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不同砧木对特罗维塔甜橙植株生长、产量和果实品质的影响

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摘 要:采用6种6 a生特罗维塔甜橙砧穗组合植株作试材,在相同管理条件下不同砧木对特罗维塔甜橙植株营养生长、产量以及果实品质(外观内质)的影响进行了比较研究。结果表明,以李齐16-6枳(LC)为砧的特罗维塔单位树冠体积产量最高,以兰普莱蒙(RL)、沃尔卡姆柠檬(VL)、卡里佐枳橙(CT)和光皮酸桔(GS)砧穗组合次之,而以孙楚沙桔(SM)为砧特罗维塔植株单位树冠体积产量最低。不同砧木对特罗维塔甜橙植株单株产量,以VL、RL和CT为砧单株产量较高,而以GS和SM为砧的特罗维塔植株单株产量最低。试验所采用的砧木对特罗维塔果实单果重影响不显著,但以RL和LC为砧特罗维塔植株果实体积最大。砧木对特罗维塔甜橙果实品质有显著的影响,其中以LC、CT、GS和RL为砧果实果汁含量显著高与其他砧穗组合果实;而以CT和LC为砧的砧穗组合果实可滴定酸含量最高,以RL为砧次之;以LC、CT、GS和RL为砧果实维生素C含量显著高于其他砧穗组合果实。不同砧木对特罗维塔甜橙植株生长有显著影响,其中以CT为砧的植株冠层体积最大,以RL和VL为砧的特罗维塔植株次之,而以GS和SM为砧植株冠层体积较小。同时不同砧木对特罗维塔甜橙果实油斑病发生率和单果发生程度有显著影响,其中以RL为砧特罗维塔果实单果油斑病发生程度最高。

关键词:特罗维塔甜橙;砧木;接穗;品质;油斑病
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Effects of rootstocks on tree growth yield, and fruit quality of Trovita sweet orange in south China

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Abstract: Tree size, yield, fruit quality and oleocellosis rate of six year old Trovita sweet orange (*Citrus sinensis* L.) grafted on 6 rootstocks were evaluated under south China conditions. Trees on Liqi16-6 citrange (LC) were the most productive in terms of yield in unit canopy volume, followed by trees on Rangpur lemon (RL), Volkamer lemon rootstock (VL), Guangpi sour orange (GS) and Carrizo citrange (CT), while trees on 'Sunchusha' mandarin (*C. reticulata* Blanco) (SM) had the lowest yield efficiency. However, trees on VL and RL had the highest yield per tree, while those on GS and SM had the lowest yield per tree. Although there was no significant difference in fruit weight among these rootstocks, fruit from the trees on RL and LC were the largest. Fruit from trees on LC, CT, GS and RL had a higher juice content than on the other two rootstocks, and fruit from trees on CT and LC had the highest acid (TA) content, followed by those on RL. Vitamin C content was higher in fruit from trees on LC, CT, GS and RL than on the other rootstocks. Trees size was the largest on CT, followed by those on RL and VL, and it was the smallest on GS and SM. The results indicated that rootstock affected tree growth, fruit size and yield, juice recovery, Brix, acidity and Brix:acid ratio. Based on the results, CT and VL would be the most promising rootstocks for Trovita sweet orange in south China, and fruit from trees on RL were highly susceptible to oleocellosis.

Key words: Trovita sweet orange; Rootstock; Scion; Fruit quality; Oleocellosis

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Trovita sweet orange (*Citrus sinensis* L.) originated as a bud mutation on a Washington navel orange tree, and Trovita has several advantages including high yield, good quality and late maturation. Trifoliate orange [*Poncirus trifoliata* (L.) Raf.] (TO) and sour orange (*C. aurantium* L.) (SO) used to be the most popular rootstock in south China[1]. Rootstock influences tree growth as well as yield, fruit quality, and tolerance to biotic and abiotic stresses[2]. In the mountainous areas in south China, Trovita sweet orange trees on TO and SO is weak and low yielding due to shallow soil. There is little information about rootstock selection for improvement of yield and fruit quality of Trovita sweet orange. Furthermore, the development of nutrient deficiency symptoms in Trovita sweet orange trees on TO and SO in soils with high calcium carbonate content justifies the importance of rootstock studies to select appropriate rootstocks for Trovita sweet orange grown in south China.

The influences of rootstock on the adaptability of a scion cultivar to the prevailing soil conditions as well as on its horticultural characteristics such as tree growth, yield and fruit quality are the major concerns in rootstock selection. Therefore, it is important to assess those characteristics under local edaphic and environmental conditions in south China. The objective of this study was to compare yield, fruit size, peel percentage, juice recovery, total soluble solids (TSS), titratable acids (TA), and tree size of 6-year-old Trovita sweet orange grafted on six rootstocks in south China.

1 Materials and Methods

1.1 Plant materials

The rootstocks used for this study were Volkamer lemon (*Citrus volkameriana* Ten and Pasq.) (VL), Guangpi sour orange (*C. aurantium* L.) (GS), *Carrizo citrange* [*C. sinensis* (L.) Osbeck ×*Poncirus trifoliata* (L.) Raf.] (CT), Rangpur lime (*C. sinensis* × *limonia* Osbeck) (RL), liqi16-6 (*P. trifoliate* L.) (LC) and Sunchusha mandarin (*C. reticulata Blanco*) (SM).

The seedlings were budded in spring 2000 using virus-free budwoods taken from the same clonal stain of Trovita sweet orange (*Citrus sinensis* L.). During March 2001, uniform 1-year-old trees were planted at a high density (3 m×4 m) in the experimental orchard in the Citrus Research Institute, Southwest University, Chongqing, China (Latitude, 29°45′51″ N; longitude, 106°22′21″ E; Altitude, 240 m above sea level). The trees were drip irrigated and under local conventional management.

1.2 Sample analyses

Six-year-old trees on each rootstock were chosen and labeled for this study (2007/2008). A randomized blocks design with two-trees per plot and three replicates was used. In December, 2007/2008, tree height, canopy diameters in two directions (to obtain the average diameter) and trunk girths at 10 cm above and below the budding union were measured, and scion/stock girth ratio was calculated. The canopy volume (m^3) was calculated according to the equation reported by Wutscher [3]: Tree volume = (Tree diameter^2 × Tree height)/4. The weight of harvested fruit per tree was recorded at commercial maturity, and fruit production per hectare (Ha) was calculated. The yield of unit canopy volume (yield efficiency, $kg \cdot m^{-3}$) and the average per tree yield of 2007/2008 were also calculated.

Samples of twelve fruit per replicate were randomly collected at harvest date for determination of fruit physical and chemical characteristics. Fruit weight, diameter (D) and height (H) were determined. Fruit shape index (D/H) was calculated. Fruit colour in ‘L’, ‘a’ and ‘b’ values was measured by a Konica Minolta CR-10 colormeter and Hue angle was calculated according to McGuire[4] and Voss[5].

Fruit juice was extracted by a rotary extractor, and the peel, juice and flesh recoveries (w/w) were calculated. Content of total soluble solids (TSS) was measured with a refractometer; titratable acidity (TA) and ascorbic acid (Vit. C) were determined according to AOAC[6]; and TSS/acid ratio was calculated.

Fruit oleocellsis parameters were measured after harvest according to Zheng et al[7]. The ratio of the total number of fruits with oleocellsis to total number of measured fruits was recorded as ratio of oleocellosis (RO), and the number of oleocellosis spots larger than and smaller 0.25 cm in diameter per fruit were recorded as x_1 and x_2, respectively. Then the degree of oleocellosis per fruit (DO) of each fruit was calculated as follows:

DO $=x_1^*0.5+x_2^*0.25$.

Note: The square correlation coefficient (R^2) between DO and the total oleocellosis area of each fruit was 0.92 (n=20). So the DO can present the degree of oleocellosis of per fruit.

1.3 Statistical analysis

Data recorded in all seasons were statistically analyzed using the SPSS 17.0 (SPSS Inc., Chicago, IL, USA)[8]. Data were presented as the means of three replicates. One-way analysis of variance was used to compare means. After analysis using Levene's test, means with equal variance were tested by least-squares determination, whereas means with unequal variance were analyzed using Dunnett's T3 test. Differences at $P < 0.05$ were considered significant.

2 Results and Analysis

2.1 Tree growth

2.1.1 Tree height Trees of Trovita sweet orange budded on CT, LC and VL were significantly higher than those on GS, while tree height on RL and SM had no significant difference from the other rootstocks (Table 1).

2.1.2 Canopy diameter Trees grafted onto VL had the largest canopy diameter. The canopy diameter was significantly higher on CT and RL than on LC, SM and GS, while trees on GS had the smallest canopy diameter (Table 1).

Table 1 Effect of rootstocks on the tree growth of 6-year-old Trovita sweet orange

Rootstocks	Tree height/m	Canopy diameter/m	Tree volume/m^3	Girth		Scion/stock girth ratio
				Scion	Stock	
CT	2.743 a	3.108 b	6.626 b	34.67 a	40.90 a	0.85 b
LC	2.660 a	2.550 c	4.324 c	26.33 b	36.63 ab	0.72 c
RL	2.307 ab	3.300 b	6.280 b	37.00 a	41.48 a	0.90 ab
VL	2.817 a	3.408 a	8.180 a	33.00 ab	32.08 b	1.03 a
GS	1.820 b	1.917d	1.671 d	25.33 b	33.40 b	0.76 bc
SM	2.500 ab	2.390 c	3.570 c	25.67 b	27.53 c	0.93 ab

Note: Different letters in the same column mean significant differerce at $P<0.05$. The same below.

2.1.3 Tree volume Similar to canopy diameter, canopy volume of the trees budded on VL was significantly larger than those on the other rootstocks. The trees budded on CT had a similar volume to those budded on RL. Trees budded on LC, SM and GS had a significantly smaller canopy than those budded on other rootstocks, and the trees on GS had a significantly smaller canopy size than those on the other rootstocks.

2.1.4 Scion trunk girth, stock trunk girth and scion/stock trunk girth ratio Table 1 shows that trees on RL, CT and VL had a significantly greater scion girth than those on the other rootstocks. Stock girth of trees on CT and RL was the greatest followed by those on LC. The ratio between scion and rootstock trunk girth indicates scion/rootstock compatibility, where values close to 1 show good compatibility[9]. The highest compatibility was found in VL, which had the highest scion/stock ratio (1.03). The lowest compatibility was found in GS and LC (0.76 and 0.72, respectively).

2.2 Yield

2.2.1 Fruit weight and Fruit number Fruit weight was not significantly affected by rootstocks in this study, although the trees on RL produce relatively larger fruit (Table 2). However, fruit number per tree was significantly affected by rootstocks. Trees grafted on VL gave the highest fruit set, and those on CT, LC and RL had a significantly higher fruit set than trees on SM and GS.

2.2.2 Per-tree fruit yield Trees on VL produced a significant higher yield (39.9 kg per tree) than trees on

Table 2 Effect of rootstocks on fruit yield of six years old Trovita sweet orange

Rootstocks	Fruit number	Fruit mass	Fruit yield		Yield efficiency
	Per tree	/g	Tree/kg	Ha/t	/kg·m^{-3}
CT	146.667 b	169.000 a	24.787 b	20.656 b	3.741 c
LC	163.333 ab	153.667 a	25.099 b	20.916 b	5.804 a
RL	176.667 ab	171.667 a	30.328 ab	25.273 ab	4.829 b
VL	243.333 a	164.167 a	39.947 a	33.289 a	4.883 b
GS	48.333 c	156.000 a	7.540 c	6.283 c	4.511 bc
SM	60.000 c	151.333 a	9.080 c	7.567 c	2.543 d

the other rootstocks. The lowest yield were found in those on GS (7.5 kg per tree) and SM (9.1 kg per tree), which had no significant difference (Table 2). Fruit yield per hectare displayed the same pattern.

2.2.3 Yield efficiency Table 2 shows that trees on LC had the highest yield efficiency among all studied rootstocks in the 6th YAP, and yield efficiency on CT and SM was the lowest.

2.3 Fruit external quality

2.3.1 Fruit colour Fig. 1-A and B show that rootstocks did not significantly affect these color parameters except for VL, which had the lowest a and h values. Fruits from trees on RL had the highest C value, and fruits from trees on GS and SM had a relatively lower C value than on the other rootstocks (Fig. 1-B).

2.3.2 Fruit size and shape Rootstocks did not significantly affect these fruit size and shape (Fig. 1-C).

2.3.3 Fruit oleocellosis Fruits from trees budded on RL had the highest degree of oleocellosis (DO) and ratio of oleocellosis (RO), and those from trees on CT and VL had relatively lower DO and RO than on LC, SM and RL (Fig 1D).

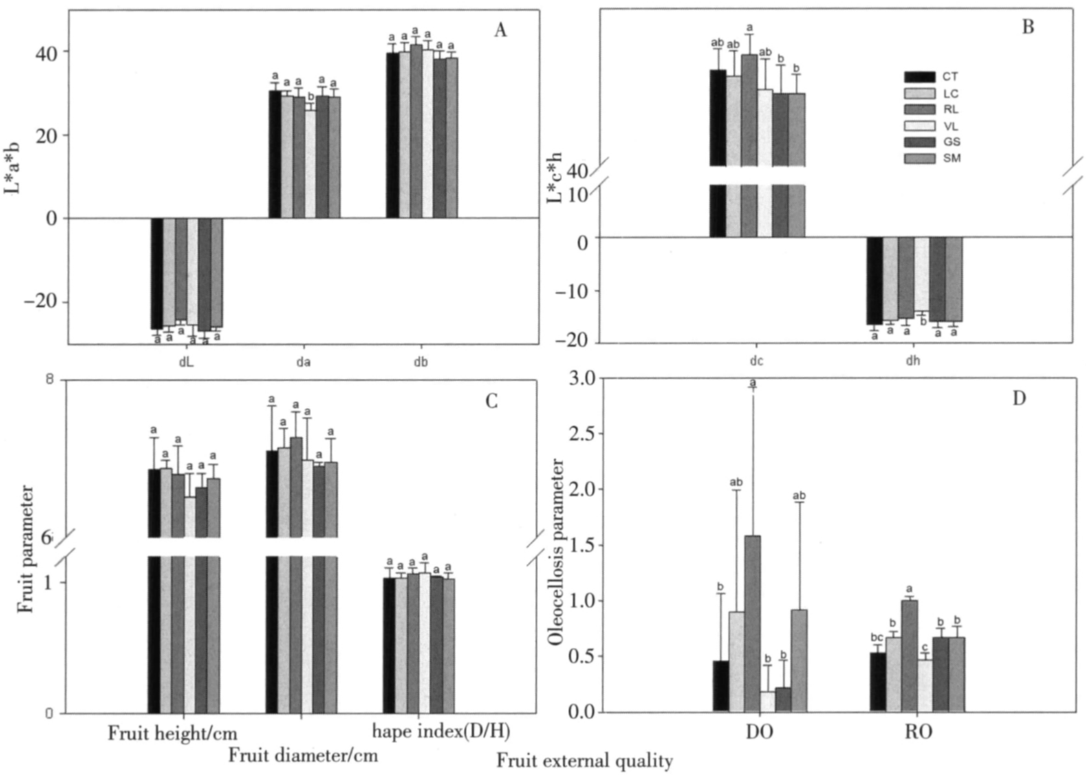

Fig. 1 Effect of rootstocks on external quality of Trovita sweet orange. Vertical bars above columns indicate Standard Deviation of means from 3 replicates

2.4 Fruit internal quality

2.4.1 Recoveries of flesh, peel and juice Fig. 2-A shows significant differences in these parameters among rootstocks. Fruits from trees on CT, RL and GS had a higher flesh recovery than on the other rootstocks. Fruits produced from CT, RL, VL and GS had a higher juice recovery than from LC and SM, whilst fruits from trees on LC, VL and SM had relatively higher a peel recovery than fruits from on other rootstocks.

2.4.2 TSS, TA, T/A and Vit. C Rootstocks did not significantly affect TSS (Fig. 2-B). However, the highest juice acidity was found in fruits from trees on CT rootstock, and the lowest one was detected in fruits from trees on VL, SM and GS. Fruits from trees on LC and RL had a significantly higher TA value than from trees on VL, SM and GS. Fruits from trees on VL, SM and GS had a significant higher T/A value than fruits from trees on other rootstocks, and the lowest Vit. C concentration was found in fruits from trees on VL and SM.

3 Discussions

Although there are the substantial body of knowledge on citrus rootstocks, relatively little information

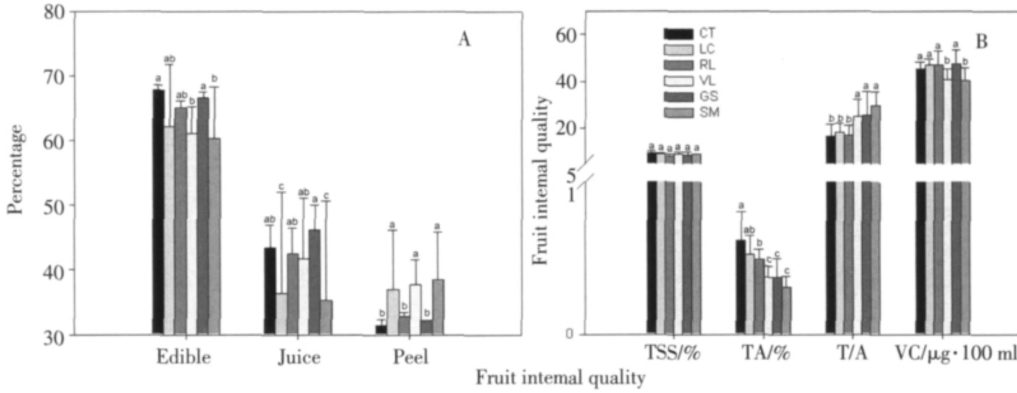

Fig. 2 Effect of rootstocks on internal quality of Trovita sweet orange. Vertical bars above columns indicate Standard Deviation of means from 3 repliates

exists concerning long-term effects with Trovita sweet orange. High yield, large fruit size, high flesh recovery, juice recovery and acid content, and low peel recovery are desirable characteristics in commercial citrus production. Based on data collected in this study, it is evident that rootstocks exert a significant effect on fruit yield, fruit quality, and tree performance.

As shown previously, CT, VL and RL proved to be satisfactory rootstocks for Trovita. It is generally accepted that yield efficiency of most citrus fruits grown on VL and RL rootstocks are lower than on other stocks [10]. Trees on CT had a relative higher per-tree yield, internal quality and juice recovery than on the other rootstocks. However, in other studies, no significant difference in cumulative yields was found among rootstocks including Sour orange, VL, RL and CT[10]. It may be due to differences in scion cultivars, tree age, climatic conditions, and soil characteristics. The differential ability of the rootstocks to absorb water and nutrients and the physical differences among the root systems can further affect fruit quality, growth, and health of the scion cultivar[11].

At the same time, a good rootstock also should exceed some or all of certain horticultural and pest and disease resistance standards dictated by prevailing local conditions. RL lime has been widely used by growers in Brazil due to its heavy and early bearing, drought resistance and Tristeza resistance; however, it is susceptible do Blight and Sudden Death[12]. CT are tolerant to tristeza virus, Phytophthora root rot and citrus nematodes[13], whilst, Carrizo citrange is susceptible to salinity and lime-induced chlorosis[14]. It is worth mentioning, that planting of VL rootstock under calcareous soil conditions proved to be superior to the other rootstocks in its growth and leaf nutrient content [15]. In areas of high disease incidence, RL has been replaced or used in conjunction with a second rootstock on the same plants.

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