

Early Performance of Duong Mandarin (*Citrus reticulata* Blanco) on Three Rootstock under Acid Sulfate Soil Fields at Mekong Delta of Vietnam

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Abstract— About 1.6 billion hectare area of acid sulfate soils is at Mekong Delta of Vietnam, and Duong mandarin fruits are valued for the fresh market due to the easy peeling, attractive flavor, and health and nutritional properties; thereby, the investigation on early performance of Duong mandarin on three rootstock under acid sulfate soil fields (pH below 4) at Mekong Delta of Vietnam was undertaken from 2009 to 2012 for determination of the most promising scion stock combination of Duong mandarin, which introduced to growers for expanding citrus production to increase in income of farmers, and helping to use the sustainable and efficient land resource at acid sulfate soil region of Mekong Delta. Primary results showed that Duong mandarin grafted on Mat orange, Tau lemon and Carrizo citrange were significant difference in vegetative parameters, fruit yield and quality. It proved that Duong mandarin trees grafted on Tau lemon were better growth and development on acid sulfate soil fields with below 4 pH in soil and water suspension of 1:2.5 ratio) as compared to those grafted on Mat orange and Carrizo citrange rootstocks; whereby, that induced trees with 171.48 cm height, 6.65 m³ canopy volume and 51.84 mm trunk diameter, 1.08 scion/ stock ratio in third year after growing. Moreover, Duong mandarin trees grafted on Tau lemon were with spreading growth performance. In regarding to fruit yield and quality, Duong mandarin trees grafted on Tau lemon produced highest fruit yield of 9.21 kg per tree per year in third year after planting, and fruit with 115.30g weight, 8.85 brix juice, thinner and somewhat easy peel rind.

Keywords—Acid sulfate soil; Duong mandarin; grafting; Mekong Delta of Vietnam

I. INTRODUCTION

At the Mekong Delta region of Vietnam, acid sulfate soil area covers about 1.6 million hectares. When pH soil drops below 5, the main problems of these soils in crop production are changings in physico-chemical soil properties, that influence directly and/ or indirectly the plant growth and development with nutrient deficiency of several essential micro- and macro nutrients including phosphorous, calcium, magnesium and potassium and toxicity of Al³⁺, Fe²⁺, Mn²⁺ and H⁺ ions dissolving predominantly in the soil solution about the plant root zone; therefore, less growth and development of the root system of sensitive to acid soil plants results in reduction of the absorption capacity of water and nutrients to match for the plant growth and development [1]-[4].

At the Mekong Delta, the acid sulfate soil with 3.4 pH limited the growth and development of vegetable maize [5].

Moreover, in industrial fruit production, rootstock have been used for the tolerance and/or resistance to pest, disease and the adverse environmental conditions, and for improvement of the growth and development, yield and fruit

quality [6] From [7] and [8], they had found that Mat orange (*C. senensis* L. Osbeck), Tau lemon (*C. limonia*), Long co pumelo (*Citrus grandis* Osbeck) and Carrizo citrange (*C. sinensis* x *P. trifoliata*) were better tolerant to acid sulfate soils with 3.4 and 3.17 pH (in soil and water suspension with 1 and 2.5 ratio) at Mekong Delta of Vietnam. These selections were based on the primary selections of local citrus genotypes under natural open fields combined with screening for aluminum tolerance in hydroponic, and selecting for acid sulphate soils under trial field conditions [9], [6].

Meanwhile, Duong mandarin fruits have been valuable for the fresh market in Southern Vietnam, because the specific characteristics of these fruits are with the easy peeling, attractive flavor, and health and nutritional properties.

Keeping the above facts into consideration, the meanwhile investigation of early performance of Duong mandarin on three rootstocks under acid sulfate soil fields at Mekong Delta of Vietnam was undertaken from 2009 to 2012 for determination of the most promising scion stock combination of Duong mandarin, which introduced to

growers for expanding citrus production area to increase in income of farmers, and for helping to use the sustainable and efficient land resource on acid sulfate soils at Mekong Delta of Vietnam.

II. MATERIALS AND METHODS

This investigation was conducted into two experimental sites on acid sulfate soil region, which is belong to Dong Thap Muoi area of Mekong Delta in Vietnam. Soil characters were pH of 2.92 and 3.06, organic content of 3.9 and 6.41%, aluminum exchange of 9.38 meq/100g (844.2 ppm) and 11,5meq/100g (1.035ppm) as followed:

TABLE I
SOIL CHARACTERISTICS OF TWO TRIAL SITES

Characters	Site of experiment 1	Site of experiment 2
pH (soil:water=1:2,5)	2,92	3,06
pH (KCl)	2,69	2,81
EC (mS/cm)	1,67	0,74
OC (%)	3,9	6,41
Al ³⁺ (meq/100 g)	11,5	9,38
N(%)	0,18	0,17
P ₂ O ₅ (mg/kg)	14,1	1,46
K ₂ O(meq/100 g)	0,05	0,09
Ca (ex.) (meq/100 g)	0,11	0,06
Mg (ex.) (meq/100 g)	0,85	0,18

The first experiment was laid out at Long An province from 2009 to 2011 because flooding disaster in late 2011 caused the grafted trees of first experiment to die, and second experiment that was carried out at Tien Giang province in the duration of 2009-2012.

Three rootstocks of Mat orange (*C. senensis* L. Osbeck), Tau lemon (*C. limonia*) and Carrizo citrange (*Citrus sinensis* × *Poncirus trifoliata* (L.) Raf.) selected as promising genotypes for aluminum toxic and acid sulfate soil tolerance at Southern Horticultural Research Institute (SOFRI) Vietnam were propagated by rooted cuttings and grafted on with Duong mandarin (*Citrus reticulata* Blanco) scion, following the chip bud method.

The experiments were established in early March 2009, with 3 meter and 5 meter spaces between trees and rows, the soil adment completely randomized block designs with three treatments consisted of Duong mandarin grafted on Mat orange, Tau lemon and Carrizo citrange, seven replications, and using one grafted tree per plot. 500g lime for tree was applied with broadcasting method before planting, uniform applications of fertilizers, water, pesticides and weed control was undertaken, and tree pruning and fruit thinning were not performed.

Evaluations of plant growth were carried out in December 2011 and December 2012, and tree height was determined by measuring the distance from the ground to the tree top. Tree canopy was orthogonally measured with measuring tape and then canopy volume (m³) was determined followed the equation: $CV = \frac{4}{3} \pi ab^2$; where: The major axis = length/2 (a) and the minor axis = length/2 (b) [10].

The scion and stock diameters were measured at 5 cm above and below grafted union line with digital caliper and

expressed in mm. The scion and stock ratio was calculated using the equation of scion/ stock ratio = scion diameter / stock diameter.

Annual fruit yield was quantified by fruit weight. At each harvesting, all fruits harvested were weighed with digital balance during the period of 2011-2012. Ten fruits from each grafted tree were sampled to carry out the analysis. These were weighed with digital scale and mean fruit weight was determined by the equation of ten fruit mass (g) divided by ten and expressed in gram (g).

For determination of rind fruit thickness, fruits was cut into half and rind thickness was measured with digital caliper and expressed in millimeters (mm). Total soluble solid content of fruit juice was determined with ATAGO digital refractometer (Brix meter). A drop of juice squeezed from the pulp vesicles of fruit was placed on the prism of the refractometer and percent total soluble solid was observed from reading and readings were expressed as °brix.

Meanwhile, external fruit color, color and flavor of fruit juice were evaluated with visual and sensorial methods as compared to specific characteristics of Duong mandarin fruits.

Recorded data were analysed of variance (ANOVA) using MSTAT-C software and mean comparisons were undertaken with least significant difference (LSD) at five percent level of probability.

III. RESULTS AND DISCUSSION

A. Vegetative parameters in 2011

Data presented in table 2, it showed that in first experiment the graft tree of Duong mandarin on Tau lemon produced 148.60cm tree height, 1.58m³ canopy volume, 30.41mm trunk diameter and 0.77 scion/stock ratio, and tree of Duong mandarin grafted on Mat orange was with 130.3cm, 1.22cm³, 25.16mm, 0.73, respectively. These were not significant different. Meanwhile, tree grafted on Carrizo citrange was least growth with height 94.29cm, tree canopy volume 0.18cm³, trunk diameter 13.74mm and scion stock ratio 0.64.

In second experiment, tree of Duong mandarin grafted on Tau lemon were with 153.4cm height, 3.89m³ tree canopy volume, 32.6mm trunk diameter and 0.81 ratio; these were significantly different from that of Duong mandarin grafted on Mat orange (114.4 cm, 1.29m³, 21.55 mm and 0.72) and on Carrizo citrange (101.6cm, 0.54m³, 17.94mm and 0.60) (figure 1).

In regarding to scion and stock ratio, scion/ stock ration 0.72 found from trees of Duong mandarin grafted on Tau lemon rootstock was not significant different from 0.81 from grafted on Mat orange rootstock; in contrast, these values were closer to 1.0, and larger than that on Carrizo citrange rootstock. The relationship between trunk diameter above and below the graft union reflectes the degree of compatibility between scion and rootstock; so, Mat orange and Tau lemon were considered as better rootstocks for Duong mandarin.

In consideration to means of two experiments, Duong mandarin grafted on Tau lemon induced 150.9 cm tree height, 2.73 m³ canopy volume and 31.51mm trunk diameter; these were significantly higher than that from Duong

mandarin on Mat orange of and Duong mandarin on Carrizo citrange roostock.

TABLE II
TREE HEIGHT, CANOPY VOLUME, TRUNK DIAMETER AND SCION/STOCK RATIO OF DUONG MANDARIN TREES ON ACID SULFATE SOILS AT MEKONG DELTA OF VIETNAM IN 2011 AND 2012

Tree/ rootstock	2011			2012
	Experi- ment 1	Experi- ment 2	Mean	Experi- ment 2
<i>Tree Height</i>				
Duong mandarin/ Mat orange	130.3	114.4	122.4	132.61
Duong mandarin/ Tau lemon	148.6	153.4	150.9	171.48
Duong mandarin/ Carrizo citrange	94.29	101.6	97.83	110.61
CV (%)	15.59	16.42	11.49	16.72
LSD (5%)	22.59	23.54	16.56	26.92
<i>Canopy Volume</i>				
Duong mandarin/ Mat orange	1.22 (1.10)	1.29 (1.14)	1.25 (1.12)	2.02 (1.42)
Duong mandarin/ Tau lemon	1.58 (1.26)	3.89 (1.97)	2.73 (1.65)	6.65 (2.58)
Duong mandarin/ Carrizo citrange	0.18 (0.42)	0.54 (0.73)	0.36 (0.60)	0.73 (0.85)
CV (%)	18.66	23.79	15.68	23.89
LSD (5%)	0.20	0.34	0.27	0.43
<i>Trunk diameter</i>				
Duong mandarin/ Mat orange	25.16	21.55	23.36	31.78
Duong mandarin/ Tau lemon	30.41	32.60	31.51	51.84
Duong mandarin/ Carrizo citrange	13.74	17.94	15.84	25.64
CV (%)	18.37	14.44	9.79	8.57
LSD (5%)	4.94	4.04	2.69	3.64
<i>Scion/Stock ratio</i>				
Duong mandarin/ Mat orange	0.73 (0.85)	0.81 (0.90)	0.77 (0.88)	0.85 (0.92)
Duong mandarin/ Tau lemon	0.77 (0.88)	0.72 (0.85)	0.74 (0.86)	1.08 (1.04)
Duong mandarin/ Carrizo citrange	0.64 (0.80)	0.60 (0.77)	0.62 (0.79)	0.85 (0.92)
CV (%)	3.81	11.86	5.58	6.39
LSD (5%)	0.04	0.12	0.05	0.06

Note: Values in parentheses were transformed to square root ($x+0.5$)

B. Vegetative parameters in 2012

Flooding disaster happened in late 2011 caused the grafted trees of first experiment to die; so, data of second experiment in the third year of 2012 were recorded continually and presented in table 2. Those proved trees of Duong mandarin grafted on Tau lemon were better vegetative growth with tree height of 171.48cm, canopy volume of 6.65m³, trunk diameter of 51.84mm and scion/stock ratio of 1.08 than grafted on Mat orange and Carrizo citrange with 132.61cm, 2.02m³, 31.78mm, 0.85 and 110.61cm, 0.73m³, 25.64mm and 0.85 in growth



Fig 1. Growth from tree of Duong mandarin grafted on Tau lemon in second after growing (2011)

parameters, respectively as in figure 2.



Fig 2. Growth and graft union from tree of Duong mandarin grafted on Tau lemon in third year after growing (2012)

C. Fruit yield and quality in 2011

Data in table 3 showed clearly that fruit yield from tree of Duong mandarin grafted on Tau lemon was 5.04kg; and these fruits were with 125.65g weight, 63.50mm diameter and that were not significant different from grafted on Mat orange of 2.33kg fruit yield, 152.24g fruit weight and 63.27mm diameter.

Fruit rind thickness from grafted on Mat orange was 2.21mm, higher than on Carrizo citrange with 1.4mm, but not on Tau lemon with 1.82mm thickness.

Total soluble solid of fruit juice and seed number of fruit was 9.68 percent and 7.81 seeds, respectively; from Sweet mandarin grafted on Mat orange, 8.91 percent and 9.42 seeds on Tau lemon and 9.01 percent and 8.6 seeds from Carrizo citrange; although no significant difference was found in this characteristics form different grafted combinations.

In regarding to color and taste of fruit juice, the evaluation proved in table 3 demonstrated that fruits from trees grafted on Mat orange were better quality with orange to deep orange color and light sour to sweet taste of fruit juice; whereas, orange color and sour to sweet taste of fruit juice was of fruit from grafted on Tau lemon. Fruit quality with light orange to orange color was evaluated on fruits from trees grafted on Carrizo.

D. Fruit yield and quality in 2012

Fruit yield was recorded as 9.21kg per tree from Duong mandarin grafted on Tau lemon, and higher than that on Mat orange with 6.6kg and Carrizo citrange with 3.01kg, as in table 3. Although, fruit weight from grafted on Tau lemon was 105.0g, lower than that on Mat orange (122.86g).

Diameter of fruit from grafted on Mat orange was 60.15mm, no significant different from that on Tau lemon (59.90 mm). Similarly, difference of fruit rind thickness was not found from fruits of trees grafted on Mat orange (1.81mm) and Tau lemon (1.70 mm). Thinnest fruit rind of 1.35mm was recorded on fruits from trees grafted on Carrizo citrange rootstock.

Total soluble solids of fruit juice from trees grafted on Mat orange was 10.29 percent, higher than that on Tau lemon with 8.79 percent.

Total seed number of fruit from trees grafted on Mat orange was 7.43 seeds; whereas 8.0 seeds per fruit was observed from trees grafted on Carrizo citrange rootstock, and Duong mandarin grafted on Tau lemon produced fruit with 9.0 seeds; however, these significant differences were not found (table 3).

TABLE III
ANNUAL PRODUCTION, FRUIT QUALITY OF OF DUONG MANDARIN TREES
GRAFTED ON THREE ROOTSTOCKS GROWN ON ACID SULFATE SOILS AT
MEKONG DELTA OF VIETNAM FOR THE PERIOD 2011- 2012

Tree/ rootstock	Yield (kg/cây)			Fruit weight (g)		
	2011	2012	Sum	2011	2012	Mean
Duong mandarin/ Mat orange	2.33 (1.53)	6.60	8.93	152.24	122.86	137.50
Duong mandarin/ Tau lemon	5.04 (2.24)	9.21	14.25	125.65	105.00	115.30
Duong mandarin/ Carrizo citrange	0.80 (0.89)	3.01	3.81	88.12	121.43	104.80
CV (%)	51.88	31.26	37.77	32.22	5.19	18.68
LSD (5%)	0.97	2.29	3.96	45.78	7.04	25.93
	Fruit diameter (mm)			Rind thickness (mm)		
	2011	2012	Mean	2011	2012	Mean
Duong mandarin/ Mat orange	63.27	60.15	61.71	2.21	1.81	2.01
Duong mandarin/ Tau lemon	63.50	59.90	61.70	1.82	1.70	1.76
Duong mandarin/ Carrizo citrange	57.43	63.92	60.67	1.40	1.35	1.37
CV (%)	8.67	3.72	5.53	31.67	15.80	22.62
LSD (5%)	6.20	2.66	3.95	0.67	0.30	0.45
	Brix			Seed number		
	2011	2012	Mean	2011	2012	Mean
Duong mandarin/ Mat orange	9.68	10.29	9.98	7.81	7.43	7.63
Duong mandarin/ Tau lemon	8.91	8.79	8.85	9.42	9.00	9.21
Duong mandarin/ Carrizo citrange	9.01	9.57	9.29	8.60	8.00	8.30
CV (%)	10.02	9.38	9.23	37.60	35.42	35.83
LSD (5%)	1.07	1.04	1.00	3.77	3.36	3.50

Cumulative fruit yields of two harvested season in 2011 and 2012 was 14.25kg per tree grafted on Tau lemon as presented in table 3, this was higher than that from grafted on Mat orange with 8.93 kg. However, meaned fruit weight of 137.50g, and fruit diameter of 61.71mm were from trees grafted on Mat orange, and these were not significant different from that grafted on Tau lemon (115.30g and 61.7mm), and Carrizo citrange (104.80g and 60.67mm).

TABLE IV
COLOR, TASTE OF FRUIT JUICE OF DUONG MANDARIN TREES GRAFTED ON
THREE ROOTSTOCKS GROWN ON ACID SULFATE SOILS AT MEKONG DELTA
OF VIETNAM FOR THE PERIOD 2011- 2012

Tree/ rootstock	2011		2012	
	Color	Taste	Color	Taste
Duong mandarin/ Mat orange	Orange to deep orange	Light sour to sweet	Orange to deep orange	Light weat to sweet
Duong mandarin/ Tau lemon	Orange	Sour-to-sweet	Light orange	Sour-to-sweet
Duong mandarin/ Carrizo citrange	Light orange to orange	Sour	Light orange	Sour sweet

Fruit rind thickness of 2.01mm and was from grafted on Mat orange, not significant different from 1.76mm from grafted on Tau lemon; although, it was higher than 1.37mm fruit rind thickness from grafted on Carrizo citrange.

Total soluble solids of 9.98 percent in fruit juice was from grafted on Mat orange, higher than 8.85 percent of fruits from grafted on Tau lemon. In contrast, significant difference in seed number of fruit was not found in fruits from different graft trees.

Mean of seed content was 7.63 seeds from fruits of Duong mandarin grafted on Mat orange; while 9.21 seeds and 8.30 seeds were obtained from fruits of trees grafted on Tau lemon and Carrizo rootstock; although, statistical significant difference was not detected (table 3).

With sensorial evaluation of juice color and taste of fruits, as shown in table 4, fruits from trees of Duong mandarin grafted on Mat orange were with orange to deep orange color and light sweet to sweet taste; while light orange color and sour to sweet taste of fruit juice were of Duong mandarin fruits from grafted on Tau lemon as in figure 3. Duong mandarin grafted on Carrizo rootstock produce fruits with fruit juice of light color and sour sweet taste.

In visual evaluation of tree growth behavior (table 4), trees of Duong mandarin grafted on Tau lemon produced spreading growth behavior, precocity, fruits with sphere shape, yellow-green color of external fruit, tight peel rind, and those fruits were with somewhat smaller size, lower brix of fruit juice, more seed as compared to specific characteristics.



Fig 3. Fruits from tree of Duong mandarin grafted on Tau lemon

E. Discussion

Different rootstocks of Mat orange, Tau lemon and Carrizo effected on tree growth and development, fruiting and fruit quality of Duong mandarin scion; in other words, larger tree size consisted of tree height, canopy volume, trunk diameter, and higher yield reflected the adaptability to the acid sulfate soils and compatibility between scion and stock. Under acid sulfate soils, the strong root systems and scion and stock compatibility helps to absorb and translocate more water and nutrients for better growth and development of grafted trees.

TABLE V
SPECIFIC CHARACTERISTICS FROM DUONG MANDARIN, AND DUONG
MANDARIN TREE GRAFTED ON TAU LEMON ROOTSTOCK GROWN ON ACID
SULFATE SOILS AT MEKONG DELTA OF VIETNAM
FOR THE PERIOD 2011- 2012

Characteristics	Specific characteristics ^(*)	Tree grafted on Tau lemon
Tree growth behaviour	Somewhat spreading	Spreading
Fruit shape	Sphere shape	Sphere shape
Fruit rind, mm	Yellow-green, easily peeling	Yellow-green, tight peel
Fruit weight, g	123 g	115.30 (105.0g-125.65 g)
Độ brix, %	9.5-10.5	8.85
Seed number of fruit	8-10	9.21
Starting to yield fruits	2-2.5 years after planting	8 month after planting

Note: ^(*) Source from Southern horticultural Research Institute (SOFR) Vietnam, 2009

Regarding tree growth in 2011, larger tree size with means of both experiment sites presented as 150.9 cm tree height, 2.73 m³ canopy volume and 31.51mm trunk diameter was recorded on trees of Duong mandarin grafted on Tau lemon. Similarly, in 2012, trees grafted on Tau lemon depicted the superior growth with height 171.48cm, canopy volume 6.65m³, trunk diameter 51.84mm and scion/stock ratio 1.08. Highest cumulative yield 14.25kg, and fruits with mean weight 115.30g and diameter 61.7mm, rind thickness 1.76mm, total soluble solids 8.85 percent, seed content 9.21 were from trees grafted on Tau lemon; although fruit juice color and taste was somewhat inferior as compared to fruits from trees grafted on Mat orange.

These findings were in lines with previous reports of [11], who found that rootstocks of Carrizo citrange and Cleopatra mandarin affected fruit yield and quality of Clemenules mandarin scion under saline conditions.

On the other hand, these results also agreed with [12], they studied on performance of 'Oneco' mandarin on six rootstocks in South Brazil, they reported that vegetative development, fruit yield and quality, bearing behavior of Oneco mandarin were affected by different rootstocks.

Similarly, from [13] it had been demonstrated that rootstock affected on tree size, yield, fruit quality consisted of fruit size and weight, rind thickness, brix of Nova mandarin and he found that Palestine sweet lime rootstock induced largest tree and highest yield among eleven rootstocks.

Moreover, yield and seed content of Nova and Robinson mandarins were affected by the rootstock. For Robinson mandarins, the fruit weight and size were not affected by the rootstock, whereas the fruit color was found to be affected by the rootstocks [14].

From [15], it was reported that Robinson mandarin produced the greatest yield when grafted on sour orange rootstock and trees of Clausellina mandarin budded on four rootstocks produced differences in terms of fruit yield and quality [9].

IV. CONCLUSIONS

This primary study demonstrated that difference rootstocks of Mat orange, Tau lemon and Carrizo citrange effected on Duong mandarin scion in vegetative parameters, fruit yield and quality under acid sulfate soil trial fields.

It proved that trees of Duong mandarin grafted on Tau lemon were outstanding of vegetative parameters as compared to grafted on Mat orange and Carrizo citrange rootstocks; whereby, that induced tree with 171.48 cm height, 6.65 m³ canopy volume, 51.84 mm trunk diameter and 1.08 scion/stock ratio. Moreover, trees of Duong mandarin grafted on Tau lemon were visually evaluated as spreading growth habit.

In regarding to fruit yield and quality, Duong mandarin tree grafted on Tau lemon produced highest yield of 9.21kg in third year after planting, and fruit with 115.30g weight, 8.85 percent of total soluble solids (brix) in fruit juice, thin rind 1.76mm, and somewhat easy peel rind.

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