Effects of Leaf-to-Fruit Ratio on Fruit Quality of Oval Kumquat (*Fortunella margarita* Swingle)

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Key words: Kumquat, Leaf-to-fruit ratio, Fruit quality

Summary

A study on effects of leaf-to-fruit ratio on oval kumquat fruit quality was carried out at the Viticulture Research Station, National Chung Hsing University, Wufeng, Taichung, Taiwan in 2006-2007. Twenty-four 3 years old oval kumquat trees grafted on sour orange stocks were used for fruit thinning to provide trees with 5, 10, 15 and 20 leaves per fruit, respectively. The result showed that increasing the leaf-to-fruit ratio resulted in an increase in fruit size, fruit weight, TSS and fruit color. TSS in peel was higher than that in juice and TSS of winter fruits was higher than that of summer fruits. The ratio of leaf-to-fruit did not affect the weight and percentage of peel, juice, TA and TSS/TA ratio. It was found that oval kumquat fruit quality was low when leaf-to-fruit ratio was lower than 10.

Introduction

Tree management can affect fruit growth by changing the assimilate supply and water availability. Fruit are strong sinks and changing leaf-to-fruit ratios can alter the balance of photoassimilates, water and nutrients supplied to fruit, thereby affecting fruit quality (Simmons *et al.*, 1998). Fruit thinning is used to ensure an adequate leaf area is available to support the

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growing fruit. Fruit thinning reduces competition for carbohydrates between mango fruits and also improves fruit quality in terms of firmness, soluble solids content and anthocyanin formation, hence red skin color (Yeshitela *et al*., 2004). Generally, the tree size and its carbohydrate storage capacity are one of the most important factors that determine the number of fruit per tree can nurture to maturity.

Kumquats (*Fortunella* Swingle) are mainly grown in USA, China, Taiwan, Japan, Puerto Rico, Guatemala, Surinam, Colombia, Brazil, South Indian, Australia and South Africa (Morton, 1987). Kumquats are used to eat fresh, or to make candies, preserves, jelly and liqueur. There were many studies about effects of leaf-to-fruit ratio on fruit quality of orange (Yuan *et al*., 2005), mango (Simmons *et al*., 1998; Lechaudel *et al*., 2005; Lechaudel *et al*., 2002), apple (Frree and Cahoon, 1987; Forshey, 1986) and other fruit crops, however studies on kumquats are still limited. This study investigated the effects of different levels of fruit thinning on fruit quality of oval kumquat.

Material and Methods

I. Area description

The trial was conducted at the Viticulture Research Station, National Chung Hsing University (NCHU), Wufeng, Taichung, Taiwan in 2006 - 2007 (two harvest seasons).

II. Plants and material

Twenty-four oval kumquat trees grafted on sour orange were used for 5, 10, 15 and 20 leaves per fruit treatments. The trees had been planted since 2003 with planting distances 4 m x 4 m, and it were trained to the open natural form and had size 1.3 m in height, 3 cm of trunk in cross-section and 1.4 m in canopy diameter.

The total number of fruits per tree was counted in late May (season 1) and September (season 2), 2006 (one month after blooming) and the average of leaf number per fruit was 9.36 and 6.70, respectively. The fruit thinning was adjusted with 10, 15, 20 leaves per fruit (May) and 5, 10, 15, 20 leaves per fruit (September). All new leaves and flowers were thinning out after fruit thinning.

III. Parameters studied and design used

In mid-August (summer) and December (winter) of 2006, ten ripe fruits from the middle part of the canopy were harvested. The fruit samples were cleaned in water and dried in room temperature and then was measured with parameter as following fruit size, fruit weight, fruit color, peel weight, juice content, total soluble solid (TSS) and titratable acid (TA).

The fruit color was measured by Minolta Chroma Meter at two equidistant locations on each fruit and expressed as L, a and b values. Fruit width and fruit length were recorded by measuring greatest transversal and longitudinal of fruit, respectively. Fruit, peel and juice weight were measured by Mettler PJ 400 electric balance. TSS (^{o}Brix) and TA (%) of juice were measured by Lafayette 99-70369L hand-held digital refractometer and DL 12 Titrator.

Results

I. Fruit size

Fruit width was significantly smaller in 5 and 10 leaves per fruit treatments. Fruit width was largest in 20 leaves per fruit treatment with 24.53 mm and 24.23 mm in summer and winter, respectively (Table 1).

Fruit length was not significant difference among treatments in summer and was significantly longer in 20 leaves per fruit than other treatments in winter. Fruit length was longer in winter fruits compared to summer ones (Table 1).

Table 1. Effects of leaf-to-fruit ratios on the width and length of oval kumquat fruits.

Treatments	Fruit width (mm)		Fruit length (mm)	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	23.30c	-	32.87c
10 leaves / fruit	23.79b [z]	23.72bc	32.54a	33.34bc
15 leaves / fruit	24.42a	23.93ab	32.84a	33.94b
20 leaves / fruit	24.53a	24.23a	33.18a	34.86a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

The volume of fruits in both harvest seasons was significantly larger in treatments with higher number of leaves per fruit. Fruits from 20 leaves per fruit treatment were largest (10.98 cm^3 in summer and 11.14 cm^3 in winter) and were smallest for 5 leaves per fruit (9.96 cm^3 in winter). Same as fruit volume, fruit weight was significantly larger in higher leaf-to-fruit ratio treatments. Fruit weight in winter was larger than that of summer (Table 2).

Table 2. Effects of leaf-to-fruit ratios on the volume and weight of oval kumquat fruits.

Treatments	Fruit volume (cm^3)		Fruit weight (g)	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	9.96d	-	9.61d
10 leaves / fruit	10.43b [z]	10.39c	9.90b	10.14c
15 leaves / fruit	10.83a	10.81b	10.39a	10.50b
20 leaves / fruit	10.98a	11.14a	10.51a	10.85a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

II. Component parts of fruit

The effect of leaf-to-fruit ratios on the weight of peel and juice are shown in Tables 3 and 4. The peel weight of summer fruits were 4.12, 4.33 and 4.40 g in 10, 15 and 20 leaves per fruit, respectively. In winter fruits those were 4.28, 4.37, 4.49 and 4.60 g in 5, 10, 15 and 20 leaves per fruit treatments, respectively. Increasing the leaf-to-fruit ratio did not significantly affect weight and percentage of peel (Table 3).

Juice weight increased with increases in leaf number per fruit in winter fruits. The percentage of juice weight per fruit was not significantly different between treatments in the same season (Table 4).

Table 3. Effects of leaf-to-fruit ratios on weight and percentage of peel in oval kumquat fruits.

Treatments	Peel weight (g)		Peel percentage (%)	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	4.28a	-	44.56a
10 leaves / fruit	4.12a [z]	4.37a	41.67a	43.11a
15 leaves / fruit	4.33a	4.49a	41.68a	42.80a
20 leaves / fruit	4.40a	4.60a	41.85a	42.43a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

Table 4. Effect of leaf-to-fruit ratios on weight and percentage of juice in oval kumquat fruits.

Treatments	Juice weight (g)		Juice percentage (%)	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	2.07b	-	21.47a
10 leaves / fruit	2.22a [z]	2.28ab	22.38a	22.46a
15 leaves / fruit	2.34a	2.47ab	22.53a	23.51a
20 leaves / fruit	2.36a	2.57a	22.47a	23.71a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

III. Total soluble solid (TSS) and titratable acid (TA)

TSS of juice in summer fruits was not significantly different among different leaf-to-fruit ratios (Table 5). For winter fruits, TSS of juice significantly increased in 10, 15 or 20 leaves per fruit compared to 5 leaves per fruit. TSS of 20 leaves per fruit was the highest (7.7 ^{o}Brix in summer and 8.03 ^{o}Brix in winter).

TSS in peel was higher than that in juice. There was no significant difference in peel TSS among leaf-to-fruit ratios in summer fruits, whereas that was significantly different in winter fruits. TSS of peel in 15 or 20 leaves per fruit was 10.4～10.65 ^{o}Brix, and that in 5 leaves per fruit was only 9.68 ^{o}Brix in winter fruits (Table 5).

Table 5. Effects of leaf-to-fruit ratios on TSS (^{o}Brix) in juice and peel of oval kumquat fruits.

Treatments	Juice		Peel	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	7.37c	-	9.68c
10 leaves / fruit	7.55a [z]	7.75b	9.87a	10.17b
15 leaves / fruit	7.68a	7.87ab	10.12a	10.40ab
20 leaves / fruit	7.70a	8.03a	10.22a	10.65a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

TA of juice and peel was not significantly different among treatments in the same harvest season. TA in peel was lower than that in juice. TA in juice reached 4.14%～4.37% at harvest, whereas in peel it was reached only 2.48%～2.66% (Table 6).

Table 6. Effects of leaf-to-fruit ratios on TA (%) in juice and peel of oval kumquat fruits.

Treatments	Juice		Peel	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	4.14a	-	2.52a
10 leaves / fruit	4.26a [z]	4.19a	2.48a	2.69a
15 leaves / fruit	4.29a	4.20a	2.57a	2.66a
20 leaves / fruit	4.37a	4.26a	2.66a	2.48a

[z]: Value in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

Total soluble solids of fruit juice and peel were not significantly affected by fruit thinning. The ratio of TSS to TA was from 1.8 to 1.9 in juice, and 3.9 to 4.2 in peel (Table 7).

Table 7. Effects of leaf-to-fruit ratios on the ratio of TSS to TA in juice and peel of oval kumquat fruits.

Treatments	TSS / TA in juice		TSS / TA in peel	
	Summer	Winter	Summer	Winter
5 leaves / fruit	-	1.79a	-	3.94a
10 leaves / fruit	1.78a [z]	1.86a	4.22a	3.88a
15 leaves / fruit	1.80a	1.88a	4.11a	3.98a
20 leaves / fruit	1.77a	1.89a	3.99a	4.22a

[z]: Value in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

IV. Fruit coloration

The color of fruit was changed by the change in leaf-to-fruit ratio. In summer fruits, the L (lightness) value was only significantly different in 20 leaves per fruit compared to 10 leaves per fruit, whereas the a and b value significantly different when leaf-to-fruit ratio was 15 or 20, compared to 10 leaves per fruit. In 5 leaves per fruit, all L, a and b values were lower than that in others (Table 8). The color of fruits in 20 leaves per fruit appeared lighter and more orange color. In winter fruits, L and b values were not significantly different among different leaf-to-fruit ratios. The a value was significantly higher in 15 or 20 leaves per fruit than that in 5 leaves per fruit. The highest of L, a and b values reached 56.01, 13.03 and 54.61, respectively (in 20 or 15 leaves per fruit) (Table 8). The fruits in 15 or 20 leaves per fruit appeared more red and yellow color.

Table 8. Effects of leaf-to-fruit ratios on fruit color.

Treatments	Summer			Winter		
	L	a	b	L	a	b
5 leaves / fruit	-	-	-	54.35a	4.52c	49.91a
10 leaves / fruit	51.48b[z]	5.66b	47.07b	53.00a	7.54bc	48.65a
15 leaves / fruit	54.76ab	12.16a	52.94a	54.01a	13.03a	52.60a
20 leaves / fruit	55.26a	12.86a	53.61a	56.01a	11.56ab	54.62a

[z]: Values in the same column followed by the same letter are not significantly different by Duncan's multiple rang test at 5% level.

Discussion

The results of Ferree and Cahoon (1987) on apple indicated that although increases in the leaf-to-fruit ratio from a relatively low level to a high level resulted in a 15% reduction in the number of fruit per tree, however yield per tree was not influenced. The increase in fruit size was sufficient to compensate for the reduction in yield by thinning. The increased natural fruit drop likely occurred at the low leaf-to-fruit ratio compared to the high rates.

The higher fruit size and fruit weight at harvest were achieved by leaving 15 or 20 leaves per fruit. This problem may be accounted by photoassimilate during fruiting. Similar increases in starch concentrations and reduced stomatal conductance in leaves of high leaf-to-fruit ratio

have been observed in apple (Schechter and Proctor, 1994) and in mango (Lechaudel *et al.*, 2005). Higher leaf starch concentration indicated that excess photoassimilates were being accumulated during fruiting, which may have led to “end-product inhibition” of photosynthesis and consequently reduced stomatal conductance (Schechter and Proctor, 1994). The more accumulation during fruit growth was the cause of larger fruit size in treatments with higher leaf-to-fruit ratio.

In mango, further increases in fruit size by increasing the leaf-to-fruit ratio to 120 is likely to have caused an imbalanced in photoassimilate (carbohydrate), water and mineral flows to the fruit (Simmons *et al.*, 1998). Decreasing the leaf-to-fruit ratio may have resulted increase volume of water being lost via the xylem to surrounding leaves during the day because of higher leaf transpiration rates and possibly higher fruit osmotic and water potentials, so dry mass and total soluble solid of fruit were decreased (Simmons *et al.*, 1998; Chaney and Kozlowski, 1971; Lechaudel *et al*., 2002; Lechaudel *et al*., 2004).

The increase of fruit size and fruit weight in high leaf-to-fruit ratio treatments (such as 15 or 20 leaves per fruit) was synonymous with increase in peel weight and juice weight. In this study also indicated that fruit size, peel weight and juice weight in December harvest season were bigger than that in August. Seasonal change was one of causes of changes in fruit size, peel weight and juice weight.

It was also observed when the number of fruit per tree was decreased, the accumulation of assimilates per fruit (like TSS) would be increased. Fruit thinning reduced the competition for carbohydrates among fruits, thus, total soluble solid and coloration increased (Forshey, 1986), and fruit quality was improved. The increase in soluble solids associated with the big fruit in the high level of leaves per fruit also was indicated by the increase leaf-to-fruit ratios (Ferree and Cahoon, 1987). In this study, total soluble solid increased from 7.37 ^{o}Brix (in 5 leaves per fruit) to 8.03 ^{o}Brix (in 20 leaves per fruit) in December harvest season.

Transformation of stomata to lenticels on the fruit skin can be accelerated by rapid fruit growth and expansion, and may account for increased lenticel spotting on the big fruit from the high leaf-to-fruit ratio (Simmons *et al*., 1998). Similar increases in fruit mass, TSS, dry mass percentage and red blush with higher leaf-to-fruit ratios have been observed in thinned apple crops (Ferree and Cahoon, 1987). In this study, the color of kumquat fruits in high leaf-to-fruit ratio (20 leaves per fruit) were lighter and more red and yellow color than that in low leaf-to-fruit ratio. The more fruit in low leaf-to-fruit ratio often resulted in the branch being weighed down with fruit hidden within the canopy. The retention of more green peel color of fruit from low leaf-to-fruit ratio treatments may have also been due to greater fruit shading as generally observed with fruit inside the canopy.

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葉果比對長實金柑果實品質之影響

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關鍵字：金柑、葉果比、果實品質

摘要：以疏果調整葉果比之方式調查其對長實金柑果實品質之影響。在 2006 年至 2007 年於台中縣霧峰鄉國立中興大學葡萄中心進行試驗，選取 24 株 3 年生之長實金柑植株進行疏果，並將葉果比調整為 5、10、15、20。結果發現葉果比越大者其果實越大，冬果的全可溶性固形物(TSS)越高，無論夏果或冬果，果皮之全可溶性固形物皆高於果汁。另外葉果比越大者，其果皮著色越呈現黃紅色，但是葉果比對果皮重、果皮率、果汁重、果汁率、夏果之 TSS、酸度及糖酸比並無影響。綜合本研究之結果可知葉果比若低於 10 以下時，其果實之品質較差。

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