

## Early Evaluation of Compatibility between Commercial Citrus Varieties and Kaffir Lime (*Citrus hystrix*) and Carrizo Citrange (*C. sinensis* Osb. x *P. trifoliata* L. Raf.) Rootstocks at Mekong Delta, Vietnam

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**Abstract**— The results of investigation on early evaluation of compatibility between commercial citrus varieties, and Kaffir lime (*Citrus hystrix*) and Carrizo citrange (*C. sinensis* Osb. x *P. trifoliata* L. Raf.) rootstocks, at Mekong Delta Vietnam, during four successive years from 2010 to 2013, reported that out of the tested combinations of the recent commercial citrus varieties, included Da xanh pumelo (*C. grandis* Osbeck), seedless Mat orange (*C. sinensis* L. Osbeck), Sanh orange (*C. nobilis* Lour.) and Duong mandarin (*C. reticulata*), budded on Kaffir lime and Carrizo citrange, in the 3<sup>rd</sup> and 4<sup>th</sup> year after planting under the trial fields at Mekong Delta Vietnam, the trees of Sanh orange (*C. nobilis* Lour.) budded on Kaffir lime (*Citrus hystrix*) were superior with precocity, producing high number of fruits (16.67 fruits per tree), and very good fruit quality of larger fruit size (334.6 g and 11.16 cm, fruit weight and diameter, respectively), higher total soluble solids (12.5 brix), better orange-yellow juice color development, and excellent flavor and aroma of juice, as compared to the typical characteristics; meanwhile these were followed by trees of seedless Mat orange budded on Kaffir lime, which produced the highest number of fruits (47.33 fruits per tree), with little inferior quality of seedy fruit (1-3 seeds per fruit), lower total soluble solids (7.33%), and no good flavor and aroma, as somewhat differed from the typical fruit traits.

**Keywords**— Citrus spp., grafted, Kaffir lime, Mekong Delta, rootstock, Vietnam.

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### I. INTRODUCTION

Investigations of citrus scion and rootstock combinations have clearly revealed that the rootstocks impart to the tolerance or resistance to pest, disease, and the adverse environmental conditions as cool, drought, saline the growth and development, yield and fruit quality of the grafted trees [4]; and today, under climate changing, the watering source might be scarce and limit; so studying and using the drought resistant rootstocks of fruit crops may be required; moreover, there are around 29,320 hectares of the natural area of foot hills, with 300 to 710 m high above sea level, at Tri Ton and Tinh Bien district of An Giang province, Mekong Delta region, Vietnam; where the local farmers have always encountered with many difficulties in agricultural production, because of the extreme limiting of water resource for irrigation in dry season. So, the selection of the citrus graft trees for drought tolerance in cultivation is the important helping for the effective land using and sustainable agricultural production in this region; so that it may

contribute to increase farmers' income. Therefore, the results of the long term researches consisted of the primary evaluation and selection of the local citrus genotypes, being wild and cultivated, for drought tolerance under the natural conditions at Vietnam southern region; and screening for drought tolerance, under the combined artificial (in greenhouse) and natural (in trial field) drought stressor demonstrated that out of 28 local citrus genotypes plus 2 hybrids, Kaffir lime (*Citrus hystrix*); which had been mountainous wild plant in South Vietnam; while used as leafy spice in Asia nations such as Thailand, Indonesia, Malaysia; Chua pumelo (*C. grandis* Osbeck), Thanh tra pumelo (*C. grandis* Osbeck), Do pummelo (*C. grandis* Osbeck) had been selected as better drought tolerance based on some physiological responses of chlorophyll fluorescence, visual wilting symptoms, biochemical traits consisted of total chlorophyll, proline, soluble sugar and starch contents, and morphological traits [2, 3]. Extensively, a investigation on early evaluation of compatibility between commercial citrus varieties and Kaffir lime (*Citrus hystrix*) and Carrizo

citrange (*C. sinensis* Osb. x *P. trifoliata* L. Raf.) rootstocks in greenhouse and under trial field at Mekong Delta, Vietnam in duration of 2010-2013 was conducted to determine the good scion and stock combination for drought tolerance and good production with high fruit quality to introduce to citrus growers at the region with limiting irrigation water source.

## II. MATERIALS AND METHODS

### A. Experimental Layout

The recent commercial varieties of citrus consisted of Da xanh pumelo (*C. grandis* Osbeck), seedless Mat orange (*C. sinensis* L. Osbeck), Sanh orange (*C. nobilis* Lour.) and Duong mandarin (*C. reticulata*) were budded on rootstocks of Kaffir lime (*Citrus hytrix*) and Carrizo citrange (*C.sinensis* Osb.x*P. trifoliata* L. Raf.) propagated with cutting method. The experiment was established in early September 2010, in split plot design with three replications and single graft tree with 6 months after budding, per replication. Trees were planted at five and six meter planting distance in plants and rows, at foot-hill area with 4-40 meters above sea level, around 8 degree slope, located at Nui Dai area belong to Tri Ton district, An Giang province in Mekong Delta, Vietnam. The soil characteristics of trial field was 6.03 pH in 1:2.5 soil: water suspension, 0.06 mS/cm electric conductivity in the saturation extract, 0.99 percent organic content.

TABLE I  
SOIL CHARACTERISTICS AT TRIAL SITE

pH	6.03
Electric conductivity (mS/cm)	0.06
Organic matter (%)	0.99
Sand (%)	86.50
Silt (%)	11.40
Clay (%)	2.11

The climate conditions in dry seasons at experimental site from 2010 to 2012 were presented as below:

TABLE II  
TEMPERATURE, PRECIPITATION, EVAPORATE AND SUNSHINE HOURS AT TRIAL SITE IN 2010-2011

	Temperature (° C)	Precipitation (mm/month)	Evaporate (mm)
Nov, 2010	26,7	408,0	83,6
Dec, 2010	26,3	23,2	103,5
Jan, 2011	25,7	-	122,7
Feb, 2011	26,0	1,6	89,9
Mar, 2011	27,4	115,8	129,0
Apr, 2011	28,2	30,3	120,8
May, 2011	28,7	109,7	108,1

The trees were irrigated weekly from December to March using basal irrigation method. In the first year after planting, the trees were fertilized with Urea and Di-ammonium Phosphate; and later on applied with NPK-20-20-15 fertilizer. Disease and pest populations were controlled according to integrated pest management (IPM) method.

TABLE III  
TEMPERATURE, PRECIPITATION, EVAPORATE AT TRIAL SITE IN 2011-2012

	Temperature (° C)	Precipitation (mm/month)	Evaporate (mm)
Nov, 2011	27,8	179,1	77,8
Dec, 2011	26,0	40,6	103,1
Jan, 2012	26,6	0,2	84,5
Feb, 2012	26,8	1,4	81,0
Mar, 2012	28,1	51,2	102,8
Apr, 2012	28,7	97,2	100,8
May, 2012	28,5	155,5	89,5

### B. Recordings of Vegetative Traits

In december, 2013, as four years after planting, tree height, and canopy height and canopy diameter in the two directions were measured. Then, the canopy volume (CV) was calculated from canopy height and spread, by using the formula suggested by Westwood (1993):  $CV = \frac{4}{3}\pi ab^2$ , where  $a$  is the major axis length/2, and  $b$  is the minor axis length/2 [6]. In addition, stock and scion trunk diameters were measured 5cm below and above the bud union by digital caliper, and scion/stock ratio was calculated as described by Legua *et al.* (2011) [7].

### C. Recordings of Fruit Yield and Quality

Fruit yield of each tree was annually determined during harvesting in season of 2012 and 2013, when fruits were harvested, counted and weighed at harvest time, from the end of January to early April, and 3 to 10 random fruits per tree were sampled to weight and to measure diameter; then the rind thickness was undertaken with helps of digital caliper, after cutting fruit in haft, for seed number trait, seeds of fruit were counted, total soluble solids (TSS) content of fruit juice was determined with a refractometer (Atago, Japan), using few drops of juice and the fruit flavor and aroma were evaluated using sensorial and visual acceptability as compared to the typical characteristics.

### D. Data Analysis

The data recorded were subjected to ANOVA analyse using MSTAT-C program and mean comparisons were done with least significant difference (LSD) at five percent level of probability.

## III. RESULTS AND DISCUSSION

### A. Vegetative Parameters

There were differences in the vegetative parameters among scions, rootstocks and the scion and rootstock combinations in the fourth year after planting, as data presented in Table 4.

Mean tree height, canopy volume, trunk diameter and ratio of scion and stock of Kaffir lime rootstock were better than that of Carrizo citrange; meanwhile, the tallest tree of 283.83cm value was produced by Sanh orange scion and lager canopy volume of 8.44m<sup>3</sup> value and trunk diameter of 72.45mm were recorded on Da xanh pumelo scion.

TABLE IV  
TREE HEIGHT, CANOPY VOLUME, TRUNK DIAMETER AND SCION AND STOCK RATIO

Scion/ rootstock	Tree height (cm)	Canopy volume (m <sup>3</sup> )	Trunk diameter (mm)	Scion/stock ratio
Seedless Mat orange/Kaffir lime	220.00	8.02 (2.51)	62.63	1.00 (1.00)
Sanh orange/Kaffir lime	285.33	6.20 (2.45)	74.27	0.99 (1.00)
Da xanh pumelo/Kaffir lime	263.33	10.11 (3.07)	74.30	1.00 (1.00)
Duong mandarin/Kaffir lime	143.33	0.53 (0.67)	34.17	1.03 (1.01)
Seedless Mat orange/Carrizo citrange	105.00	0.66 (0.81)	45.03	0.96 (0.98)
Sanh orange/Carrizo citrange	282.33	1.60 (1.26)	57.20	0.94 (0.97)
Da xanh pumelo/Carrizo citrange	206.67	6.76 (2.42)	70.60	1.05 (1.02)
Duong mandarin/Carrizo citrange	166.67	1.94 (1.29)	44.20	1.02 (1.01)
LSD (5%)	24.56	0.82	14.52	0.02
Seedless Mat orange	162.50	4.34 (1.66)	53.83	0.98 (0.99)
Sanh orange	283.83	3.90 (1.86)	65.73	0.97 (0.98)
Da xanh pumelo	235.00	8.44 (2.74)	72.45	1.03 (1.01)
Duong mandarin	155.00	1.24 (0.98)	39.18	1.03 (1.01)
LSD (5%)	22.14	0.71	12.05	0.01
CV (%)	13.30	49.44	26.18	1.71
Kaffir lime	228.00	6.21 (2.17)	60.42	1.00 (1.00)
Carrizo citrange	190.17	2.74 (1.45)	55.18	0.99 (1.00)
LSD (5%)	19.02	0.79	15.81	0.02
CV (%)	4.73	22.65	14.22	1.00

Note: Values in the parentheses were transformed to square root

TABLE V  
QUALITY OF FRUIT FROM SANH ORANGE BUDED ON KAFFIR LIME AND SPECIFIC CHARACTERISTICS OF SANH ORANGE

Traits	Sanh orange/Kaffir lime			Specific characteristics <sup>(*)</sup>
	2012	2013	Mean	
Yield (kg/tree)	4,95±1,91	5,53±0,52	5,24	-
Fruit weight (gr)	300±41	334,6±17,61	317	270
Brix of fruit juice (%)	8±0,41	12,5	10,25	8,3
Seeds	9,33±1,15	15±7	12,17	11,8
Fruit diameter (cm)	8,5±0,63	11,16±0,81	9,83	8,5
Rind thickness (mm)	4,5±0,56	4,45±0,54	4,48	4,48
Fruit juice percentage (%)	41±0,8	41,48±0,47	41,24	37,2
Fruit juice flavor	Mild acid- sweet	Sour-sweet		Sour-sweet
Fruit shape	Sphere	Suppress-sphere		Suppress-sphere
Juice color	Orange-yellow			Orange color

Note: <sup>(\*)</sup> Sources from Southern Horticultural Research Institute, 2009

TABLE VI  
FRUIT YIELDED, FRUIT WEIGHT AND DIAMETER IN 2013

Scion/ rootstock	Fruits/tree	Fruit weight (g)	Fruit diameter (cm)
Seedless Mat orange/Kaffir lime	47.33	200.00	8.10
Sanh orange/Kaffir lime	16.67	334.60	11.16
Da xanh pumelo/Kaffir lime	6.67	1.260.00	15.75
Duong mandarin/Kaffir lime	8.33	123.33	6.47
Seedless Mat orange /Carrizo citrange	5.33	201.67	8.03
Sanh orange /Carrizo citrange	5.33	303.33	9.4
Da xanh pumelo /Carrizo citrange	4.00	1.186.67	14.83
Duong mandarin /Carrizo citrange	6.33	126.67	6.57
LSD (5%)	2.76	20.60	0.60
Seedless Mat orange	26.33	200.83	8.07
Sanh orange	11.00	318.97	10.28
Da xanh pumelo	5.33	1.223.33	15.29
Duong mandarin	7.33	125.00	6.52
CV (%)	11.12	4.62	5.17
LSD (5%)	1.11	17.17	0.41
Kaffir lime	19.75	479.48	10.37
Carrizo citrange	5.25	454.58	9.71
CV (%)	19.8	2.47	4.55
LSD (5%)	4.76	22.16	0.88

As considered to graft trees, results showed that tree height of Sanh orange budded on Kaffir lime was 285.33cm, followed by 263.33cm of Da xanh pumelo budded on Kaffir lime, and these were significantly taller than that from seedless Mat orange budded on Kaffir lime with 220.0cm height and Duong mandarin on Kaffir lime being 143.33cm high. Moreover, the canopy volume of Da xanh pummelo budded on Kaffir lime of 10.11 m<sup>3</sup> was followed by that of seedless Mat orange on Kaffir lime with 8.02 m<sup>3</sup> volume and Sanh orange on Kaffir lime with 6.20 m<sup>3</sup> volume; but no significant difference was found among these combinations; meanwhile, the smallest canopy volume was found on Duong mandarin budded on Kaffir lime with 0.53 m<sup>3</sup> volume.

In addition, data revealed clearly that tree of seedless Mat orange on Kaffir lime produced 105.0 cm tree height were dwarfish; meanwhile, its large canopy volume was not significant different from combinations of Sanh orange and Da xanh pumelo budded on Kaffir lime.

With regarding to trunk growth of budded trees, the results showed that larger trunk diameter of 62.63mm value was obtained from the trees of seedless Mat orange budded on Kaffir lime, and followed by that from Da xanh pumelo budded on Kaffir lime with 74.30mm value and Sanh orange budded on Kaffir lime of 74.27mm trunk diameter; however, the least trunk diameter of 34.17mm value was obtained from trees of Duong mandarin budded on Kaffir lime.

Although, significant difference in scion and stock ratios among combinations of seedless Mat orange 1.00, Sanh orange 0.99, Da xanh pumelo 1.0 and Duong mandarin 1.03 budded on Kaffir lime was not found.

These results having obtained from the tested combinations of scion and Kaffir lime and Carrizo citrange were agreement with findings of Ercan et al. (2013), who found that rootstock affected tree growth and development of orange cultivars of Rhode Red, Valencia, Valencia Late, and mandarin [9]. In addition, Bassal (2009) also reported that Carrizo citrange rootstock did not induced the better growth of Marisol mandarin trees as compared to Sour orange rootstock [5]. On other hand, in Vietnam condition, the earlier research on grafted trees of citrus conducted at Gia Lam, Ha noi, Pham Thi Huong (2006) proved that methods of propagation of the tested rootstocks imparted into the vegetative parameters of Duong canh mandarin scion [8].

### *B. Fruit Yield and Quality*

In the third year after planting of 2012, the most outstanding of experimental combinations was demonstrated primarily that trees of Sanh orange budded on Kaffir lime produced precociously good quality fruits with 300g weight, high total soluble solids of 41.0 brix, 4.5mm rind thickness, better color development, and better flavor and aroma of fruit juice as compared to the specific fruit attributes; as presented in table 5.

Subsequently, in fourth year of 2013, after planting, all combinations of scion and rootstock produced firstly fruits, except trees of Sanh orange budded on Kaffir lime which were the second season of harvesting. And data tabulated in

table 6 clearly showed that trees budded on Kaffir lime were higher number of 19.75 fruits than that on Carrizo citrange with 5.25 fruit number. Similarly, fruit quality consisted of fruit size, total soluble solid, number of seeds and rind thickness was better from budded on Kaffir lime.

These investigation also demonstrated that the highest fruit number harvested was 47.33 fruits per tree from trees of seedless Mat orange budded on Kaffir lime, and followed by 16.67 fruits from trees of Sanh orange budded on Kaffir lime, 8.33 fruits from Duong mandarin, and 6.67 fruits from Da xanh pumelo budded on Kaffir lime.

The fruit weights and diameters, respectively were 1.260g and 15.75cm from trees of Da xanh pumelo, 334.6g and 11.16cm from Sanh orange, 200g and 8.1cm from seedless Mat orange, whereas lowest fruit size of 123.33g and 6.47cm from Duong mandarin budded on Kaffir lime.

In addition, total soluble solid content of fruit juice were 12.5 brix observed from fruits of Sanh orange trees budded on Kaffir lime, and followed by 9.23 brix from Da xanh pumelo budded on Kaffir lime; meanwhile, 8.33 brix of soluble solid content of fruit juice was of fruits from trees of Duong mandarin budded on Kaffir lime; finally, the lowest total soluble solids was 7.33 brix of the fruits from seedless Mat orange budded on Kaffir lime.

Moreover, data obtained in table 4 also showed that the seed number of fruit was 15.0 seeds from Sanh orange budded on Kaffir lime, and 9.0 seeds from Da xanh pumelo budded on Kaffir lime; finally 8.33 seeds per fruit were recorded on Duong mandarin budded on Kaffir lime; however, seedless Mat orange was found as natural mutation genotype under commercial production field, in this investigation fruits from seedless Mat orange grafted on Kaffir lime were occasional 0 to 3 seeds.

With regarding to the fruit rind thickness, that ranged 16.33 mm, 4.45mm, 3.1mm and 1.47 mm were found from Da xanh pumelo, Sanh orange, seedless Mat orange and Duong mandarin budded on Kaffir lime, respectively. Therefore, these significant differences were mostly contributed by specific characteristics of citrus species budded on Kaffir lime.

Meanwhile, the tested combinations budded on Carrizo citrange rootstock produced from 4.0 to 6.33 fruits per tree, and significant difference was found among these combinations. In considering to fruit quality, fruit weight and diameter were 1.186.67g and 14.83cm, respectively, of fruits from trees of Da xanh pumelo on Carrizo citrange, 303.33g and 9.4cm of Sanh orange on Carrizo citrange, 201.67g and 8.03cm of seedless Mat orange on Carrizo citrange, and 126.67g and 6.57cm of Duong mandarin budded on Carrizo citrange.

Similarly, total soluble solid content of fruit juice from combinations on Carrizo citrange ranged from 7.23 to 10.67 of brix; and seed number of fruit also varied from 9.67 to 14.33 seeds per fruit; excepted to trees of seedless Mat orange budded on Carrizo citrange rootstock that maintained the seedless fruit of specific characteristics.

TABLE VII  
TOTAL SOLUBLE SOLIDS (BRIX, %) OF FRUIT JUICE, NUMBER OF SEEDS AND RIND THICKNESS

Scion/ rootstock	Brix (%)	Seed number	Rind thickness (mm)
Seedless Mat orange/Kaffir lime	7.33	0.67 (1.00)	3.10
Sanh orange/Kaffir lime	12.50	15.00 (3.87)	4.45
Da xanh pumelo/Kaffir lime	9.23	9.00 (2.82)	16.33
Duong mandarin/Kaffir lime	8.33	8.33 (2.97)	1.47
Seedless Mat orange /Carrizo citrange	7.23	0 (0.71)	3.50
Sanh orange /Carrizo citrange	10.67	14.33 (3.81)	4.60
Da xanh pumelo /Carrizo citrange	9.00	12.00 (3.41)	18.33
Duong mandarin /Carrizo citrange	7.87	9.67 (3.17)	1.43
LSD (5%)	0.96	0.89	1.01
Seedless Mat orange	7.23	0.33 (0.86)	3.30
Sanh orange	11.58	14.67 (3.84)	4.53
Da xanh pumelo	9.12	10.50 (3.12)	17.33
Duong mandarin	8.1	9.00 (3.07)	1.45
CV (%)	5.72	31.04	8.76
LSD (5%)	0.41	0.67	0.46
Kaffir lime	9.35	8.25 (2.66)	6.34
Carrizo citrange	8.69	9.00 (2.78)	6.97
CV (%)	9.48	21.97	13.39
LSD (5%)	1.65	1.15	1.71

Noted: Values in parentheses were transformed in square-root ( $x+0.5$ )



Fig. 1. Fruits, leaves of Kaffir lime (*Citrus hystrix*)



Fig. 2. (Left to right) Performance, grafted union and fruit of Sanh orange budded on Kaffir lime Vietnam (2013)



Fig. 3. (From left to right) Performance, grafted union and fruit of seedless Mat orange grafted on Kaffir lime, at Mekong Delta, Vietnam (2013)

Likewise, data in table 7 also showed that rind thickness of fruit were range from 1.43mm of Duong mandarin to 18.03mm of Da xanh pumelo. For determining the good compatibility between scion and rootstock, the visual and sensorial evaluations of color, flavor and aroma of fruit juice were also undertaken and presented in table 8, the trees of Sanh orange budded on Kaffir lime produced fruits with better color development, better flavor and aroma of fruit juice. So, the most prominent quality of fruits were from

trees of Sanh orange budded on Kaffir lime and followed by that of seedless Mat orange on Kaffir lime, which produced highest number of harvested fruits with seedy fruit, lower total soluble solids. As compared to the typical fruit quality, Da xanh pumelo budded on Kaffir lime yielded seedy fruits with the loose juice sacs, bitter flavor fruit juice. In addition, fruits from tested other combinations of scions and rootstocks were inferior color, flavor and aroma of fruit juice, differed from the specific characteristics.

TABLE VIII  
FRUIT QUALITY AS COMPARED TO SPECIFIC CHARACTERISTICS

Scion/stock	Compared to specific characteristics of variety
Seedless Mat orange/Kaffir lime	-Seedy fruit, lower total soluble solids
Sanh orange/Kaffir lime	-Larger fruit size, higher total soluble solids, better color development of fruit juice, better flavor and aroma of fruit juice
Da xanh pumelo/Kaffir lime	-Thinner fruit rind, seedy fruit, lower brix value, looser juice sacs, bitter fruit juice and loosen juice sacs
Duong mandarin/Kaffir lime	-Lower total soluble solids
Seedless Mat orange/Carrizo	-Lower total soluble solids
Sanh orange/Carrizo	-Larger fruit size, higher total soluble solids, thicker fruit rind, higher number of seeds
Da xanh pumelo/Carrizo	-Smaller fruit size, larger rind thickness, lower total soluble solids, higher number of seeds, loosen juice sacs, bitter flavor of fruit juice
Duong mandarin/Carrizo	- Lower total soluble solids

The results of the current investigation agreed with earlier reports of Tazima et al. (2013) on affecting of rootstock on yield, who found that Okitsu Satsuma grafted on Swingle citrumelo gave heavier yield of fruit as compared to that on Rangpur lime and Volkamer [10]. Likewise, Pham Thi Huong (2006) found that growth and yield of Duong Canh mandarin was affected by rootstock [8].

On the other hand, those were also in lines with the findings mentioned by Ercan et al. (2013), those investigations were growth and development of the grafted trees, fruit yield, fruit weight and total soluble solid of orange cv. Rhode Red Valencia and Valencia Late mandarin depended on the different rootstock used for grafting [9].

Likewise, Benjamin et al. (2013) proved that rootstocks affected sensory quality, total soluble solids and aroma volatiles compositions of 'Or' and 'Odem' mandarins; especially, fruit flavor depended on specific rootstock/ scion interactions [1].

So, the results primarily demonstrated that Kaffir lime rootstock was a superior to Carrizo citrange, better for current commercial variety scions of Da xanh pumelo, Sanh orange, seedless Mat orange, Duong mandarin. Out of the experimental combinations of Kaffir lime rootstock, it was found that Sanh orange budded on Kaffir lime was elite combination when based on starting to produce fruits after planting, vegetative traits of tree height, canopy volume, trunk diameter, scion and stock ratio; on number of harvested fruits; and on the fruit quality of larger fruit size, higher total soluble solids, better color development of fruit juice, excellent flavor and aroma in comparison to the typical variety characteristics.

#### IV. CONCLUSIONS

Therefore, it could be safely concluded that in 3<sup>rd</sup> and 4<sup>th</sup> year after planting under field trial, the trees of Sanh orange (*C. nobilis* Lour.) budded on Kaffir lime (*Citrus hystrix*) were outstanding of the tested combinations, based on precocity, on producing high number of fruits (16.67 fruits per tree) with good fruit quality of larger fruit size (334.6 g and 11.16 cm, fruit weight and diameter, respectively), higher total soluble solids (12.5 brix), better orange-yellow juice color development, and excellent flavor and aroma of juice, as compared to the typical characteristics; and this was followed by trees of seedless Mat orange budded on Kaffir lime, that produced the highest number of fruits (47.33 fruits per tree) with little inferior fruit quality of seedy fruit (1-3 seeds per fruit), lower total soluble solids (7.33 brix), and no good flavor and aroma, as somewhat differed from the typical fruit traits.

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