Performance of 'Hamlin' Orange on 16 Rootstocks in East-central Florida

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Abstract. 'Hamlin' orange (*Citrus sinensis* L. Osbeck) was grown on 15 rootstocks: four citrumelos [*C. paradisi* Macf. x *Poncirus trifoliata* (L.) Raf.], five mandarin x trifoliolate orange hybrids (*C. reticulata* Blanco x *P. trifoliata*), two pummelo x trifoliolate orange hybrids [*C. grandis* (L.) x *P. trifoliata*], Vangasay lemon (*C. limon* Burm. f.), Norton citrange (*C. sinensis* x *P. trifoliata*), and two Smooth Flat Seville (*C. aurantium* L. hybrid?) hybrids. These scion–rootstock combinations were compared to trees on Swingle citrumelo, the most widely used citrus rootstock in Florida. One Smooth Flat Seville hybrid was eliminated early because of poor growth and variability in size, and the Vangasay lemon rootstock was eliminated because of severe freeze damage. At age 5, the trees on Norton citrange developed citrus blight and were eliminated. Remaining in the experiment for 7 years, 'Hamlin' trees on six of the 13 rootstocks produced more fruit than trees on Swingle citrumelo. Of these six, HRS 852 (Changsha mandarin x English large-flowered trifoliolate orange) was the best overall rootstock, with trees on it producing large quantities of high-quality fruit on medium-sized canopies.

Until the 1960s, the citrus rootstock situation in Florida had been stable for decades, with rough lemon used on deep sandy soils; sour orange on poorly drained flatwoods soils; and Cleopatra mandarin for tangelos, tangors, and other mandarin hybrids. Citrus blight outbreaks, a decline of yet undetermined cause, and more virulent tristeza virus disease in the 1980s created a need for new rootstocks resistant to these diseases (Castle et al., 1993; Wutscher, 1988). Currently, the most planted rootstock is Swingle citrumelo, but it does not perform well on high-pH and clay soils (Jack Hebb, personal communication; Rouse and Wutscher, 1985). However, clay soils are common in limited areas in Florida. With the availability of many new hybrids from the U.S. Dept. of Agriculture breeding program (especially bred as rootstocks), new and better rootstocks are emerging from tests planted in the last 15 years. Our report compares the performance of 'Hamlin', the dominant early orange cultivar in Florida, on Swingle citrumelo with that of 'Hamlin' on 12 new rootstocks, one citrange, and two citrumelos little used in the past for this cultivar.

Materials and Methods

The rootstock seedlings (Table 1) were budded in a field nursery in Spring 1985 with the registered 'Hamlin' budline 815-XE F/D 5-4 obtained from the Florida Dept. of Agriculture and Consumer Services Budwood Registration Bureau, Winter Haven, Fla. The budded trees were planted on 10 Dec. 1986 at the test site near St. Cloud, Fla., with 4.2 x 6.6-m spacing. There were six, three-tree replications on each rootstock arranged in randomized complete blocks. The site was previously in pasture; it was modified for planting by cutting and filling drainage ditches on two sides. The soil was mostly Myakka fine sand (sandy, siliceous, hyperthermic aeris haplaquods) at pH 5.5. The trees were irrigated with microsprinklers, and standard cultural practices were used, including chemical weed control within the rows and grass between the rows. Five to six fertilizer applications were hand-applied before the trees were 4 years old, and then three applications were made per year with a spreader, totaling 180 kg N and 149 kg K/ha per year.

Yield records were taken at harvests on 5 Nov. 1990, 25 Nov. 1991, 12 Jan. 1992, and 2 Dec. 1993 when the trees were 4 to 7 years old. Yields per three-tree replication were measured by gauging the depth of fruit in standard 10-box tubs with a calibrated stick inserted in a crossbar placed over the tub. Each box equals 40.8 kg fruit.

Fruit quality was determined at each of the four harvests on 30-fruit samples by weighing them, extracting the juice with an electric reamer, and determining total soluble solids with a temperature-compensated refractometer and total acids by titration with 0.1560 N

NaOH. Juice color was measured with a chromameter (model CE 200; Minolta Camera Co., Osaka, Japan), which integrates tristimulus measurements into the color number used for grading juice. Peel color was determined by visually rating the fruit with a color chart (Harding et al., 1940). Two composite samples were collected at every harvest, one from the nine trees in replications 1 to 3 and one from the nine trees in replications 4 to 6. Parallel 40-fruit samples were processed in the commercial-type test facility of the Florida Dept. of Citrus, Lake Alfred. Tree height and width were measured at the last harvest, and the canopy volume was calculated by the formula (width² x height)/4. Width was limited by machine hedging, which kept the interrow space at 2.4 m. The data were tested using an SAS program for analysis of variance; mean separation was by Duncan's multiple range test at $P \leq 0.05$.

Results and Discussion

The trees grew normally the first 3 years in the field and began to fruit in 1989, producing an estimated 3 to 35 kg/tree. The Christmas freeze in 1989 damaged the trees; most were defoliated, but trees on Vangasay lemon were damaged so severely that they were removed. Trees on HRS 920 (Smooth Flat Seville open-pollinated hybrid) were stunted and unthrifty, and they also were eliminated. Trees on Nakorn pummelo x Flying Dragon trifoliolate (HRS 898) also were variable in size, but they remained in the test. Five years after planting, all trees on Norton citrange (HRS 815) showed the Zn deficiency symptoms characteristic of citrus blight. Diagnostic tests, water injection with a syringe (water absorption in syringe injection tests: trees on Norton 32.7 ml·min⁻¹, healthy trees on Swingle 65.7 ml·min⁻¹) (Lee et al., 1984), and analysis of the outer trunk wood (Zn in the outer trunk wood: Norton, 9 µg·g⁻¹; Swingle, 4 µg·g⁻¹) (Wutscher et al., 1977) confirmed the diagnosis. The trees on Norton also were removed. Of the remaining trees on 13 rootstocks, four trees on Nakorn pummelo x Flying Dragon trifoliolate orange and two trees each on Changsha x English small-flowered trifoliolate orange (HRS 801) and Swingle (HRS 874) were lost to undetermined causes.

HRS 852 (Changsha mandarin x English large-flowered trifoliolate orange) emerged as the best rootstock in the test. A similar hybrid (FFI-131-20) performed well in an earlier test in southern Florida (Wutscher and Bistline, 1988). Trees on HRS 852 were of medium size (Table 1) and produced as much fruit as the much larger trees on HRS 802 (Siamese pummelo x Gotha Road trifoliolate orange), but cumulative solids production per tree was equal for trees on HRS 802, HRS 852, and HRS 900 rootstocks (Table 2). Solids production determines the profitability of orange groves in Florida, where 90% of the oranges are processed. The growers get paid for the weight of solids delivered, not for the weight of fruit. Trees on Sacaton citrumelo (HRS 900) performed surprisingly well considering results

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from other locations (Gardner and Horanic, 1967; Wutscher, 1979), which were probably due to rigorous selection of presumed nucellar seedlings in the seedbed. Sacaton has 50% to 60% gametic seedlings, which when used as rootstocks, produces variable tree populations (Hutchison, 1977; Wutscher, 1979). Trees on the HRS 801 selection of the same parentage

as HRS 852 and HRS 809 (Changsha x English small-flowered trifoliolate orange) were small and had the same high-yield efficiency (Table 1). These rootstocks would be appropriate for trees in high-density plantings. The trees on six rootstocks produced more fruit than those on Swingle citrumelo (Table 1).

The ranges of nine fruit quality factors

were narrow (Table 3). Trees on Changsha x English small-flowered trifoliolate orange (HRS 801) and 81-17 citrumelo (HRS 931) produced some of the largest fruit, those on Sacaton citrumelo (HRS 900) and HRS 809 the smallest fruit. Fruit from trees on HRS 801 and HRS 811 had the lowest acid levels and corresponding high solids : acids ratios. Fruit from

Table 1. Tree height, tree volume, and yield efficiency of 'Hamlin' orange trees on 13 rootstocks.

HRS ^y code	Rootstock	Bionomials	Tree size ^z		1993 Yield efficiency ^z	
			Ht (m)	Vol. (m ³)	Fruit (kg·m ⁻³)	Solids (kg·m ⁻³)
802	Siamese pummelo x Gotha Road trifoliolate orange	<i>Citrus grandis</i> (L.) Osb. x <i>Poncirus trifoliata</i> L. Raf.	4.0 a	17.7 a	13.9 d	0.7 e
852	Changsha mandarin x English large-flowered trifoliolate orange	<i>C. reticulata</i> Blanco x <i>P. trifoliata</i>	3.0 cd	11.4 cd	20.7 b	1.1 b
900	Sacaton citrumelo	<i>P. trifoliata</i> x <i>C. paradisi</i> Macf.	3.6 b	14.5 b	15.9 cd	0.8 de
902	Mott grapefruit x Gotha Road trifoliolate orange (citrumelo)	<i>C. paradisi</i> x <i>P. trifoliata</i>	3.2 c	11.9 c	19.7 b	1.0 bc
886	W-4 citrumelo	<i>C. paradisi</i> x <i>P. trifoliata</i>	3.7 b	15.1 b	15.0 d	0.8 de
801	Changsha mandarin x English small-flowered trifoliolate orange	<i>C. reticulata</i> x <i>P. trifoliata</i>	2.5 fg	6.8 gh	25.3 a	1.3 a
874	Swingle citrumelo	<i>C. paradisi</i> x <i>P. trifoliata</i>	3.0 cd	9.1 ef	20.2 b	1.0 bc
809	Changsha mandarin x English large-flowered trifoliolate orange	<i>C. reticulata</i> Blanco x <i>P. trifoliata</i>	2.6 fg	7.1 f-h	24.0 a	1.3 a
896	Cleopatra mandarin x Rubidou trifoliolate orange	<i>C. reticulata</i> x <i>P. trifoliata</i>	2.6 fg	8.4 f-h	19.0 b	1.1 b
898	Nakorn pummelo x Flying Dragon trifoliolate orange	<i>C. grandis</i> x <i>P. trifoliata</i>	2.7 ef	7.5 f-h	20.1 b	1.1 b
811	Smooth Flat Seville x Swingle citrumelo	<i>C. aurantium</i> L. hybrid? x (<i>C. paradisi</i> x <i>P. trifoliata</i>)	2.7 ef	8.9 e-g	18.4 bc	0.9 c-e
931	81-17 citrumelo, Duncan grapefruit x trifoliolate orange	<i>C. paradisi</i> x <i>P. trifoliata</i>	2.9 de	9.9 de	14.2 d	0.8 d
897	Cleopatra mandarin x Flying Dragon trifoliolate orange	<i>C. reticulata</i> x <i>P. trifoliata</i>	2.4 g	6.6 h	20.2 b	1.1 b

^zMean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

^yA code system used at the U.S. Horticultural Research Laboratory, Orlando, Fla.

Table 2. Fruit and solids yield of 'Hamlin' orange trees on 13 rootstocks.

HRS code ^y	Rootstocks	kg fruit/tree ^z					kg solids/tree ^z				
		1990-91	1991-92	1992-93	1993-94	Cumulative yield	1990-91	1991-92	1992-93	1993-94	Cumulative yield
802	Siamese pummelo x Gotha Road trifoliolate orange	98.7 bc	142.2 ab	295.2 a	245.0 a	781.1 a	1.4 b-d	6.6 b	14.8 a	11.8 ab	34.6 ab
852	Changsha mandarin x English large-flowered trifoliolate orange	108.2 b	153.8 a	272.0 a	235.3 ab	769.2 a	1.7 ab	7.7 a	14.8 a	12.4 a	36.6 a
900	Sacaton citrumelo	98.7 bc	133.3 a-c	274.2 a	225.3 ab	731.5 ab	1.6 bc	6.3 bc	14.0 a	11.8 ab	33.7 ab
902	Mott grapefruit x Gotha Road trifoliolate orange citrumelo	80.8 b-d	132.7 a-d	223.8 b	221.2 b	658.5 c	1.0 de	6.1 b-d	11.4 bc	11.1 b	29.6 cd
886	W-4 citrumelo	70.7 c-e	110.7 c-e	232.7 b	226.7 ab	640.8 c	1.0 de	5.3 c-e	13.3 ab	11.8 ab	31.4 bc
801	Changsha mandarin x English small-flowered trifoliolate orange	165.8 a	110.0 c-e	173.5 cd	172.2 cd	621.5 c	2.1 a	4.8 de	9.0 de	8.6 c-e	24.5 e-g
874	Swingle citrumelo	89.7 b-d	122.0 b-d	204.3 bc	178.2 c	594.2 d	1.5 bc	6.0 b-e	11.5 bc	9.2 c	28.2 c-e
809	Changsha mandarin x English large-flowered trifoliolate orange	75.5 c-e	111.5 c-e	177.5 cd	171.7 de	536.2 de	1.3 b-d	5.7 b-e	9.9 c-e	9.2 c	26.3 d-f
896	Cleopatra mandarin x Rubidou trifoliolate orange	85.7 b-d	114.8 c-e	175.5 cd	156.7 c-e	532.7 de	1.4 b-d	5.7 b-e	10.3 cd	9.0 cd	26.4 d-f
898	Nakorn pummelo x Flying Dragon trifoliolate orange	95.2 b-d	97.3 ef	172.8 cd	149.0 d-f	514.3 de	1.5 bc	5.4 c-e	9.6 c-e	8.1 c-e	24.6 e-g
811	Smooth Flat Seville x Swingle citrumelo	49.0 e	75.3 f	177.0 cd	161.8 dc	463.1 e	0.6 e	3.3 e	8.5 de	7.8 ef	20.2 h
931	81-17 citrumelo, Duncan grapefruit x trifoliolate orange	64.5 de	95.8 ef	163.8 d	138.7 ef	462.8 e	1.1 cd	4.8 e	8.2 de	7.9 ef	23.0 f-h
897	Cleopatra mandarin x Flying Dragon trifoliolate orange	66.0 de	108.8 de	153.8 d	133.3 f	461.9 e	1.0 de	5.3 c-e	8.0 e	7.0 f	21.3 gh

^zMean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

^yA code system used at the U.S. Horticultural Research Laboratory, Orlando, Fla.

Table 3. Fruit quality of 'Hamlin' orange on 13 rootstocks.^z

HRS code ^y	Rootstocks	Fruit wt (g)	Fruit diam (cm)	Peel color ^x	Rind thickness (mm)	Juice content (%)	Total soluble solids (%)	Total acids (%)	TSS : TA ^w	Juice color ^v
802	Siamese pummelo x Gotha Road trifoliolate orange	169 b-d	7.0 b ^u	I	3.5 ab	49.0 b-d	9.0 fg	0.73 e	12.3 c-e	33.5 a
852	Changsha mandarin x English large-flowered trifoliolate orange	172.0 bc	7.0 b	H	3.4 a-c	50.2 a	9.6 cd	0.79 d	12.2 c-e	33.3 a-c
900	Sacaton citrumelo	162.5 cd	6.8 c	H	3.4 a-c	48.7 cd	9.5 de	0.79 d	12.0 e	33.4 ab
902	Mott grapefruit x Gotha Road trifoliolate orange citrumelo	181.5 ab	7.1 ab	H	3.7 a	48.3 d	9.2 ef	0.75 e	12.3 c-e	33.3 a-c
886	W-4 citrumelo	177.3 b	7.0 b	H	3.5 ab	48.6 cd	9.6 cd	0.84 a	11.4 f	33.4 ab
801	Changsha mandarin x English small-flowered trifoliolate orange	190.6 a	7.3 a	H	3.7 a	46.5 e	9.2 ef	0.70 f	13.1 a	33.3 a-c
874	Swingle citrumelo	173.8 bc	7.0 b	H	3.4 a-c	49.2 b-d	9.7 b-d	0.80 cd	12.1 de	33.2 a-c
809	Changsha mandarin x English large-flowered trifoliolate orange	159.6 d	6.8 c	H	3.2 c	49.0 b-d	10.0 ab	0.82 a-c	12.0 e	33.2 a-c
896	Cleopatra mandarin x Rubidou trifoliolate orange	174.5 b	7.0 b	H	3.3 bc	49.9 ab	10.1 a	0.80 cd	12.6 b-d	33.1 bc
898	Nakorn pummelo x Flying Dragon trifoliolate orange	177.5 b	7.1 ab	I	3.5 ab	49.3 a-c	9.9 ab	0.81 b-d	12.2 c-e	33.2 a-c
811	Smooth Flat Seville x Swingle citrumelo	176.9 b	7.1 ab	I	3.5 ab	46.9 e	8.9 g	0.68 f	13.1 a	33.3 a-c
931	81-17 citrumelo, Duncan grapefruit x trifoliolate orange	191.8 a	7.3 a	H	3.7 a	49.8 ab	9.9 ab	0.83 ab	11.9 e	33.0 c
897	Cleopatra mandarin x Flying Dragon trifoliolate orange	175.4 b	7.1 ab	H	3.3 bc	49.5 a-c	9.4 de	0.74 e	12.7 bc	33.3 a-c

^zMean of two composite 30-fruit samples (replications 1 to 3 and 4 to 6) collected at each of four harvests in 1990-93.

^yA code system used at the U.S. Horticultural Research Laboratory, Orlando, Fla.

^xPeel color according to color tables in Harding et al. (1940); colors range from A (completely green) to L (dark red).

^wTSS : TA = total soluble solids : total acid ratio.

^vJuice color as color number determined with chromameter (model CE 200; Minolta Camera Co., Osaka, Japan).

^uMean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

trees on HRS 852, HRS 896, HRS 898, HRS 931, and HRS 897 had the highest juice content. Comparing the juice content obtained by hand-reaming and by commercial extracting machines in the Dept. of Citrus Laboratory (data not shown) indicated that 5% to 10% more juice was extracted in the test house. This procedure also increased kilogram solids per cubic meter of canopy volume and the weight of solids produced per tree to levels greater than those reported in Tables 1 and 2, more closely resembling those that would be attained in commercial production. There was little difference in juice color due to rootstock (Table 3); juice color from fruit on trees on all rootstocks was typical for 'Hamlin' orange and well below color number 36, required for grade A juice.

All of the rootstocks in the experiment were tested previously as plants in pots (Grimm and Hutchison, 1973; Hutchison, 1985) and found to be tolerant to *Phytophthora parasitica* Dastur and tristeza. Also, the experimental site was tristeza-infected. The trees on Norton citrange developed citrus blight early; little can be said of the potential tolerance to this decline of the 12 rootstocks other than Swingle (Castle et al., 1988), which is resistant. HRS

852 (Changsha mandarin x English large-flowered trifoliolate orange) likely will be released for commercial use as soon as seed sources can be established. Most of Florida's soils are sandy and acidic, as in our test plot; therefore, similar results can be expected in much of the state's citrus areas.

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