for differences in chemical composition of 'Valencia' oranges over two seasons. During the first season of the study the orchards differed significantly in physical as well as chemical characteristics. In the first orchard fruit size, fresh and juice weight were higher throughout the 2000 season. Rind thickness and juice percentage did not differ. In the second orchard soluble solid content, titratable acid and kilogram soluble solids per metric ton were higher while the solid to acid ratio was comparable between the orchards. At harvest yield and soluble solids per hectare were higher for the second orchard. However, fruit from the second season did not indicate any significant differences between the orchards. Variation in subsoil layers enhanced differences between orchards in the first season due to high rainfall not found present in the second.

Introduction

Within the citrus production area of Brits certain growers produce fruit of much higher quality (total soluble solids) while utilising comparative standard management practices and plant material. In New Zealand, McAneney *et al.* (1995) observed consistent differences in juice quality between similarly managed orchards subject to the same synoptic weather patterns and inputs of photosynthetic radiation.

This study examines possible causes for such differences, using comparative orchards within a 2 km distance of each other underlain by the same mother material and both on a north facing slope.

Materials and methods

Characteristics of the experimental plot and surrounding area

The study was carried out during the 2000 and 2001 citrus season in two non-adjunct orchards of 2 ha each . The experimental sites consisted of 'Valencia' (*Citrus sinensis* (L.) Osb.) orange trees grafted on Rough lemon (*C. limon* (L.) Burm. f.) rootstock. Both orchards were planted in 1987 and situated in the North West Province, near Brits (25°S 27°E, 1107 m.a.s.l.) in South Africa. Trees were spaced 5.8 m apart within rows and 5.8 m between rows (300 trees / ha). Healthy vigorous trees, uniform in canopy size, were used in the trial. Refer to Chapter 4 for orchard practices were maintained throughout the duration of the study and for general natural veld type and vegetation of the surrounding area (Anon, 2001).

Fruit quality determinations

Fruit were picked from the northern, external position of the trees, at shoulder height and consisted of six fruit per treatment replica. Fruit diameter and weight, juice weight, rind thickness, total soluble solids and titratable acidity were measured every three weeks beginning in June (19/6), through July (10/7, 31/7), August (21/8), September (11/9), early October (2/10), 2000 and August (21/8) and October (2/10) 2001. Fruit were sectioned equatorally so that peel thickness could be measured with an electronic hand calliper and the juice extracted by hand with a Pineware CS2 citrus juicer. Total soluble solids were determined with a temperature-compensating digital refractometer (Palette PR-101) and titratable acidity by titration of a 10 ml aliquot of juice using 0.1N NaOH to an endpoint with phenolphthalein as an indicator (Wardowski *et al.*, 1979).

Soil, leaf and fruit samples

A sample of forty sub-samples was taken in June 2000 and each analysed individually for percentages sand, silt and clay. During late August 2001 leaf samples were taken from ten randomised trees per orchard as described by Abercrombie (1994). In October 2001, four three fruit samples per locality were randomly selected over the orchard, at shoulder height and from northern, eastern, southern and western sides, for chemical analyses. Fruit were separated into the epicarp (flavedo) and mesocarp (albedo), and endocarp (edible portions). The endocarp consisted of segment cover, juice sacs carpellary membranes and vesicles. Fruit were analysed for nitrogen, phosphate, potassium, calcium, magnesium, zinc, copper, manganese, iron and boron.

Yield

Individual tree yields were taken at the time of non-selective commercial picking at the beginning of October 2000. Yield was determined in kilogram per tree replica for each separate treatment.

Statistical analyses

The data was tested for normality by a Proc Univeriate and variance analysis was performed using the GLM procedure of SAS (Statistical Analysis System) computer program (Anon, 1989). Means were compared according to a students t-test at a 1 and 5% level of significance.

Results

Fruit physical characteristics are compared over the 2000 season in Table 5.1. Only where of significance is reference made to the 2001 season. Rind thickness and juice percentage did not differ significantly between the orchards over the 2000 season. Diameter, fresh and juice weights were significantly larger in Orchard 1 over all samplings (Table 5.1).

Table 5.1 Table of physical characteristics comparing fruit from Orchard 1 with Orchard 2 over the duration of the 2000 sampling season. Means with different letters differ significantly at 1% level.

Physical Characteristic	**Sample date**											
	19/6		**10/7**		**31/7**		**21/8**		**11/9**		**2/10**	
Diameter												
Orchard 1	67.98	a	68.58	a	68.01	a	68.98	a	69.21	a	70.06	a
Orchard 2	65.82	b	66.91	b	65.61	b	65.98	b	67.13	b	67.94	b
Rind												
Orchard 1	4.96	a	4.99	a	4.97	a	4.83	a	4.80	a	4.50	a
Orchard 2	5.00	a	4.93	a	4.77	b	5.89	a	4.71	a	4.55	a
Fresh weight												
Orchard 1	167.22	a	171.89	a	166.93	a	161.34	a	173.41	a	179.80	a
Orchard 2	152.15	b	161.62	b	151.29	b	149.68	b	162.08	b	172.20	b
Juice weight												
Orchard 1	87.17	a	90.79	a	87.55	a	80.24	a	91.97	a	95.49	a
Orchard 2	78.49	b	84.26	b	79.41	b	72.31	b	81.16	b	92.88	a
Juice %												
Orchard 1	51.78	a	52.88	a	52.33	a	49.63	a	52.92	a	53.03	a
Orchard 2	51.19	a	52.12	a	52.20	a	48.02	a	50.10	b	53.80	a

Seasonal changes in soluble solids and titratable acid were significantly higher ($P<0.01$) in Orchard 2 through out the season (Figure 5.1a and b). The solid to acid ratio between the orchards was highly comparable and only differed significantly on two occasions (Figure 5.1c).

Soluble solids per metric ton echoed the same trend as found with soluble solids and titratable acid. Fruit from trees in Orchard 2 yielded higher solids per ton over the entire season ($P<0.01$) (Figure 5.1d). In Orchard 2 the kilogram soluble solids was on average 9% higher than found in fruit from Orchard 1.

Significantly higher values were observed in yield (8.76 ton per hectare), kilogram soluble solids per ton fruit (3.55), and tonnage solids produced per hectare (1.15) for Orchard 2 at harvest ($P<0.01$). However, when fruit were sampled in August and October 2001 (for corresponding 2000 dates) no significant differences were found between the orchards for any of the measured parameters (Figure 5.2).

However, at harvest soluble solids per metric ton were 13.35 and 8.14 kilogram per ton higher for the 2001 season in Orchard 1 and 2 respectively (Table 5.2). In general, over both orchards fruit size and juice percentage were lower during the second season while soluble solids were higher for the same.

Sand, silt and clay percentages determined in the top 30 cm of the soil where highly comparable between the orchards (Table 5.3). When soil profiles were compared, no significant compaction layers were found. However, in the second orchard a significant increase of 12 to 21% in clay percentage was observed from 30 to 60 cm (Table 5.4).

Nutrient element concentrations in leaf samples taken in late August 2001 from the respective orchards are presented in Table 5.5. According to the standards for nutrient levels in citrus leaves presented by Weir and Cressewell (1993), nitrogen and phosphorus are deficient while potassium is considered to be low for both orchards. In Orchard 1 calcium and boron are deficient, zinc and copper low, magnesium high, and manganese and iron normal. In the second orchard zinc was found deficient, copper and boron low, manganese and iron high, and calcium and manganese normal.

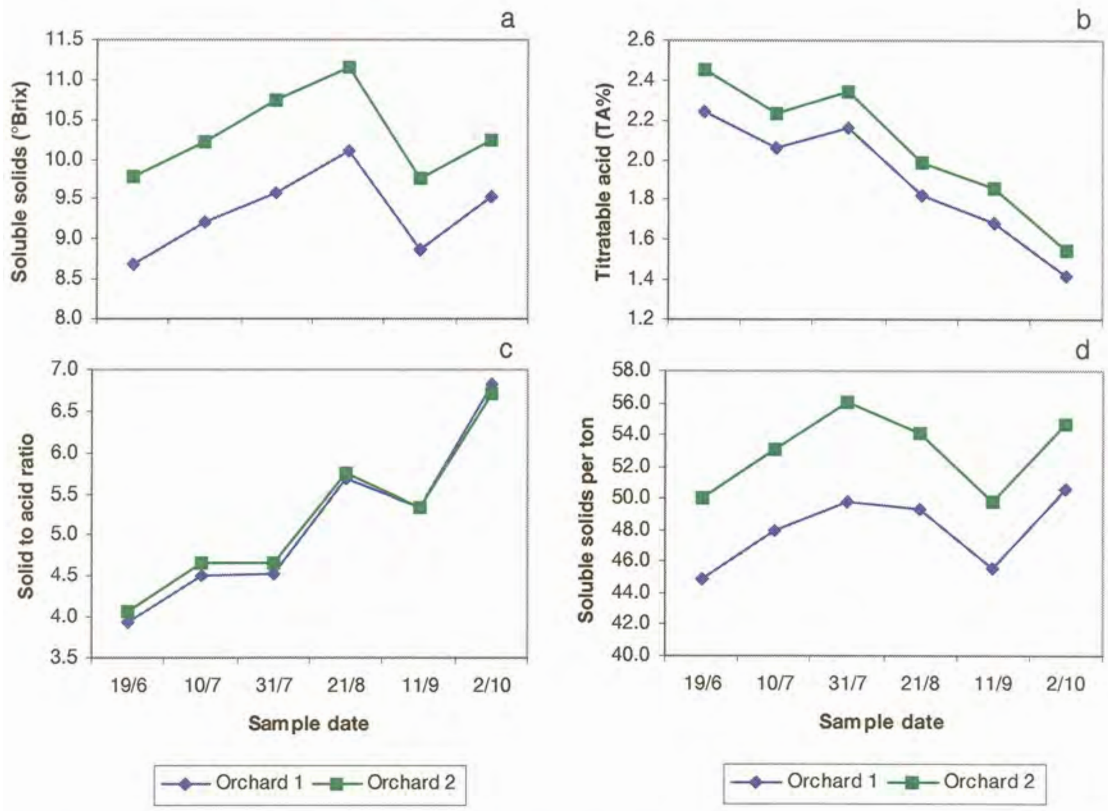

Figure 5.1 Comparison of seasonal changes in the chemical composition of 'Valencia Late' oranges grown on Rough lemon rootstock in two orchards in the Brits area during the 2000 season. Soluble solids (a), titratable acid (b) and the soluble solids per metric ton (d) differed significantly at a 1% level between orchards. However, the solid to acid ratio (c) was only significant on the second and third sample dates.

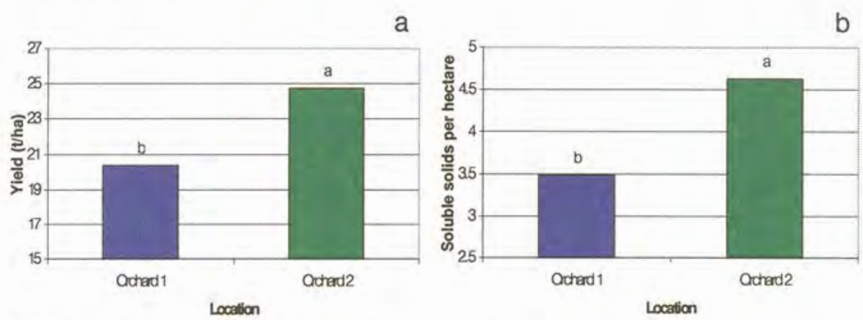

Figure 5.2 Yield (a) and production of soluble solids per hectare (b) of 'Valencia Late' oranges grown on Rough lemon for Orchard 1 and 2 in the Brits production area during the 2000 season. Trees are planted at a density of 300 trees / ha Means with different letters differ significantly at 1% level.

Analyses results for fruit samples analysed are presented in Table 5.6. No clear differences were found among most of the elements. Magnesium indicated the largest difference of 0.212 %, followed by iron (186 mg/kg) and zinc (18 mg/kg). Larger amounts of calcium and magnesium are concentrated in the epicarp of fruit analysed also found by Sinclair (1984).

Table 5.2 Table of chemical characteristics comparing fruit from Orchard 1 with Orchard 2 at harvest for the 2000 and 2001 seasons. Means with different letters differ significantly at 1% level.

Chemical	Orchard 1		Orchard 2	
Characteristic	2000	2001	2000	2001
Juice percentage	53.32	51.07	54.25	51.91
TSS (°Brix)	9.44	12.45	10.05	12.03
Kg TSS / t	50.32	63.67	54.51	62.65

Table 5.3 Particle size distribution for the top 30 cm soil from Orchard 1 and 2 taken during June 2000.

Location	Sand %	Silt %	Clay %	pH(water)
Orchard 1	81	6	13	7.1
Orchard 2	82	5	14	6.8

Table 5.4 Particle size distribution for the top (0-30 cm) and bottom (30-60 cm) soil from Orchard 2 taken during August 2001.

Orchard 2	Sand %	Silt %	Clay %
Top (0-30 cm)	86	2	12
Bottom (30-60 cm)	78	1	21

Table 5.5 Results for nutrient element concentrations for leaf samples taken in late August 2001.

Location / Element	Orchard 1	Orchard 2
Nitrogen	1.98	1.99
Phosphate	0.097	0.078
Potassium	0.42	0.46
Calcium	0.92	3.42
Magnesium	0.861	1.010
Zinc	22	15
Copper	5	6
Manganese	27	30
Iron	198	156
Boron	6.6	27.8
N:K	4.7	4.3

Table 5.6 Results of chemical analysis for fruit sampled on October 2001. Epicarp and mesocarp were analysed separate from the endocarp.

Location	**Orchard 1**		**Orchard 2**		**Total**	
Sample	*Epicarp and mesocarp*	*Endocarp*	*Epicarp and mesocarp*	*Endocarp*	**Orchard 1**	**Orchard 2**
Nitrogen	0.65	0.87	0.38	0.60	1.52	0.98
Phosphate	0.061	0.153	0.050	0.153	0.169	0.203
Potassium	0.73	1.18	0.65	1.28	1.91	1.93
Calcium	0.63	0.25	0.61	0.23	0.88	0.84
Magnesium	0.159	0.121	0.237	0.122	0.280	0.492
Zinc	7	19	6	38	26	44
Copper	2.1	2.3	2.1	2.7	4.4	4.8
Manganese	10	3	7	3	13	10
Iron	257	25	64	32	282	96
Boron	24.6	13.8	22.2	13.1	38.4	35.3

- nitrogen, phosphate, potassium, calcium, magnesium (macro elements) are presented in percentage while zinc, copper, manganese, iron and boron (trace elements) are presented in mg/kg.

Discussion

The value of continuous fruit collection and testing procedures for the interpretation of in-seasonal changes in juice quality and yields lies in the prediction of optimal picking dates. South Africa is generally regarded as a country of extremes in terms of its climate and topography and this is no different for producers in the Brits production area. Ripening in sweet citrus cultivars, with respect to internal parameters, is characterised by an increase in juice percentage, a decrease in acidity an increase in soluble solids, mainly sugars, and ratio of soluble solids to acid (Sinclair, 1961; Howie and Lloyd, 1989; Richardson and Mooney, 1992; McAneney *et al.*, 1995). Results obtained in this study confirmed the findings of Chen (1990) and Yakushiji *et al.* (1996) for 'Washington Navel' oranges grown in California and Satsuma mandarin fruit in Japan respectively. In general, total soluble solids increase as the fruit develop and ripen on the tree, but a decline in total soluble solids occur in overripe fruit left to hang indefinitely (Sinclair, 1961). The results attained from continuous sampling over the 2000 season indicated the soluble solids in 'Valencia' fruit to increased towards the end of August where-after it decreased. Data taken one season previously indicated a similar trend (Chapter 3, Figure 3.2). A similar trend was found for kilogram soluble solids per metric ton, indicating that fruit were left too long before harvest. Tzur *et al.* (1992) described soluble solids per metric ton increasing up to a point, where after it decreased and again increased beyond the original peak of increase, similar to the results found in this study although Tzur *et al.* (1992) made no attempt to clarify the reason for the trend observed.

Due to the long fruit growth period and the dependency of harvest date on the processing factory's potential intake for that time frame in the season, fruit are left to hang on trees until earlier maturing cultivars have been harvested and processed. This has an important implication for the carbohydrate economy of the tree in that the period between harvest of the current season's fruit, which is a strong sink, and the following seasons flowering, is shortened. It is not uncommon to find a tree in full bloom, or even with a newly set crop, with the previous crop still on the tree. In citrus the spring flush, floral development, anthesis, and fruit set demand large amounts of energy that cannot be furnished by current photosynthesis and must be obtained from tree reserves (Bustan and Goldschmidt, 1998). The relatively low rates of photosynthate production and annual fluctuations in carbohydrate reserves underscore the limitations of carbon for citrus tree growth. Thus, the intensity of carbon limitations in citrus trees may result in alternating years of high and low yield (Syvertson and Lloyd, 1994). Experiments with labelled CO_2 indicated that reserve carbohydrates were utilised mainly to support reproductive development, while photosynthesis from mature leaves supplied the needs of vegetative growth (Akao *et al.*, 1981). It is thus hypothesised that carbohydrates in the tree are concentrated in the fruit resulting in a potential source of energy for the following season's growth and flowering, which have become stronger sinks than the current fruit. Reserves are then translocated out of the fruit resulting in a decline in soluble solids because current burst in spring growth can not be supported by photosynthesis alone and reserves, other than in the fruit.

When considering the effects of stress on citrus trees it has been well documented that the soluble solid content in fruit are increased when levels of stress are increased (Cruse *et al.*, 1982; Yakushiji *et al.*, 1996; Yakushiji *et al.*, 1998). This is true for moderate stress when sugar accumulation is caused by an increase in the translocation of photosynthates into fruit, especially into the juice sacs, which have a high sink activity (Yakushiji *et al.*, 1998). However, when trees are exposed to severe stress, the percentage of photosynthates in the juice sacs is lower than for control fruit (Yakushiji *et al.*, 1998). The sharp decline in soluble solid content and soluble solids per metric ton observed on the fifth sampling can be ascribed to stress due to prevailing weather conditions (Figure 5.1a and d).

The weather conditions were compared for days prior to sampling where windspeeds of 130 and 120 km/h were encountered, peaking at 207 km/h on the day of sampling (Agromet, 2000). The relative humidity was 50% lower for two days before and after. Increase in transpiration as a result of wind is not proportional to the wind velocity. When plants are suddenly exposed to wind, there is a sharp increase in the rate of transpiration, followed by a gradual decrease in the rate of increase, indicating that the effect of wind on transpiration may be rather complex (Devlin, 1975). However, when wind blows over an evaporative surface, there is a significant cooling effect. It can then be suggested that there was a significant decrease in the temperature of the orchard microclimate and that specifically the temperature of the leaf canopy decreased. Hartt (1965) found that when root temperature is kept higher than shoot temperature, translocation to the root increases and translocation to the top decreases. The warmer root temperatures can be ascribed to the buffering properties of the soil. With the combined stress of a significant decrease in temperature and increase in evaporation, as well as transpiration of soil and leaf surfaces, it would therefore be suggested that firstly, the translocation of photosynthates from source leaves to fruit was decreased (Hartt, 1965) and secondly that solutes were possibly extracted from the fruit (Yakushiji *et al.*, 1998), resulting in the drop in total soluble solids and consequently, soluble solids per metric ton. A detailed physiological study would have to confirm this hypothesis.

The optimal picking date for fresh marketing differs from that of picking for processing. When orchards are designed for fresh marketing, there is often a conflict of interest, since the solid to acid ratio which determines dates for fresh marketing often occurs earlier than the soluble solids per metric ton required by the processing industry (Sinclair, 1961; Tzur *et al.*, 1992). Results in this study indicate that the highest soluble solid values did not coincide with that of the solid to acid ratio or soluble solids per metric ton. The latter two parameters, as well as juice percentage reached their maximum on the last sample date (2/10) (Figure 5.1). In the first orchard, solids produced per metric ton and per hectare were highest during harvest indicating that although soluble solids were not at an optimum, it should not be considered in seclusion when considering the optimum harvest date for maximum solids per metric ton. However, solids produced per metric ton and per hectare in the second orchard, were highest at the end of July (31/7), although not significant, while soluble solid content reached its maximum for the season three weeks later (21/8). The decrease in soluble solids per ton and per hectare from the end of July (31/7) to harvest (2/10) was a non-significant at 1.4 kilogram soluble solids per metric ton and 0.1 ton soluble solids produced per hectare.

If a regression line (not shown) is fitted to data points for samples one, two, three and six of the first orchard's data, a R^2=0.9995 is achieved for soluble solids per metric ton (Figure 5.1d). The line indicates a maximum of 51.3 kilogram soluble solids per metric ton is reached on 10/9, a day before the fifth sample was taken. If a regression line is fitted to data points of the second orchard for the same sample dates, a R^2=0.9863 is achieved for soluble solids per metric ton (Figure 5.1d). The line indicates a maximum of 56.82 kilogram soluble solids per metric ton is reached on 27/8. This principle forms an important component for a modelling program to estimate dates for the optimum gain of soluble solids per metric ton and should receive detailed attention in future studies due to the various factors and seasonal variation influencing the accumulation of soluble solids in citrus fruit.

Du Plessis and Koen (1988) suggested that leaf samples taken during April should indicate N:K values between 2.4 and 3.0 with nitrogen higher than 2.1% and potassium higher than 0.8% for maximum yield. For maximum fruit size, they found the ratio to be between 1.6 and 2.2 with nitrogen higher than 1.8% and potassium higher than 0.9%. Results from leaf analysis in August 2001 suggested that N:K values are much higher with both nitrogen and potassium being lower than suggested by Du Plessis and Koen (1988) for maximum yield. However, according to Weir and Cresswell (1993) nitrogen values indicated by Du Plessis and Koen (1988) would be deficient. From leaf samples it would seem as if all the major macro-elements are either low or deficient.

No obvious differences could be found between the orchards during the 2001 season. Suggestions for differences in fruit quality during the 2000 season can be suggested on two levels. Firstly, according to irrigation. In the first orchard drip and in the second micro irrigation is applied. As this was not a irrigation trial, no specific data was obtained other than personal communication. In general the second orchard received higher rates of irrigation over a larger area while the drip irrigation supplied moisture from only three to four drippers (personal observation). On several occasions during June to October, for both seasons, leaves from the first orchard indicated signs of water stress (curled leaves). Yakushiji *et al.* (1998) observed a decrease in the partitioning rate in the translocation of photosynthates and consequently sugar accumulation in fruit of severe stressed trees. From visual observations the trees from the second orchard were larger and in no specific way, healthier looking.

The second would be the subsoil layers as no significant differences were found for top soil layers (0-30 cm). As nitrogen and potassium are readily leached out of soil profiles under conditions of high water supply, it is suggested that the high clay percentage found in the subsoil from 30 cm in the second orchard preserved these elements to a larger extent than in the first orchard. Studies on the distribution of citrus fibrous roots have shown that the highest density of roots are usually located in the top 60 cm of soil (Noling, 1997). The amount of water supply could have played a critical role as statistical differences were found in fruit quality for the 2000 season but not for the 2001 season where 1257 and 525 mm rain fell during the fruit growth and maturation period respectively.

In comparing orchards McAneney *et al.* (1995) cautioned against seeking better understanding via statistical analyses in that small differences could amount to large variation in juice quality. Underlying differences have more pronounced effects on internal fruit quality under severe conditions. Comparison should in future be regarded with discretion.

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Chapter 6

FRUIT CHEMICAL CHARACTERISTICS AS INFLUENCED BY ROOTSTOCK

Abstract

In a study conducted at the Experimental farm of the University of Pretoria in 2001, three rootstocks (Rough lemon, Swingle citrumelo and X639) were evaluated for their effect on soluble solid content in the juice of fruit and per ton fruit of 'Valencia' oranges. Two samples were taken during the maturation period (13/6 and 21/8). Juice percentage and titratable acid decreased while soluble solids, the solid to acid ratio and soluble solids per ton increased between sample dates. The highest soluble solids for juice and per ton was achieved by fruit from scions grafted on Swingle citrumelo. Fruit from Rough lemon rootstock yielded the highest solid to acid ratio and lowest titratable acid.

Introduction

That rootstocks influence the quality of citrus fruits produced by the scion cultivar has long been recognised (Bitters, 1961; Gardner, 1969; Monteverde *et al.*, 1988; Recupero *et al.*, 1992; Sosa *et al.*, 1992; Tuzcu *et al.*, 1992; Georgiou and Gregoriou, 1999; Georgiou, 2000). Rootstocks have also been found to cause variation in nutrient concentrations in citrus leaves through the enhancement of absorption and translocation of some nutrients (El-Shazly *et al.*, 1992, Georgiou, 2000; Zekri, 2000). Yield (Wright and Aubert, 1999; Georgiou, 2000; Zekri, 2000), disease (Casale and Baldwin, 1996) and nematode (Duncan *et al.*, 1994; Noling, 1997; Niles *et al.*, 1995) resistance, and salt tolerance (Vardi *et al.*, 1988; Syvertson and Lloyd, 1994) to name a few, are also affected by rootstock.

The objective of this study was to confirm previous findings on the influence of various rootstocks on the physical characteristics and chemical composition of scion fruit. And in specific that of Rough lemon, Swingle citrumelo and X639 on four year old 'Valencia' orange fruit.

Materials and Methods

Characteristics of the experimental plot

Trees used in this study originated from a trial started at the University of Pretoria Experimental farm in 1997 and planted in 200 L black planting bags supported by wire mesh. The study was abondoned in 2000 after which no fertilisation was applied and trees were irrigated once a week. During the previous study (1997-2000), the trees were subjected to a nutrient solution containing 25 mg N / L as NH_4NO_3, 20 mg K / L as K_2SO_4, and trace elements of a commercial foliar spray (Microplex, South Africa), containing 1.68 Fe, 0.03 Cu, 0.02 Zn, 0.05 B and 0.05 mg Mo / L. Sodium and chloride were added to the nutrient solution as combination (12.7 mM Na / L and 13.1 mM Cl / L). The irrigation was carried out manually using a watering can when the soil matrix potential reached the threshold of 30 kPa. Fruit were sampled from 'Valencia' (*Citrus sinensis* (L.) Osb.) orange trees grafted on Rough lemon (*C. limon* (L.) Burm. f.), Swingle citrumelo (*C. paradisi X P. trifoliata*) and X639 (*C. reticulata* X *P. trifoliata*) rootstocks on 13/6/2001 and 21/8/2001 with six and three fruit per treatment replica respectively.

Fruit quality determinations

Fruit weight, juice weight, peel thickness, total soluble solids, titratable acidity, and solid to acid ratio were measured for individual fruit. Fruit were sectioned equatorally so that peel thickness could be measured with an electronic hand caliper and the juice extracted by hand with a Pineware CS2 citrus juicer. Total soluble solids were determined with a temperature-compensating digital refractometer (Palette PR-101) and titratable acidity by titration of a 10 ml aliquot of juice using 0.1N NaOH to an endpoint with phenolphthalein as an indicator (Wardowski *et al.*, 1979).

Experimental design and statistical analyses

Data was statistically analysed as a complete randomised design with three treatments and ten replications per treatment. One way Anova according to Tukey's t-test at 5% level of significance was applied to the data.

Results

Fruit grafted on Rough lemon (RL) rootstock were larger with thicker rinds on both sample dates, followed by X639 (Table 6.1). In all cases the larger the fruit, the thicker the rind. Fruit diameter and rind thickness decreased between sample dates.

Juice percentage during the first sampling (13/6) was highest for Swingle citrumelo (SC) which differed significantly from X639 (Figure 6.1a). By the second sampling (21/8) juice percentage for all rootstocks decreased with SC indicating the highest decrease at 7.2 %, X639 at 6.9 % and RL at 0.3 %. In all rootstocks an increase in soluble solids was observed between samplings in Figure 6.1b. No significant trends between rootstocks were found for soluble solid content in the juice of fruit for either sampling dates. Titratable acid did not differ between SC and X639, and were significantly higher than in RL (Figure 6.1c). Acid content decreased between sample dates continuing a comparable trend between rootstocks. The solid to acid ratio (Figure 6.1d) was higher for fruit from RL on both sample dates due to the lower titratable acid on both occasions.

Table 6.1 Fruit diameter and rind thickness of 'Valencia' orange fruit as influenced by rootstock on two sample dates. Means with different letters differ significantly at 5% level between rootstocks for single dates.

Rootstock	**Rough lemon**	**Swingle citrumelo**	**X639**
Physical characteristic			
Fruit diameter			
13/6	64.14 a	58.74 b	59.27 b
21/8	61.28 a	57.22 b	58.05 b
Rind thickness			
13/6	5.56 a	5.14 b	5.23 b
21/8	5.14 a	4.35 b	4.63 b

The highest soluble solids per metric ton were yielded during the first sample date by fruit from scions grafted on RL but were surpassed by fruit on SC in the second sampling (Figure 6.2). The rootstock X639 achieved intermediate values during the second date above that of RL.

Discussion

A rootstock should be adaptable to climate and soil, tolerant to disease, and induce high yield and fruit quality (Monteverde *et al.*, 1988). Principle juice constituents followed normal changes in chemical composition during maturation, soluble solids increased, titratable acid decreased, and the solid to acid ratio increased for fruit in this study as described by Sinclair (1961).

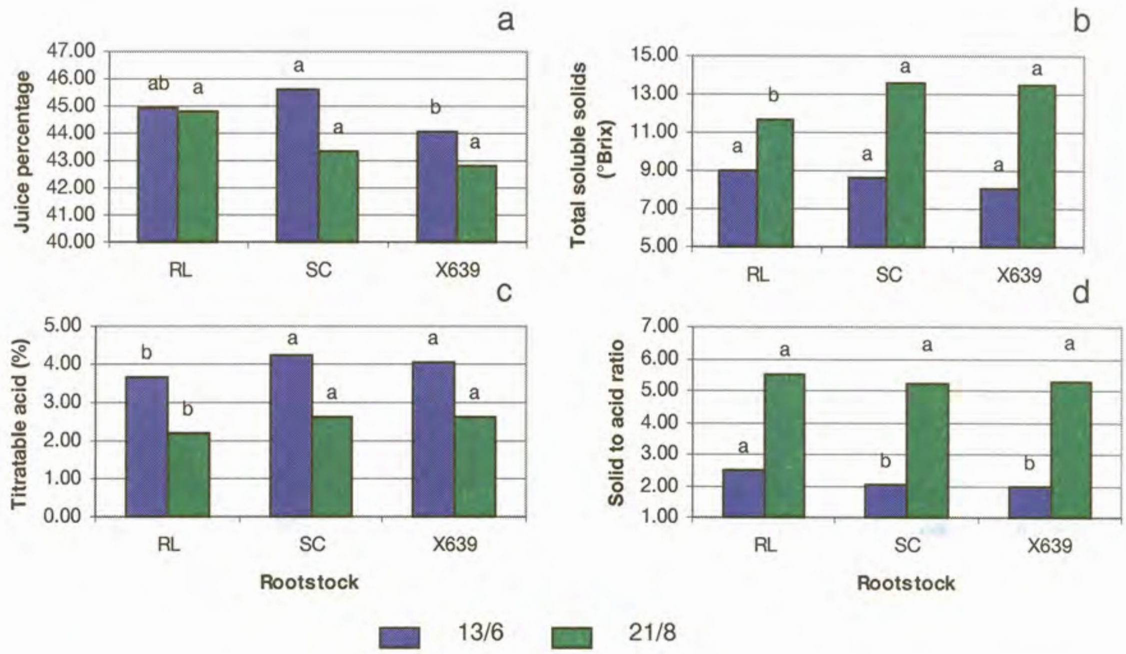

Figure 6.1 Changes in juice percentage (a), soluble solids (b), titratable acid (c) and solid to acid ratio (d) at two sample dates (13/6 and 21/8) for 'Valencia' oranges grafted on Rough lemon (RL), Swingle citrumelo (SC) and X639. Means with different letters in each series differ at 5% level between rootstocks for a single sample date.

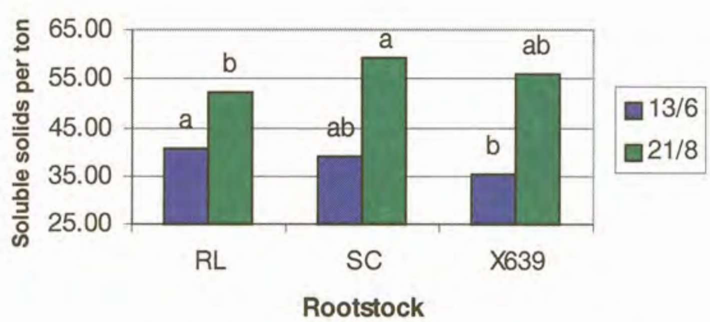

Figure 6.2 Soluble solids per metric ton at two sample dates (13/6 and 21/8) for 'Valencia' oranges grafted on Rough lemon (RL), Swingle citrumelo (SC) and X639. Means with different letters in each series differ at 5% level between rootstocks for a single sample date.

Juice percentage decreased in this study which is contrary to findings by Sinclair (1961). This could be due to the fact that August 2001 was accompanied by very hot and dry conditions, and that fruit were sampled beyond standards for fresh consumption and had already started to dehydrate after transpiration from stomata of fruit peel surfaces (Yakushiji *et al.*, 1998).

The South African Citrus Industry has placed its focus largely on the breeding and evaluation of scion and rootstock selections for fresh consumption, grossly neglecting the requirements for that of processing. Even in international literature reference is seldom made to the suitability of a scion or rootstock for the production of high soluble solids per metric ton. Rough lemon is regarded as a vigorous rootstock susceptible to the citrus nematode (*Tylenchulus semipenetrans*) and *Pythophthora* root rot. The rootstock is excellent for the production of round oranges used for processing (Anon, 1997). Swingle citrumelo and X639 are considered as intermediate rootstocks under South African conditions (Anon, 1997). Hybrid X639 is a Cleopatra mandarin (*Citrus reticulata)* and *P. trifoliata* crossing made in the early fifties by Dr. Hojby (Von Broembsen, 1985). Results obtained indicated X639 to have characteristics similar to that of Swingle citrumelo (Von Broembsen, 1985). Fruit sizes are medium to large with excellent internal quality (Anon, 1997).

From results attained in this study indicated higher soluble solids in juice and per metric ton for rootstocks derived from *P. trifoliata* crossings. In a study conducted by Anderson and Beñatena (1996) twelve orange cultivars budded on Rough lemon were most productive while Trifoliate orange (*P. trifoliata*) and Troyer citrange (*C. sinensis* X *P. trifoliata*) produced smaller trees with highest values of soluble solids out of six rootstocks evaluated. The practical implications of this study would be to consider Swingle citrumelo and X639 for new plantings of 'Valencia' oranges due to high soluble solids in juice and per ton, average titratable acid and solid to acid ratio. However, the high productivity of Rough lemon could lead to a higher production of soluble solids per hectare (Anon, 1997) which should be kept in mind when markets for produce are considered before planting. Unfortunately in this experiment yield and thus the solids production per tree could not be attained due to the theft of fruit during the season. Yield is an important consideration when comparing rootstock and especially when fruit are produced solely for processing.

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Chapter 7

FRUIT CHEMICAL CHARACTERISTICS AS INFLUENCED BY CLIMATIC CONDITIONS

Abstract

The fact that climate affects fruit quality is well known. Fruit quality data was obtained from the Magaliesburg Citrus Co-operation (MCC) for the last three seasons. Soluble solids (°Brix) and soluble solids per metric ton were annually compared to rainfall within the production area. Heat units for the years 1999 and 2000 were correlated to the soluble solids per metric ton for fruit delivered at the MCC. A high correlation was found between the internal quality and rainfall indicating a decrease in fruit quality within years of high downpour. Although no high correlation coefficient was found for heat units, in general the soluble solids per ton increased linearly over time but plateaued towards the end, before decreasing.

Introduction

More than most fruits, citrus quality varies sharply with climate (Grierson and Ting, 1978). The comparison of fruit quality parameters is a useful diagnostic tool for the rapid detection of differences between the effects of year-to-year weather patterns (Shalhevet and Levy, 1990).

The heat unit approach has been widely used to predict crop maturity for corn, tomatoes and peas for harvesting and has also been suggested to predict seasonal changes in the solid to acid ratio for practical applications in the citrus industry (Chen, 1990).

Jones *et al.* (1962) determined that fruit composition was more closely related to heat units than to other measured factors of climate such as maximum, minimum or mean temperature, total sunlight, etc. Chandler and Nicol (1978) developed mathematical relations between maturation periods and quality factors, such as soluble solids and acid contents, and the ratios thereof, for the prediction of the best date to harvest several months in advance of commercial maturity. The accuracy of linear models was also found comparable to that of the conventional heat unit system for early estimation of seasonal change in soluble solids and solid to acid ratio (Chen, 1990).

The aim of this study was to attempt to establish possible reasons for the large variation observed in soluble solids per metric ton between years within the production area of the Magaliesburg Citrus Co-operation (MCC).

The MCC has only in recent years implemented a program for detailed data collection of fruit to be processed. Thus, due to the limited seasonal data available from the MCC the results represented are only indicative of possible trends and it is recommended that a minimum of at least ten seasons data be used to obtain more reliable trends.

Materials and Methods

Four years consecutive fruit quality data for 'Valencia Late' orange fruit grown in the Brits production area was obtained from the MCC for the years 1998, 1999, 2000 and available data for 2001. Data from three weather stations (Brits, Buffelspoort, and Rustenburg) were obtained from the AGROMET Section of the ARC-ISWC (Agricultural Research Council Institute for Soil, Water and Climate). Rainfall was confirmed by producers within the production area. Rainfall for a season was determined from September of the previous year to the end of September of the current year encompassing an entire fruit growth and maturation period. The cumulative summation of heat units was determined similarly to that of rainfall except summation continued to date of delivery to the processing plant. Upon closer inspection of the fruit quality data, it was found that the 1998 season was too incomplete to include in the study.

Soluble solids per metric ton were tested for normality by the REG procedure of SAS (Statistical Analysis System). The remaining data was tested for normality by a Proc Univeriate and variance analysis was performed using the GLM procedure of SAS computer program (Anon, 1989). Means were compared according to a students t-test at a 5% level of significance.

Results

The 2000 season was characterised by abnormal high rainfall (Figure 7.1). Juice percentage, and to a lesser extent soluble solids (°Brix), remained constant over the three seasons while soluble solids per metric ton varied more distinctly according to rainfall experienced during the fruit growth and maturation period.

Over the three seasons studied for soluble solids and four seasons for soluble solids per metric ton, rainfall indicated a strong correlation for both parameters

(Figure 7.2). The 100% fit of the regression line to soluble solid data (Figure 7.2a) is due to the too few data points, and will decrease with the addition of new seasons data. The line is however useful to indicate trends over the past three seasons in that with decreasing rainfall during fruit growth and maturation, an increase in soluble solids is observed. Similarly, soluble solids per metric ton increase with decreasing rainfall (Figure 7.2b) until reaching a minimum at 473 mm rainfall.

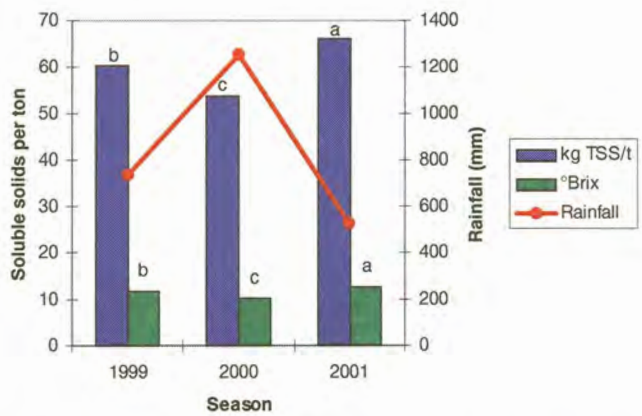

Figure 7.1 Averages for soluble solids per ton, soluble solids and rainfall for the 1999, 2000 and 2001 season for 'Valencia Late' orange fruit in the Brits production area. Means with different letters differ significantly at 5% level between years.

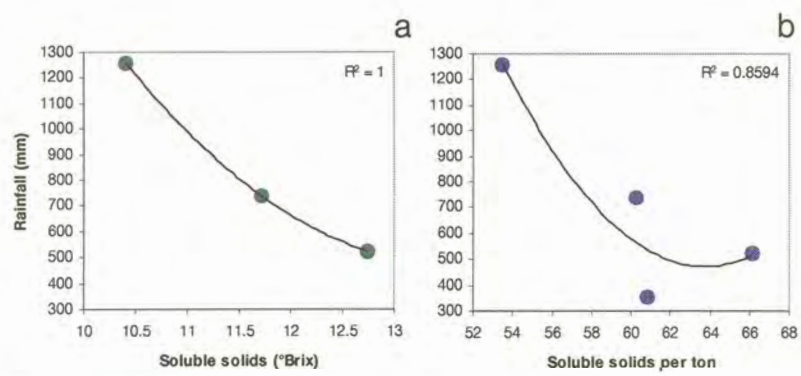

Figure 7.2 Regression analysis for averages over a three year period for soluble solids (a) and four year period for soluble solids per metric ton (b), in the 'Valencia Late' orange fruit from the Brits production area. Data represented is not sufficient to conclude reliable long term trends.

In Figure 7.3 a correlation between heat units accumulated over the fruit growth and maturation period and total soluble solids per metric ton delivered is indicated for the 2000 season. The regression line showed a poor (less than 10%) fit to data. As increase in heat units is connected to time, the trend displayed in Figure 7.3 is comparable to that found for data in Chapter 3 and 5, where soluble solids per metric ton initially increase, plateau and then decrease.

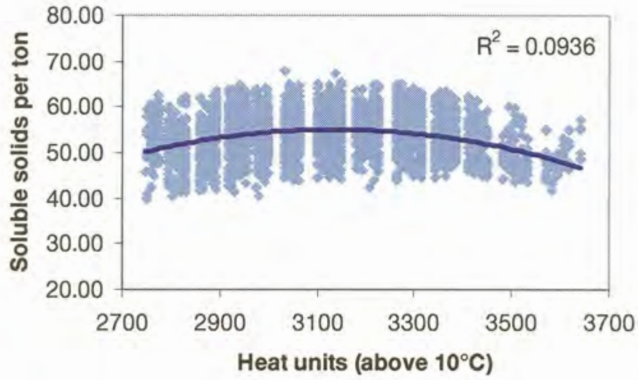

Figure 7.3 Regression analysis for 2668 individual data points during the 2000 season for 'Valencia Late' orange fruit produced in the Brits production area. Heat units were compiled from three weather stations and summed cumulatively per day from September 1999 to date of delivery in 2000 covering the entire fruit growth and maturation period.

Discussion

The decisive factor for fruit quality remains climate of which rainfall has the greatest influence. The higher soluble solids per metric ton observed in lower rainfall seasons can be attributed to increased photosynthate translocation into fruit leading to higher sugar accumulation in juice sacs as found by Yakushiji *et al.* (1998) for moderately drought stressed trees. In general water shortage causes increased concentrations of soluble solids in citrus juice (Kuriymama *et al.*, 1981; Cruse *et al.*, 1982; Ginestar and Casale, 1996; Yakushiji *et al.*, 1996). Trees grown under conditions of abundant soil moisture produce fruit high in juice, low in soluble solids, and low in acid content (Jones, 1961; Jones *et al.*, 1962).

The fact of the matter is that the available data obtained from the MCC is too little to be able to formulate reliable long term conclusions within the Brits production area. The information generated is however useful in the formation of a preliminary understanding of factors affecting juice quality parameters, as mean average temperatures did not differ significantly between years.

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Chapter 8

OVERALL DISCUSSION AND CONCLUSION

Members of the Magaliesburg Citrus Co-operative (MCC) are rewarded according to the kilogram total soluble solids per metric ton delivered. In Figure 8.1 the influence of juice percentage and measured °Brix are indicated. These two factors go hand in hand. A high soluble solid per metric ton can hardly be achieved if both variables are not at an optimum. However, these two factors should not be seen in isolation. Although juice percentage and °Brix determine the kilogram soluble solids per metric ton, yield has the most profound effect on the amount of soluble solids produced per hectare, followed by °Brix and juice percentage respectively.

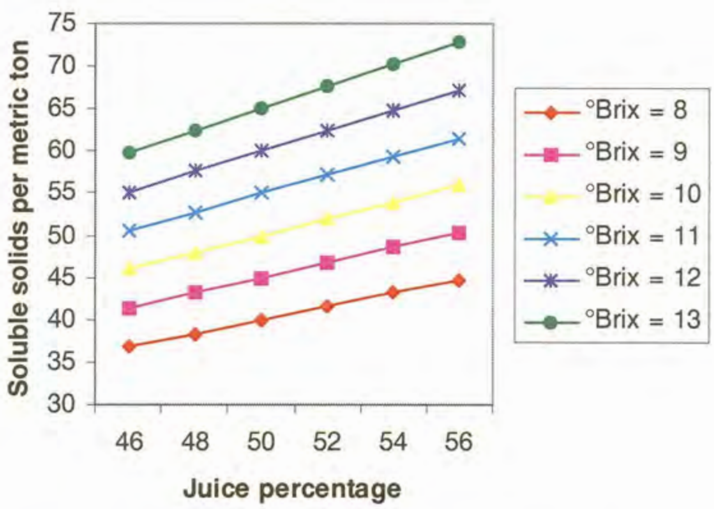

Figure 8.1 Soluble solids per metric ton as influenced by juice percentage and °Brix. Kilogram soluble solids per metric ton = (Juice% x °Brix) / 10.

Fruit from different canopy positions differ in internal fruit quality. Winter girdling of branches did not improve the soluble solid content in fruit from various canopy positions and would not be recommended on a commercial scale although earlier girdling treatments could prove more effective. Citrus trees were found insensitive to girdling treatments by Verynne (2000).

Soluble solids per fruit and per metric ton were influenced by the fruits position in the canopy, with external upper fruit having higher soluble solid concentrations. Verynne (2000) observed an increase in soluble solids for Nules clemintines but not in Mihowase satsumas during the second year of exposing internally-borne fruit to direct sunlight, by means of summer girdling. Further studies should be conducted to determine temperature and irradiance levels for specific positions in the canopy and correlated to internal fruit quality for the specific position. Lighting in an orchard should also remain an important consideration. The more light penetrating into the canopy the better, as has been proved by several authors (Reitz and Sites, 1948; Richardson and Mooney, 1992; Verynne, 2000).

The application of various organic, inorganic and biological amendments to the soil yielded various results on the improvement of soluble solids per fruit and per metric ton. Biological nematicides performed poorly in comparison to commercial aldicarb treatments. White reflective plastic increased yield and soluble solid production per hectare while aldicarb increased fruit weight and kilogram soluble solids per metric ton. Organic mulch indicated no obvious increase in internal fruit quality. Tree crops do not react immediately to treatments applied to the soil and good root health is always advisable even though there is no direct influence on internal quality. According to the findings of Verynne (2000) riding increased the soluble solid content of Bahaininha Navel. Less focus should be placed on trying to increase established orchards and more on the increase of soluble solids from the-get-go of new plantings.

When comparing two non-adjunct orchards in terms of fruit quality, large variation in physical as well as chemical parameters were found present in the 2000 season and absent in the 2001 season. While no apparent differences could be found between the orchards, the most probable explanation would be the subsoil clay layer found from 30 cm in the orchard with highest soluble solid per fruit and per metric ton. The 2000 was characterised by abnormal high rainfall and leached most of the plant available nitrogen and potassium in the orchard with no restricting soil layers.

The monitoring of changes in physical and chemical characteristics during the growth and maturation of the fruit yielded valuable information in reconsidering the harvest date for optimal gain in soluble solids per metric ton. Results indicate that the highest levels of soluble solids (°Brix) do not coincide with that of soluble solids per metric ton as juice percentage is still increasing. In the long run it would be advisable to determine these trends for all the cultivars used for processing at the MCC to gain maximum profits. Fruit chemical characteristics were severely influenced by prevailing weather conditions experienced during September 2000. Harvest should thus be avoided after severe weather or stress extremes as the results in this study indicate that a financially viable level of soluble solids per metric ton was only again recovered after two weeks following the stress condition.

Three rootstocks, Rough lemon, Swingle citrumelo and X639 were evaluated on the University Experimental farm. Swingle citrumelo has progressed to one of the most popular rootstocks in use by the citrus industry (Anon, 1997) and yielded the best results when soluble solids per metric ton were compared.

Climate has long been known to influence the vegetation found in a particular region. This is no different for citrus. The high rainfall experienced in the 2000 season made for good comparison between years. After the best choice of cultivar, rootstock, location, soil preparation and cultural practices have been made, climate still has the determining effect on internal quality. Under abnormal conditions, the best choices made will buffer the severity of the effects on fruit quality, but will always play a minor role.

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