

CITRUS ROOTSTOCKS ADAPTATION AT DIFFERENT ENVIRONMENTS OF ESPÍRITO SANTO STATE, BRAZIL

FLAVIO DE LIMA ALVES¹; ALMIR PINTO DA CUNHA SOBRINHO²; JORGINO POMPEU JÚNIOR³; AURELIANO NOGUEIRA DA COSTA¹; NILTON DESSAUNE FILHO¹

Abstract: The citrus crop has been developed at little orchards of Espírito Santo State Center-South and highland regions, with predominance of sweet oranges: 'Bahia' navel, 'Seleta', 'Lima', and 'Natal' *Citrus sinensis*; 'Ponkan' *C. reticulata* and Willowleaf, 'Mexerica' *C. deliciosa* mandarins; and Mexican lime, 'Galego' *C. aurantifolia*. Since 1980's, the clone Folha Murcha was introduced in the South of Espírito Santo, while the 'Pera' sweet orange, in extensive areas at North of Espírito Santo. The majority of orchards were formed from the poor quality seedlings produced by nurserymen. This situation was responsible for the reduction of the yield and longevity of citrus plants. At the same time, other better varieties of citrus were introduced for increasing production and sustainability of orchards. A group of new rootstocks was introduced in order to diversify scion combinations and to avoid the exclusive use of 'Rangpur' lime *C. limonia* improving fruit quality, yield and longevity of orchards. In the experiment I, located at Santa Maria of Jetiba, the rootstock 'Florida Rough' lemon stimulated high average yield (18.1t/ha); the 'Natal' IPEAL 1 produced 18.6t/ha and 'Valencia' IPEAL 27, 17.6t/ha. In the experiment II, Viana, the rootstock 'Mazoe Rough' lemon stimulated the average yield of 15.9 t/ha; the 'Valencia' IPEAL 27 produced 16.8t/ha, while the 'Natal' IPEAL 1 produced 14.9 t/ha. In the experiment III, at Linhares - ES, the rootstock 'Orlando' tangelo stimulated yield of 28.4 t/ha, being the clone 'Pera' IAC the higher with 29.4 t/ha, and Bianch, 27.3 t/ha. In general, the fruits presented a good commercial quality with preferential size, juice yield almost 50% and total soluble solids at more 11°Brix, at three State regions. In the highland region, the fruits of 'Natal' IPEAL1 and 'Valencia' IPEAL 27 presented low acids. In the highland region, the survival of plants during twenty years, is an indicative that the germplasm introductions are of superior quality.

Index terms: Citrus, Germplasm, Scion, Rootstock

INTRODUCTION

The citrus industry of the Espírito Santo State is represented for more than eight thousand grows in an area superior to 4,597 ha. It produces more than US\$2 millions in production value and in the agribusiness chain gives almost US\$8,5 millions. It takes almost 5,000 direct and indirect jobs, besides this crop contributes around US\$750 thousand of tributes (EMCAPER, 2000). At the Northern region of the Espírito Santo there is 50% of state production area with sweet oranges *Citrus sinensis* and 'Tahiti' acid lime *C. latifolia*. In the highland regions there is 45% of mandarin crops 'Ponkan' *C. reticulata*. The 'Pera' variety represents beyond 40% of orange crops, with almost 540,000 plants. The 'Natal' sweet orange

is second place, with 240,000 plants, being 110.000 of Folha Murcha clone, predominantly at South region of the Espírito Santo. The 'Ponkan' represents more than 70% of the mandarin grows and the 'Tahiti' lime 93% of the lime orchards. Approximately (74%) of the 52 citrus nurserymen are not registered. There is no control about the propagative material; however there is a seedling annual demand of 25 thousand oranges; 16 thousand mandarin; and 5 thousand acid limes. Regarding the rootstocks used there is predominance of 'Cravo' lemon or Rangpur lime *C. limonia*. The mean yield of crops is low (sweet orange 10 t/ha; mandarin 6.5 t/ha and acid limes 6 t/ha). The crop mean area is less 0.5 ha at highland region superior 1.5 ha at North; and around 1 ha at State Center-South and South regions. The orchards are

¹ Incaper - Rua Afonso Sarlo, 160 - CEP 29052-010, Vitória, (ES) Brazil.

² Embrapa Mandioca e Fruticultura - C.P. 007 - CEP 44380-000, Cruz das Almas, (BA) Brazil.

³ CCSM/IAC - Rod. Anhangüera, km 158 - C. P. 04, CEP 13490-970, Cordeirópolis, (SP) Brazil.

very dense, which held about 400 plant/ha. The life of the citrus orchard is between 8 to 12 years, at warm areas and between 10 to 15 years at highlands of the Espírito Santo. The low yield and longevity of the plants are associated with the utilization of non-certified material. Although there is no study on the behavior of the citrus tree under this environmental condition, the fruit quality is good. So, due to the potentiality of the highland regions for high quality orange fruits, either for internal market or exporting, new studies on scions and rootstocks should be made with the objective to diversify the orchards searching the sustainability of citrus industry in these regions.

MATERIAL AND METHODS

Since 1979 several citrus trials were held in the Espírito Santo State, Brazil, under partnership with EMBRAPA/CNPMPF – Cruz das Almas, BA, and CCSM/IAC – Cordeirópolis, SP, which supported technical assistance and genetic material. Data from three trials in Santa Maria of Jetibá, highland region, 750m altitude, Cfb climate and LVd₃ soil; Viana, Center-South region, with 20m altitude, AW climate and LVd₂ soil; and Linhares, North region, 65m altitude, AW climate and PVLd₁ soil (Table 1) are presented. In the two first experiments, established in 1981, two clones of sweet oranges: ‘Valencia’ IPEAL 27 and ‘Natal’ IPEAL 1 on the following rootstocks: ‘Rangpur’ lime *C. limonia*, Rough lemons ‘Florida’ and ‘Mazoe’ *C. jambhiri*, Volkamer lemon *C. volkameriana* and ‘Sunki’ mandarin *C. sunki* were

evaluated at 7 x 6m spacing, in factorial (2 x 5) randomized blocks design, with three replications. In the third one, established in 1991, two clones of sweet oranges, ‘Pera’ IAC and Bianch on the following rootstocks: Rangpur lime, Rough lemons ‘Florida’ and ‘Mazoe’, Volkamer lemon; ‘Cleopatra’ mandarin *C. reshni* and ‘Sunki’ mandarin; ‘Orlando’ tangelo (*C. paradise* x *C. reticulata*) and ‘Caipira’ sweet orange *C. sinensis* were evaluated, at 5 x 5m spacing, in a factorial (2 x 8) randomized blocks, with three replications. The phenologic data were taken each two years. The yield (t/ha), fruit weight (g), juice content (%), total soluble solids (° Brix), citric acid (%) and the total soluble solids/total acidity ratio were held every year according to Coelho & Cunha (1982). The data were analyzed statistically and applied dimcan’s multiple range (P = 0.05).

RESULTS AND DISCUSSION

Experiment 1 – Location: Alto Possmousser, Santa Maria de Jetibá, ES
The ‘Florida’ Rough lemon rootstock stimulated the highest average yield to all scions tested (Table 2). The difference was superior to 4.3 t/ha as compared to the Rangpur lime (standard), but no statistical difference among both was observed. In regard the Volkamer lemon the difference was 8.8 t/ha. The Rangpur lime, ‘Sunki’ mandarin and ‘Mazoe’ Rough lemon rootstocks were not statistically different among them. The ‘Valencia’ orange yield average was higher than ‘Natal’. The Florida ‘Rough

Table 1 – Soil and climatic characteristics of citrus experimentes locations.

Characteristics	Location		
	Santa Maria de Jetibá	Viana	Linhares
Latitude (S.)	20°01'	20°25'	19° 06' – 19° 18'
Longitude (W.)	40°01'	40°32'	39° 45' – 40° 19'
Coast distance (km)	56.5	20.0	33.0
Altitude (m)	600-850	0-200	28 - 65
Experiment altititude (m)	750.0	15.0	65.0
Soil	LVd ₃	LVd ₂	PVLd ₁
Relief	Very waved	Very waved	Easy waved until plain
Climate	Cfb	Aw	Aw
Moist period (month)	Oct/Nov/Dec/Jan/Feb/Mar/Apr.	Oct/Nov/Dec/Jan	Nov/Dec.
Annual hidric excess (mm)	267-263	87-378	11-91
Dry period (month)	August	August	Aug/Sep.
Annual hidrie deficit (mm)	89-339	157-284	255-425
Annual termic value on 10°C (day degree)	3750-3190	5050-4780	5080-4570
Mean temperature of higher temperature at heater month (° C)	29.6-27.8	32.0-30.0	34.0-32.0
Mean temperature of lower temperature at cooler month (° C)	9.4-10.9	15.5-18.0	13.3-15.5
Cold periods (month)	3.5-4.5 Apr./Aug.	0	0

Sources: Agricultural climate map of Espírito Santo State (FEITOZA, L.R., 1986)
Survey of soil classification of Espírito Santo State (BRASIL, 1979)

Table 2 – Fruit yield (t/ha) of 'Valencia', 'Natal' and 'Pera' sweet oranges, on different citrus rootstocks tested in Espírito Santo State at three producing regions.

Rootstock	Location								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
Rangpur Lime	16.6	11.2	13.9	15.4	12.3	13.8	23.3	21.7	22.5
Cleopatra' mandarin	-	-	-	-	-	-	19.6	18.3	18.9
Sunki' mandarin	16.1	11.4	13.7	16.0	12.3	14.1	19.4	18.2	18.8
Florida' Rough lemon	17.6	18.6	18.1	16.7	12.8	14.7	24.8	18.9	21.8
Mazoe' Rough lemon	15.6	12.2	13.9	16.8	15.0	15.9	24.8	21.6	23.2
Yolkamer lemon	8.8	10.0	9.24	14.4	11.2	12.8	24.3	22.2	23.2
Orlando' tangelo	-	-	-	-	-	-	29.4	27.3	28.4
Caipira' sweet orange	-	-	-	-	-	-	17.3	23.4	20.3
MEAN	14.9	12.7	13.8	15.7	12.7	14.2	22.86	21.45	22.16

1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF – BA)

2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF – BA)

3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Table 3 – Fruit weight (g) of 'Valencia', 'Natal' and 'Pera' sweet oranges, on different citrus rootstocks tested in Espírito Santo State at three producing regions.

Rootstock	Location								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
Rangpur' Lime	157.0	127.0	142.0	179.7	158.7	169.2	205.0	192.6	198.8
Cleopatra' mandarin	-	-	-	-	-	-	195.2	181.5	188.3
Sunki' mandarin	153.9	128.4	141.1	163.5	159.0	161.2	186.3	178.7	182.5
Florida' Rough lemon	163.1	126.5	144.8	165.3	168.1	166.7	192.5	194.5	193.5
Mazoe' Rough lemon	165.7	126.8	146.2	170.1	166.1	168.1	190.6	183.0	186.8
Yolkamer' lemon	154.7	126.8	146.7	157.4	149.4	153.4	197.0	193.2	195.1
Orlando' tangelo	-	-	-	-	-	-	204.5	223.0	213.7
Caipira' sweet orange	-	-	-	-	-	-	202.3	198.0	200.1
MEAN	158.8	127.1	142.9	167.2	160.2	163.7	196.7	193.1	194.8

1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF – BA)

2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF – BA)

3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Table 4 – Fruit juice yield (%) of 'Valencia', 'Natal' and 'Pera' sweet oranges on different citrus rootstocks tested in Espírito Santo State at three producer regions.

Rootstocks	Places								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
Rangpur' Lime	51.9	52.5	52.2	53.8	55.9	54.8	43.1	53.3	48.2
Cleopatra' mandarin	-	-	-	-	-	-	52.2	54.4	53.3
Sunki' mandarin	52.3	53.6	52.9	53.1	56.0	54.5	51.8	53.0	52.4
Florida' Rough lemon	50.9	51.2	51.0	50.2	55.5	52.8	47.5	51.7	49.6
Mazoe' Rough lemon	49.4	52.8	51.1	51.6	55.4	53.5	49.9	50.3	50.1
Yolkamer' lemon	49.1	52.2	50.6	49.9	52.3	51.1	48.6	51.1	49.8
Orlando' tangelo	-	-	-	-	-	-	50.3	42.6	46.4
Caipira' sweet orange	-	-	-	-	-	-	53.1	49.3	51.2
MEAN	50.7	52.4	51.5	51.7	55.0	53.3	49.5	50.7	50.1

1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF – BA)

2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF – BA)

3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Table 5 – Fruit juice total soluble solids (°Brix) of 'Valencia', 'Natal' and 'Pera' sweet oranges on different citrus rootstocks tested in Espírito Santo State at three producer regions.

Rootstocks	Places								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
Rangpur' Lime	11.6	11.3	11.4	11.1	11.5	11.3	12.4	12.0	12.2
Cleopatra' mandarin	-	-	-	-	-	-	11.9	12.3	12.1
Sunki' mandarin	11.6	11.1	11.3	11.6	11.2	11.4	12.5	12.4	12.4
Florida' Rough lemon	11.6	11.4	11.5	11.5	10.7	11.1	11.7	11.7	11.7
Mazoe' Rough lemon	11.1	11.2	11.1	11.2	11.2	11.2	11.9	11.8	11.8
Yolkamer' lemon	11.7	12.2	11.9	11.8	12.1	11.9	12.1	11.6	11.8
Orlando' tangelo	-	-	-	-	-	-	11.9	11.7	11.8
Caipira' sweet orange	-	-	-	-	-	-	12.2	12.6	12.4
MEAN	11.5	11.4	11.4	11.4	11.3	11.3	12.0	12.0	11.4

1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF – BA)

2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF – BA)

3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Table 6 - Fruit juice acidity (%) of 'Valencia', 'Natal' and 'Pera' sweet oranges on different citrus rootstocks tested in Espírito Santo State at three producer regions.

Rootstocks	Places								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
'Rangpur' Lime	1.51	1.18	1.34	1.23	0.74	0.98	0.98	0.94	0.96
'Cleopatra' mandarin	-	-	-	-	-	-	0.91	0.94	0.92
'Sunki' mandarin	1.59	1.25	1.42	1.46	1.14	1.30	1.00	0.96	0.98
'Florida' Rough lemon	1.49	1.25	1.37	1.27	0.88	1.07	0.94	0.88	0.91
'Mazoe' Rough lemon	1.48	1.22	1.35	1.31	0.78	1.04	0.90	0.88	0.89
'Volkamer' lemon	1.46	1.27	1.36	1.21	0.79	1.00	0.94	0.93	0.93
'Orlando' tangelo	-	-	-	-	-	-	0.90	1.31	1.10
'Caipira' sweet orange	-	-	-	-	-	-	0.92	1.04	0.98
MEAN	1.50	1.23	1.36	1.29	0.86	1.07	0.94	0.98	0.96

(1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF - BA)

(2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF - BA)

(3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

(4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Table 7 - Fruit juice ratio (tss/% ac.) of 'Valencia', 'Natal' and 'Pera' sweet oranges on different citrus rootstocks tested in Espírito Santo State at three producer regions.

Rootstocks	Places								
	Santa Maria de Jetibá			Viana			Linhares		
	'Valencia' ¹	'Natal' ²	Mean	'Valencia' ¹	'Natal' ²	Mean	'Pera' ³	'Pera' ⁴	Mean
'Rangpur' Lime	7.84	9.58	8.71	9.21	16.30	12.75	12.78	12.71	12.74
'Cleopatra' mandarin	-	-	-	-	-	-	12.81	13.31	13.06
'Sunki' mandarin	7.52	9.05	8.28	8.14	10.42	9.28	12.24	13.02	12.63
'Florida' Rough lemon	7.93	9.08	8.50	9.39	12.66	11.02	12.70	13.35	13.02
'Mazoe' Rough lemon	7.84	9.10	8.47	8.74	14.73	11.73	13.37	13.50	13.43
'Volkamer' lemon	8.10	9.65	8.87	9.99	16.49	13.24	13.06	12.59	12.82
'Orlando' tangelo	-	-	-	-	-	-	13.24	9.17	11.20
'Caipira' sweet orange	-	-	-	-	-	-	13.42	12.68	13.05
MEAN	7.84	9.29	8.57	9.10	14.12	11.60	12.95	12.54	12.74

(1) - 'Valencia' clone IPEAL 27 (EMBRAPA/CNPMPF - BA)

(2) - 'Natal' clone IPEAL 1 (EMBRAPA/CNPMPF - BA)

(3) - 'Pera' clone tristeza cross - protected (CCSM/IAC-SP)

(4) - 'Pera' clone Bianchi (CCSM/IAC-SP)

Regarding to the fruit weight (Table 3), the 'Valencia' sweet orange presented the value higher than 'Natal'. On the Rough Mazoe and Rough Florida lemons, the fruits of 'Valencia' were slightly heavier. In relation to the juice yield (Table 4), the 'Sunki' mandarin and 'Rangpur' lime stimulated higher juice level. The 'Natal' sweet orange presented juice value higher than 'Valencia'. The Rough Mazoe and Volkamer lemons produced 50% juice yield less than in 'Valencia' fruits. The higher value in total soluble solids (Table 5) was obtained on the Volkamer lemon, while the Rough Mazoe presented the lowest. For that variable there is no difference between 'Valencia' and 'Natal' orange fruits. The fruits of 'Natal' on Volkamer lemon presented tss (°Brix) higher than in 'Valencia' fruits. On 'Sunki' mandarin occurred the opposite. On Rough 'Mazoe' lemon the Valencia fruits showed total soluble solids lower. On 'Volkamer' lemon happened the opposite for 'Natal' orange. Regards the fruit acidity it were not observed scions and rootstock interaction

Volkamer lemon and 'Rangpur' lime stimulated higher ratio (Table 7) for the juices of sweet oranges evaluated. The 'Sunki' mandarin stimulated the fewer ratios. The 'Natal' orange juice ratio was satisfactory on all the rootstocks, while 'Valencia' was only on 'Volkamer' lemon.

Experiment 2 - location: Jucuruaba, Viana-ES.

The Rough lemon 'Florida' lemon gave the higher fruit yield for the scions (Table 2), producing 1.9 t/ha more than Rangpur lime, but no statistical difference among both. For the Volkamer lemon the difference was 2.8 t/ha. The 'Valencia' orange produced more than 'Natal'. 'Valencia' orange was superior on 'Rough Florida' lemon, 'Sunki' mandarin and 'Volkamer' lemon. The Volkamer lemon stimulated the fruit average weight lower among the rootstocks tested (Table 3). The fruit average weight in 'Valencia' was higher than 'Natal'. The Rangpur lime, Sunki mandarin stimulated the highest fruit juice

yield averages and Rough lemon 'Mazoe' lemon, independent of the scions used. The 'Natal' orange was superior to the 'Valencia' orange. On the Volkamer lemon this variety presented value less 50% for juice. Regarding the total soluble solids the Volkamer lemon stimulated higher value for the sweet oranges (Table 5). In the two scions the higher total acid values occurred on 'Sunki' mandarin (Table 6). The 'Valencia' fruits presented more acidity than 'Natal'. It was observed a scion and rootstock interaction for ratio. On the 'Volkamer' lemon and 'Rangpur' lime rootstocks the juice content was higher than tss/ac. ratio, while on 'Sunki' mandarin the difference was less. The tss/ac. ratio was almost outstanding for the 'Natal' orange, which was slightly superior to the 'Valencia'. The Rough 'Florida' and Rough 'Mazoe' rootstocks stimulated an adequate tss/ac. ratio for the 'Natal' orange. On Volkamer lemon and 'Rangpur' lime this variety presented higher tss/ac. ratio, while on 'Sunki' mandarin the 'Natal' presented a satisfactory ratio.

Experiment 3 – Location: Forest Natural Reserve of Vale do Rio Doce Enterprise, Linhares, ES

The 'Orlando' tangelo rootstock stimulated fruit yield (table 2). It was superior to 5.8 t/ha as compared to Rangpur lime, and also to the others rootstock evaluated. The clones 'Pera' IAC and Bianchi orange had the same production. However, on 'Caipira' sweet orange the clone Bianchi was superior. The lower fruit average weight was obtained by the Bianchi clone on Rough 'Mazoe' lemon (Table 3). In relation to the juice yield (Table 4), the 'Pera' orange fruit, clone IAC on Rangpur lime presented the lower value. The performance of the scions on the rootstocks was similar for all rootstocks (Table 5) with just a few advantage for the 'Sunki' mandarin and 'Caipira' sweet orange that stimulated the higher values of °Brix. The 'Pera' Bianchi orange fruit on 'Orlando' tangelo presented more acidity in juice (Table 6). On the 'Rough Florida' and 'Rough' Mazoe lemon the fruits of these clones, the acid levels were lower. With regard to the total soluble solids, % acidity and ratio,

(Table 7), it was observed that 'Pera' Bianchi clone on 'Orlando' tangelo rootstock presented a ratio inferior to 10.

CONCLUSIONS

In alto Posmousser, Santa Maria de Jetibá, ES the scions of 'Valencia' IPEAL 27 and 'Natal' IPEAL 1 sweet oranges, showed higher yield on Rough lemon 'Florida' rootstock. However, the 'Valencia' IPEAL 27 presented the lower juice ratio. In Jucuruabá, Viana ES, the higher yield of these scions were obtained on Rough lemon 'Mazoe' lemon rootstock. The 'Natal' IPEAL 1 orange behave satisfactory just on this rootstock. In Linhares, ES, the 'Pera' IAC and Bianchi sweet orange showed higher yield on 'Orlando' tangelo rootstock. The fruits of these clones showed fine juice quality.

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