

Supplementary Material

Table S1. Split averages of tree size variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2020.

Tree Density (Trees·ha ⁻¹)	Rootstock	THb	DPb	DRb	CVb	RVb	THa	DPa	DRa	CVa	RVa
		----- (cm) -----	----- (cm) -----		(m ³ ·tree ⁻¹)	(m ³ ·ha ⁻¹)	----- (cm) -----	----- (cm) -----		(m ³ ·tree ⁻¹)	(m ³ ·ha ⁻¹)
513	IAC 1697	274.54	297.86	359.50	15.53	7,966.55	272.04	297.86	352.61	15.08	7,731.40
	IAC 1710	381.25	328.04	457.50	30.28	15,527.19	351.11	328.04	429.43	25.98	13,324.85
	Swingle	371.39	314.75	429.50	26.41	13,544.24	337.86	314.75	410.71	22.93	11,759.76
	Swingle 4x	274.82	284.71	305.36	13.29	6,816.59	270.89	284.71	301.71	12.88	6,603.56
696	IAC 1697	286.50	262.29	366.21	14.50	10,087.78	286.50	262.29	352.64	13.96	9,712.35
	IAC 1710	395.25	296.71	453.46	27.81	19,349.11	359.29	291.96	403.21	22.24	15,468.91
	Swingle	371.21	274.79	412.96	22.15	15,411.33	344.29	274.79	381.71	18.96	13,190.19
	Swingle 4x	274.89	254.64	308.64	11.59	8,065.50	271.32	255.61	307.25	11.36	7,902.82
1000	IAC 1697	284.79	236.04	346.39	12.33	12,329.12	279.21	236.04	308.93	10.70	10,697.13
	IAC 1710	396.61	248.71	443.75	22.84	22,844.06	365.36	249.14	357.50	17.01	17,007.15
	Swingle	376.98	243.57	390.27	18.72	18,717.36	354.29	243.57	338.45	15.26	15,259.70
	Swingle 4x	270.04	203.36	296.43	8.64	8,644.94	269.50	203.36	277.79	8.05	8,052.87
<i>p</i> -values											
Density (D)		0.3934	<0.0001	0.0082	<0.0001	<0.0001	0.1982	<0.0001	<0.0001	<0.0001	<0.0001
Rootstock (R)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D x R		0.8463	0.7920	0.7458	0.4023	0.0485	0.7177	0.7622	0.0093	0.1622	0.5149
CV% (D)		6.02	10.49	5.20	15.67	16.11	5.99	9.69	7.03	12.68	11.86
CV% (R)		6.04	8.78	6.82	16.03	15.34	5.53	8.20	5.21	14.84	13.80

TH = tree height; DP = canopy equatorial diameter parallel to the row line; DR = canopy equatorial diameter perpendicularly to the row line; CV = canopy volume of tree; RV = row volume estimated as the total canopy volume per hectare bases; (b) and (a) = before and after pruning at 8.5 years of age, respectively, in 2020. Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S2. Split averages of production variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2014-2020.

Tree Density (Trees·ha ⁻¹)	Rootstock	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY1420	EB (%)	ABI
		----- (kg tree ⁻¹) -----									
513	IAC 1697	4.50	29.52	61.14	99.16	70.95	113.72	55.84	58.57	23.36	0.34
	IAC 1710	2.99	27.70	48.85	133.19	108.72	145.15	120.04	79.83	14.23	0.32
	Swingle	3.20	29.10	33.41	103.27	119.99	128.36	98.15	69.55	14.12	0.37
	Swingle 4x	2.09	13.62	13.24	49.15	32.69	68.72	54.21	30.85	13.75	0.36
696	IAC 1697	2.95	29.02	51.43	89.95	62.74	95.61	52.85	51.07	23.56	0.33
	IAC 1710	3.02	27.11	44.01	116.56	100.39	130.51	83.88	66.64	16.04	0.32
	Swingle	3.21	20.56	29.65	82.82	63.90	107.64	75.89	49.97	15.38	0.38
	Swingle 4x	3.09	12.01	12.39	38.83	28.99	50.77	49.24	25.63	15.67	0.30
1000	IAC 1697	3.37	25.69	41.95	73.40	42.76	66.14	29.43	38.58	26.51	0.35
	IAC 1710	2.85	24.93	34.75	87.07	67.93	110.90	64.19	52.46	17.03	0.34
	Swingle	2.40	21.03	26.49	74.02	57.35	84.95	53.23	42.86	16.81	0.32
	Swingle 4x	3.13	10.62	12.65	41.68	26.09	38.50	28.06	21.87	17.31	0.37
<i>p</i> -values											
	Density (D)	0.7599	0.0097	<0.0001	<0.0001	0.0066	0.0003	<0.0001	<0.0001	0.0031	0.8009
	Rootstock (R)	0.3207	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.2916
	D x R	0.3664	0.2768	0.0040	<0.0001	0.1108	0.9740	0.0189	0.0080	0.9345	0.0816
	CV% (D)	41.38	19.82	12.98	12.54	50.01	12.90	28.59	18.75	14.57	16.27
	CV% (R)	50.62	20.40	14.33	10.25	44.93	21.16	21.71	12.05	13.51	10.92

FY = annual fruit yield from 2014 to 2020; FY1420 = average fruit yield in the 2014-2020 period. EB = early-bearing percentage (FY2014-FY2016/FY2014-FY2020); ABI = alternate bearing index calculated according to [47]. Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S3. Split averages of productivity variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2014-2020.

Tree Density (trees·ha ⁻¹)	Rootstock	FP2014	FP015	FP2016	FP2017	FP2018	FP2019	FP2020	FP1420	FPHLB	D _{HLB}
----- (t·ha ⁻¹) -----											
513	IAC 1697	2.31	15.14	31.36	50.77	36.38	58.32	28.64	210.18	189.54	0.90
	IAC 1710	1.54	14.20	25.05	68.19	55.75	74.44	61.56	286.46	250.58	0.88
	Swingle	1.64	14.92	17.13	52.87	61.53	65.82	50.33	249.58	233.18	0.93
	Swingle 4x	1.07	6.99	6.79	25.17	16.76	35.24	27.80	110.69	100.15	0.90
696	IAC 1697	2.05	20.19	35.77	62.51	43.65	66.51	36.76	248.63	222.82	0.90
	IAC 1710	2.10	18.86	30.62	81.01	69.84	90.79	58.35	324.45	268.77	0.84
	Swingle	2.23	14.30	20.62	57.56	44.45	74.88	52.79	243.26	217.20	0.90
	Swingle 4x	2.15	8.35	8.62	26.99	20.17	35.32	34.25	124.76	113.83	0.92
1000	IAC 1697	3.37	25.69	41.95	73.40	42.76	66.14	29.43	270.08	232.59	0.86
	IAC 1710	2.85	24.93	34.75	87.07	67.93	110.90	64.19	367.25	327.35	0.89
	Swingle	2.40	21.03	26.49	74.02	57.35	84.95	53.23	300.01	274.25	0.91
	Swingle 4x	3.13	10.62	12.65	41.68	26.09	38.50	28.06	153.10	149.50	0.97
<i>p</i> -values											
Density (D)		0.0040	<0.0001	<0.0001	<0.0001	0.4069	0.0111	0.6007	0.0040	0.0040	0.4812
Rootstock (R)		0.5182	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.0013
D x R		0.6576	0.0593	0.6891	0.1001	0.3110	0.2370	0.4978	0.1005	0.0519	0.0889
CV% (D)		38.71	23.50	14.45	13.16	35.67	15.39	28.38	16.38	16.68	8.43
CV% (R)		53.71	21.74	15.64	10.43	35.81	19.02	20.52	10.23	11.7	5.81

FP = annual fruit productivity from 2014 to 2020; FP1420 = cumulative fruit productivity in the 2014-2020 period. FPHLB = cumulative fruit productivity in the 2014-2020 period considering tree eradication by huanglongbing over the evaluated period; D_{HLB} = relative cumulative fruit productivity due to tree eradication by huanglongbing over the evaluated period. Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S4. Split averages of production efficiency and land use variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2014-2020.

Tree Density (Trees·ha ⁻¹)	Rootstock	AI	PEV (kg·m ⁻³ ·ha ⁻¹)	PEA (kg·m ⁻² ·ha ⁻¹)	PEC ₂₀₂₀ (kg·m ⁻³)	LU1420	LU1720
513	IAC 1697	0.43	26.77	49.03	3.63	0.94	1.25
	IAC 1710	0.61	18.71	47.74	3.97	1.28	1.94
	Swingle	0.54	18.73	46.31	3.77	1.12	1.69
	Swingle 4x	0.35	16.70	31.44	4.27	0.50	0.75
696	IAC 1697	0.52	24.81	47.44	3.65	1.11	1.49
	IAC 1710	0.73	16.95	44.75	3.01	1.45	2.17
	Swingle	0.62	15.80	39.42	3.39	1.09	1.65
	Swingle 4x	0.43	16.42	30.21	4.54	0.56	0.84
1000	IAC 1697	0.64	22.65	42.88	2.46	1.21	1.54
	IAC 1710	0.87	16.18	42.59	2.81	1.64	2.39
	Swingle	0.75	16.33	40.67	2.88	1.34	1.96
	Swingle 4x	0.47	18.19	32.69	3.37	0.69	0.99
p-values							
Density (D)		<0.0001	0.0330	0.0959	0.0012	0.0050	0.0018
Rootstock (R)		<0.0001	<0.0001	<0.0001	0.0136	<0.0001	<0.0001
D x R		0.2896	0.5228	0.5152	0.5748	0.1017	0.2506
CV% (D)		12.01	13.61	15.76	23.14	16.50	15.87
CV% (R)		12.60	18.99	15.04	25.90	10.25	12.00

AI = area index (total canopy projection area by hectare in 2020); PEV = estimated production efficiency considering the cumulative production in the 2014-2020 period and the row volume in 2020; PEA = estimated production efficiency considering the cumulative production in the 2014-2020 period and the area index in 2020; PEC₂₀₂₀ = production efficiency of the tree canopy volume in 2020; LU = land use index, the relation between the observed fruit productivity and the reference fruit productivity according to [48]) in the 2014-2020 (total evaluation period) and 2017-2020 (stable production period), respectively. Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S5. Split averages of fruit quality variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2017-2018.

Tree Density (Trees ha ⁻¹)	Rootstock	2017							2018						
		FW (g)	SS (°Brix)	TA (%)	MI	TI (kg ^B ox ⁻¹)	JC (%)	II (Boxes t ⁻¹)	FW (g)	SS (°Brix)	TA (%)	MI	TI (kg ^B ox ⁻¹)	JC (%)	II (Boxes t ⁻¹)
513	IAC 1697	160.46	13.32	0.84	16.07	3.17	58.36	208.31	215.26	11.80	0.82	14.37	2.47	51.37	267.27
	IAC 1710	193.40	11.46	0.65	17.72	2.72	58.21	242.84	243.40	10.43	0.72	14.45	2.08	48.97	317.11
	Swingle	185.00	12.41	0.81	15.77	2.93	57.88	225.51	258.62	10.88	0.91	12.20	2.12	47.62	315.13
	Swingle 4x	169.00	13.33	0.77	18.20	3.11	57.29	211.98	250.25	10.88	0.81	13.54	2.04	45.93	324.96
696	IAC 1697	158.88	13.26	0.78	17.03	3.20	59.14	206.51	217.56	11.85	0.93	12.85	2.43	50.28	271.85
	IAC 1710	183.14	11.79	0.68	17.49	2.80	58.25	235.77	231.45	10.75	0.78	14.03	2.11	48.14	313.79
	Swingle	166.53	12.84	0.93	14.04	2.91	55.63	227.14	243.57	10.93	0.86	12.75	2.11	47.47	312.58
	Swingle 4x	158.21	13.59	0.84	16.20	3.05	55.07	216.28	227.72	11.40	0.90	13.11	2.06	44.32	321.42
1000	IAC 1697	159.83	13.34	0.80	16.74	3.25	59.79	202.97	226.95	11.80	0.91	13.08	2.39	49.62	276.83
	IAC 1710	185.07	11.76	0.69	17.12	2.85	59.37	232.57	221.39	11.08	0.79	14.10	2.27	50.21	291.63
	Swingle	183.30	12.56	0.79	16.08	3.01	58.82	219.17	241.14	11.03	0.96	11.79	2.08	46.28	319.11
	Swingle 4x	150.33	13.90	0.85	16.77	3.18	56.01	208.08	245.81	11.33	0.89	13.12	2.09	45.13	319.04
p-values															
Density (D)		0.0914	0.2097	0.4364	0.5373	0.0851	0.0602	0.1090	0.3273	0.2560	0.2696	0.6841	0.8598	0.4797	0.8862
Rootstock (R)		<0.0001	<0.0001	0.0022	0.0760	<0.0001	<0.0001	<0.0001	0.0101	0.0003	0.0130	0.0551	<0.0001	<0.0001	0.0001
D x R		0.5685	0.666	0.5361	0.6836	0.8311	0.0597	0.8074	0.5345	0.8756	0.8059	0.9328	0.7700	0.6584	0.8162
CV% (D)		6.39	3.12	10.29	11.07	3.37	2.38	3.57	8.82	4.44	12.84	15.16	7.78	4.36	8.54
CV% (R)		7.80	3.06	13.45	12.20	3.06	2.12	3.37	8.29	4.83	12.59	12.35	7.75	4.24	7.97

FW = fresh weight; SS = total soluble solids concentration in the juice; TA = titratable acidity of juice; MI = maturity index (SS/TA); TI = technological index (amount of SS per standard orange box of 40.8 kg); JC = juice content in the fruit; II = industrial index (number of standard orange boxes to produce one ton of Frozen and Concentrated Orange Juice – FCOJ at 66 °Brix). Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S6. Split averages of fruit quality variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2019-2020.

Tree Density (Trees ha ⁻¹)	Rootstock	2019							2020						
		FW (g)	SS (°Brix)	TA (%)	MI	TI (kg Box ⁻¹)	JC (%)	II (Boxes t ⁻¹)	FW (g)	SS (°Brix)	TA (%)	MI	TI (kg Box ⁻¹)	JC (%)	II (Boxes t ⁻¹)
513	IAC 1697	194.42	12.36	0.65	18.94	2.92	57.94	226.01	207.80	12.82	0.73	17.60	3.22	61.44	206.09
	IAC 1710	204.95	10.69	0.62	17.34	2.44	56.00	270.41	200.85	12.12	0.62	19.53	3.06	61.81	216.54
	Swingle	226.81	10.85	0.59	18.54	2.35	53.13	281.11	210.28	12.81	0.68	19.22	3.26	62.32	203.10
	Swingle 4x	223.23	10.90	0.50	22.46	2.30	51.75	287.66	229.95	11.99	0.57	21.19	3.06	62.39	217.86
696	IAC 1697	181.45	12.59	0.62	20.32	2.96	57.57	223.44	179.58	13.47	0.73	18.66	3.37	61.29	196.02
	IAC 1710	202.69	10.69	0.60	17.69	2.42	55.44	273.61	182.44	12.53	0.67	18.88	3.07	60.13	216.51
	Swingle	218.58	11.29	0.61	18.53	2.49	54.14	265.20	205.48	12.38	0.64	19.48	3.17	62.69	209.48
	Swingle 4x	228.33	11.30	0.50	22.51	2.33	50.60	283.05	215.07	12.50	0.63	20.92	3.14	61.57	211.04
1000	IAC 1697	173.62	12.65	0.59	21.60	2.95	57.21	223.89	181.01	13.26	0.78	17.25	3.25	59.99	203.87
	IAC 1710	190.38	10.69	0.62	17.32	2.43	55.76	271.66	189.69	12.02	0.67	18.03	3.05	62.10	217.37
	Swingle	191.21	11.42	0.60	19.01	2.58	55.33	256.17	192.85	12.66	0.68	18.72	3.17	61.36	209.18
	Swingle 4x	214.50	11.92	0.59	20.09	2.59	53.28	255.48	209.36	12.82	0.73	18.29	3.11	59.56	213.13
p-values															
Density (D)		0.0151	0.1016	0.7502	0.8529	0.0501	0.0540	0.0488	0.1557	0.6916	0.5500	0.3949	0.9173	0.3950	0.9239
Rootstock (R)		<0.0001	<0.0001	0.0013	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.0123	0.0345	0.0671	0.0675	0.5341	0.0826
D x R		0.4771	0.3575	0.0867	0.3126	0.2693	0.5327	0.1992	0.6294	0.5114	0.6651	0.8442	0.9436	0.5396	0.9425
CV% (D)		4.64	3.44	9.64	9.71	3.53	1.21	3.67	12.89	7.88	24.02	15.92	10.27	3.87	10.31
CV% (R)		5.75	3.15	7.13	8.56	4.72	2.93	4.81	6.99	5.38	13.28	10.56	6.51	3.42	6.98

FW = fresh weight; SS = total soluble solids concentration in the juice; TA = titratable acidity of juice; MI = maturity index (SS/TA); TI = technological index (amount of SS per standard orange box of 40.8 kg); JC = juice content in the fruit; II = industrial index (number of standard orange boxes to produce one ton of Frozen and Concentrated Orange Juice – FCOJ at 66 °Brix). Swingle 4x = autotetraploid selection of the Swingle citrumelo.

Table S7. Split averages of mean fruit quality and soluble solids yield variables of Valencia sweet orange grafted onto four rootstocks and cultivated at three tree densities. Gavião Peixoto-SP, Brazil, 2017-2020.

Tree Density (Trees·ha ⁻¹)	Rootstock	Average values for 2017-2020							Annual and Cumulative Soluble Solids Yield				
		FW (g)	SS (°Brix)	TA (%)	MI	TI (kg·Box ⁻¹)	JC (%)	II (Boxes·t ⁻¹)	2017	2018	2019 (kg SS·ha ⁻¹)	2020	2017-2020
513	IAC 1697	195.39	12.58	0.77	16.55	2.94	57.16	227.59	3,930	2,192	4,254	2,107	12,112
	IAC 1710	211.70	11.20	0.66	17.18	2.58	56.15	261.83	4,327	2,900	4,842	4,062	15,798
	Swingle	219.99	11.82	0.76	16.20	2.69	55.42	254.16	3,972	2,103	3,957	4,283	14,335
	Swingle 4x	217.88	11.85	0.67	18.59	2.66	54.60	258.29	1,916	718	1,619	2,194	6,438
696	IAC 1697	184.84	12.80	0.77	17.03	2.99	57.06	224.52	4,765	2,457	4,830	3,222	14,910
	IAC 1710	199.69	11.49	0.69	17.00	2.62	55.58	258.33	5,313	3,630	5,412	4,563	18,678
	Swingle	207.37	11.94	0.77	16.07	2.69	55.04	252.06	4,263	2,402	4,577	3,809	14,793
	Swingle 4x	206.10	12.27	0.73	17.97	2.68	53.15	255.65	2,068	1,096	2,021	3,014	8,161
1000	IAC 1697	186.25	12.77	0.78	16.78	2.96	56.60	227.13	5,674	2,516	4,666	2,359	14,899
	IAC 1710	197.48	11.46	0.70	16.53	2.67	56.93	251.62	5,661	3,880	6,687	4,505	20,409
	Swingle	203.90	11.95	0.77	16.15	2.73	55.52	250.28	5,158	2,661	5,910	4,247	17,642
	Swingle 4x	204.78	12.56	0.78	16.81	2.76	53.56	247.80	3,072	1,195	2,246	2,149	8,616
p-values													
Density (D)		0.0071	0.0303	0.2749	0.5988	0.1983	0.1969	0.1839	0.0002	0.0241	0.0320	0.4181	0.0003
Rootstock (R)		<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D x R		0.9796	0.6517	0.2961	0.1998	0.9213	0.3285	0.9001	0.3698	0.9439	0.5011	0.0909	0.0963
CV% (D)		4.02	2.21	9.35	9.36	3.07	1.57	3.31	9.02	19.18	16.29	29.55	7.05
CV% (R)		3.62	2.68	5.12	4.37	3.61	1.64	3.79	10.49	24.71	19.11	16.34	8.27

FW = fresh weight; SS = total soluble solids concentration in the juice; TA = titratable acidity of juice; MI = maturity index (SS/TA); TI = technological index (amount of SS per standard orange box of 40.8 kg); JC = juice content in the fruit; II = industrial index (number of standard orange boxes to produce one ton of Frozen and Concentrated Orange Juice – FCOJ at 66 °Brix). Swingle 4x = autotetraploid selection of the Swingle citrumelo.