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Performance of 'Owari' and 'Brown Select' Satsuma in North Florida on Standard and Flying Dragon *Poncirus trifoliata* Rootstocks

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The performance of satsuma (*Citrus unshiu* Marc.) cultivars Owari and Brown Select on *Poncirus trifoliata* (L.) Raf. (standard and Flying Dragon) was evaluated from 2007 to 2009 at the North Florida Research and Education Center–Quincy. The orchard, established in 2004, consisted of trees planted 4.57 and 6.10 m within and between rows, respectively. Trees were not subjected to freeze protection and withstood minimum temperatures of –9.3 °C (15.3 °F) without apparent damage. Tree size (canopy area), yield, and fruit quality data were analyzed as a 2 × 2 factorial design. Average yield per tree across all genotypes was 12, 8, and 60 kg in 2007, 2008, and 2009, respectively. Yield was not significantly affected by scion or rootstock in 2007 or 2008, although both scion and rootstock effects were significant in 2009, with higher yield for 'Brown Select' scions and *P. trifoliata* (standard) rootstocks. For all years, fruit weight was significantly greater for 'Brown Select' (average = 152 g) than 'Owari' (average = 119 g). Soluble solids of orange juice were higher for satsuma on *P. trifoliata* Flying Dragon (average = 9.7 °Brix) compared to *P. trifoliata* standard (average = 9.1 °Brix) rootstocks. Fruit of 'Owari' were more acidic than 'Brown Select' in 2007 and 2008. In 2009, both cultivar and rootstock had a significant effect on tree canopy area ['Brown Select' scions and *P. trifoliata* (standard) rootstocks were larger]. Yield efficiency (yield/canopy area) was affected by scion ('Brown Select' trees were higher), but not by rootstock. In 2009, fruit number per tree was highest for 'Brown Select'/*P. trifoliata* (standard) The satsuma is a specialty crop with potential for expansion in acreage for the northern Gulf Coast region.

The satsuma mandarin (*Citrus unshiu* Marc.) originated somewhere in Southeast Asia, but was first reported in Japan over 700 years ago (Ferguson, 1996). The satsuma was introduced to St Augustine, FL, in 1876 from the province of "Satsuma" in southern Japan. During the next several decades more than a million 'Owari' satsuma were imported from Japan and planted in the states bordering the Gulf of Mexico, from Florida to Texas. Although several thousand hectares of satsuma were established in the northern Gulf Coast states, severe periodic freezes, the most recent of which were the winters of 1984–85 and 1988–89, had all but eliminated satsuma orchards in this region. During the last 20 years, there has been a resurgence of interest in satsuma orchard establishment, and currently there are several hundred hectares in the Gulf Coast region. The use of soil mounding or commercial tree wraps around the trunk, and especially microsprinkler irrigation have all facilitated successful orchard reestablishment (Ebel et al., 2004; Nesbitt et al., 2000).

Satsuma mandarins, when grown on trifoliate orange [*Poncirus trifoliata* (L.) Raf.] rootstocks, are the most cold-hardy commercial citrus that are grown worldwide (Yelenosky, 1985). The mandarins include satsumas [e.g., 'Armstrong Early', 'Brown Select', 'Early St. Ann', 'Kimbrough', 'Owari' (most popular), and 'Silverhill'] and tangerines (e.g., 'Clementine', 'Dancy', 'Ponkan', 'Sunburst'). In some cases, the terms mandarin and tangerine are used interchangeably. For example, 'Dancy' is called a tangerine in Florida, but a mandarin in California. The satsuma is the best citrus for northern Florida for several reasons. First, when grafted on trifoliate orange rootstocks, it is an extremely cold-hardy commercial citrus species (Ferguson, 1996; McClendon, 2004; Yelenosky, 1985). Second, fruit maturation occurs from 15 Oct. to 15 Dec., well before the onset of minimum winter temperatures. Early fruit ripening is also desirable from a marketing perspective. Third, the flavor of satsumas is sweet; most fruit have no seeds; and the fruit is very easy to peel (Campbell et al., 2004). The satsuma is parthenocarpic (fruit set occurs without fertilization or seeds), and does not require a pollenizer cultivar.

The purpose of this study is to quantify tree growth, yield, and fruit quality of 'Brown Select' and 'Owari' satsuma cultivars on trifoliate orange [*Poncirus trifoliata* (L.) Raf. (standard and Flying Dragon)] rootstocks in northern Florida (Flying Dragon is a dwarfing rootstock). To our knowledge, tree size, yield, yield efficiency, and fruit quality of these genotypes have not been compared in the states bordering the Gulf of Mexico.

Materials and Methods

A 0.267-ha satsuma planting was established in June 2004 at the North Florida Research and Education Center in Quincy. The experimental design was a factorial design with two satsuma (*Citrus unshiu* Marcovitch) cultivars ('Owari' and 'Brown Select') and two trifoliate orange [*Poncirus trifoliata* (L.) Raf. (standard and Flying Dragon)] rootstocks. Each scion/rootstock combination was represented between 19 and 28 times. Citrus trees were spaced 4.57 and 6.10 m within and between rows, respectively. Soil type was Orangeburg loamy fine sand (Typic Paleuduff, Silaceous). Prior to planting, a 2-m-wide in-row strip was treated with glyphosate, and 2 weeks later the strips were rototilled. Trees were supplied with microjet irrigation and

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Table 1. Yield, fruit weight, soluble solids, and pH of 'Owari' and 'Brown Select' satsuma on *Poncirus trifoliata* (standard and Flying Dragon) rootstocks from 2007 to 2009.

	Yield (kg)[z]			Fruit wt (g)			Soluble solids (°Brix)			pH		
Scion/rootstock	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
Owari/PT (standard)	10.9	8.0	48.2 b	102 c	149	119	9.9 a	8.3 ab	9.8 b	3.70 b	3.70 ab	4.05
Owari/ PT (Flying Dragon)	10.9	7.3	44.9 b	111 bc	112	123	10.1 a	8.6 a	10.4 a	3.72 b	3.65 b	4.02
Brown Select/PT (standard)	12.1	6.9	87.2 a	143 a	195	134	8.8 b	8.0 b	9.6 b	3.81 a	3.71 ab	4.04
Brown Select/ PT (Flying Dragon)	14.6	11.2	57.7 b	128 ab	188	122	9.9 a	8.7 a	10.4 a	3.78 ab	3.76 a	4.00
Statistics												
Scion (S)	NS	NS	****	****	*	*	***	NS	NS	*	*	NS
Rootstock (R)	NS	NS	**	NS	NS	NS	***	***	****	NS	NS	NS
S × R	NS	NS	NS	NS	NS	****	*	NS	NS	NS	NS	NS

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[NS, *, **, ***, ****]Nonsignificant or significant at 5%, 1%, 0.1%, and 0.01% levels, respectively.

watered on an as-needed basis. Fertilizer 10N–10P–10K plus micronutrients were applied twice a year in March and again in July. Fertilization rates were 227 g per application in 2004–05, and 454 g per application 2006–09. The only freeze protection employed was by mounding the trunks with a pyramid or cone of soil to a height of 30–40 cm, although this was not performed in the winter of 2009–10.

Satsumas were harvested on 10–12 Dec. 2007, 8–9 Dec. 2008, and 2–7 Dec. 2009. Twenty representative fruit per tree were weighed as an estimate of average fruit weight. Three to five fruit per tree were juiced for measurements of soluble solids and pH. Soluble solids were measured with an Artesco Model PAL-1 digital refractometer. The pH of orange juice was measured with an Orion pH meter. Tree height and tree width (in north–south and east–west directions) were determined 7–9 May 2009. Tree canopy area was calculated as tree height × average tree width. Yield efficiency for 2009 was calculated as yield/tree canopy area.

The experimental design was a 2 × 2 factorial with two scions ('Owari' and 'Brown Select') and two rootstocks (standard and Flying Dragon trifoliate orange). Data were also subjected to analysis of variance and mean separation by Duncan's multiple range test.

Results and Discussion

Satsuma genotypes did not sustain any apparent cold injury from 2007 to 2010. Low temperatures recorded were as follows: 2007 (20.1 °F, –6.6 °C), 2008 (22.6 °F, –5.2 °C), 2009 (20.4 °F, –6.4 °C) and 2010 (15.3 °F, –9.3 °C). The only freeze protection employed was to mound the trunk with about 0.33 m of soil, although this was not done in the winter of 2009–10. Yield and fruit quality were quantified for satsuma in the fourth thru sixth years (2007–09) (Table 1). Yield per tree was relatively low in 2007 and 2008 (6.9–14.6 kg), and yield did not vary significantly as a function of scion or rootstock. In 2009, yield increased substantially (44.9–87.2 kg), and significant differences occurred as a function of scion and rootstock. Yield was highest for 'Brown Select' on the standard trifoliate orange rootstock. After a very heavy crop load for 2009, preliminary estimates of yield for 2010 appear to be very low, indicative of alternate bearing.

Average fruit weights were 121, 161, and 125 g for 2007, 2008, and 2009, respectively (Table 1). Fruit weight was significantly affected by scion during all 3 years, with 'Brown Select' (average = 152 g) being higher than 'Owari' (average = 119 g). There was no rootstock effect on fruit weight. Fruit weights on trifoliate orange standard and Flying Dragon averaged 140 and 131 g, respectively. When subjected to multiple comparison tests, significant differences in fruit weight occurred only in 2007, where the heaviest fruit were recorded for 'Brown Select' on the standard trifoliate rootstock.

Table 2. 2009 canopy area, yield efficiency (yield/canopy area), and fruit number per tree.

Scion/rootstock	Canopy[z] area (m^2)	Yield/canopy area (kg/m^2)	Fruit no.
Owari/PT (standard)	6.50 bc	7.39 b	407 b
Owari/PT (Flying Dragon)	5.21 c	8.50 ab	353 b
Brown Select / PT (standard)	9.20 a	9.18 a	662 a
Brown Select / PT (Flying Dragon)	7.07 b	8.57 ab	478 b
Statistics			
Scion (S)	****	*	****
Rootstock (R)	****	NS	**
S × R	NS	NS	NS

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[NS, *, **, ***, ****]Nonsignificant or significant at 5%, 1%, 0.1%, and 0.01% levels, respectively.

Fruit soluble solids were significantly impacted by rootstock during all three years (Table 1). Fruit on Flying Dragon were higher in sugar (average = 9.7 °Brix) than on the standard trifoliate orange rootstock (average = 9.1 °Brix). Significant scion effects occurred only during 2007. When subjected to multiple comparison tests, significant differences in soluble solids occurred during every year. The pH of orange juice was significantly affected by scion cultivar in 2007 and 2008, where 'Owari' tended to be slightly more acid than 'Brown Select'. This is consistent with the fact that 'Brown Select' ripens about 2 to 3 weeks earlier than 'Owari' (Powell and Williams, 1998).

In 2009, tree canopy area varied significantly as a function of scion and rootstock (Table 2). 'Brown Select' trees were larger than 'Owari' and the standard trifoliate trees were larger than Flying Dragon. A multiple comparison test showed that 'Brown Select'/*P. trifoliata* (standard) trees were largest, followed by 'Brown Select'/*P. trifoliata* (Flying Dragon), 'Owari'/*P. trifoliata* (standard) and 'Owari'/*P. trifoliata* (Flying Dragon). Yield efficiency, defined as yield/canopy area, was significantly affected by scion. Yield efficiency was highest for 'Brown Select'/*P. trifoliata* (standard) and lowest for 'Owari'/*P. trifoliata* (standard). In 2009, fruit number per tree varied significantly as a function of scion and rootstock. Multiple comparison tests revealed that fruit number was highest for 'Brown Select'/*P. trifoliata* (standard) trees.

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