Performance of Ambersweet, a new citrus hybrid cultivar, on two rootstocks in Florida

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ABSTRACT

INTRODUCTION. A study was conducted in Florida to evaluate the performance of a new citrus hybrid cultivar, Ambersweet orange, budded on two citrus rootstocks. **MATERIALS AND METHODS.**The effects of Cleopatra mandarin (CM) rootstock on leaf mineral concentration, tree growth, yield, fruit quality and economics were compared to those of Swingle citrumelo (SC). The trees were planted in 1989 at a density of 538 trees/ha. They were managed according to typical commercial practices. The experiment, consisting of five replications of four tree plots, was initiated in 1993 and continued through 1996. **RESULTS AND DISCUSSION.** No significant difference in leaf mineral concentration was found between the two rootstocks, with the exception of leaf Mg concentration which was lower with SC than with CM. Fruit produced on CM were large with rough, thick peel and poor color. SC rootstock promoted higher yield, earlier fruit maturity, and better fruit and juice quality than CM. The ratio between SC and CM in terms of yield (kg solids/ha) was 6 to 1, 8 to 1, 13 to 1, and 11 to 1 for 1993, 1994, 1995 and 1996, respectively. Financial analysis showed a negative balance for trees on both rootstocks, but there was an advantage with SC over CM. **CONCLUSION.** These preliminary results indicate that Ambersweet trees on SC were more precocious and more productive than those on CM.

KEYWORDS
Florida, *Citrus*, hybrids, rootstock crops, variety trials.

Effet comparé de deux porte-greffes sur le comportement du nouvel hybride d'agrumes Ambersweet en Floride.

RÉSUMÉ

INTRODUCTION. En Floride, un nouveau cultivar d'agrume, l'hybride Ambersweet, a été évalué, greffé sur deux porte-greffes : la mandarine Cléopâtre (MC) et le citrumelo Swingle (CS). **MATÉRIEL ET MÉTHODES.** Les deux porte-greffes ont été comparés à partir de leur effet sur la composition minérale des feuilles, la croissance et le rendement de l'arbre, la qualité du fruit et certains aspects économiques. Les arbres, plantés en 1989 à une densité de 538 arbres/hectare, ont reçu les soins culturaux classiques. L'expérimentation, constituée de cinq répétitions de quatre parcelles, a débuté en 1993 et s'est poursuivie jusqu'en 1996. **RÉSULTATS ET DISCUSSION.** D'un porte-greffe à l'autre, la seule différence significative touchant la teneur en éléments minéraux de la feuille a porté sur le taux de Mg, plus bas avec CS qu'avec MC. Les fruits produits sur MC sont gros, avec une peau épaisse, peu colorée. Par rapport à MC, le porte-greffe CS donne de meilleurs rendements, une maturité précoce du fruit et améliore la qualité des fruits et du jus. Le rapport des rendements de CS et CM, exprimés en kg/ha, a été de 6 à 1, 8 à 1, 13 à 1, et 11 à 1 pour 1993, 1994, 1995 et 1996, respectivement. L'analyse financière aboutit à une balance négative pour les deux porte-greffes, cependant CS confère un avantage par rapport à MC. **CONCLUSION.** Ces premiers résultats indiquent que le cultivar Ambersweet est plus précoce et plus productif sur CS que sur CM.

MOTS CLÉS
Floride, *Citrus*, hybride, plante porte-greffe, essai de variété.

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introduction

Ambersweet is a hybrid of [*Citrus reticulata* Blanco x (*C paradisi* Macf × *C reticulata*)] × midseason orange [*C sinensis* (L) Osb] developed by the United States Department of Agriculture (USDA) breeding program in Florida. This cross gives Ambersweet fruit, 1/2 orange, 3/8 mandarin and 1/8 grapefruit (HEARN, 1989).

Limited data through the years of development of Ambersweet orange cultivar revealed several attributes and good characteristics. The fruit ripens quite early in the season and serves both the fresh and processing markets. The fruit has good texture and is easy to peel. The juice has excellent flavor and dark-orange color (HEARN, 1989). Because Ambersweet juice exceeds the minimum color standards, it can be mixed with other juices that do not meet the government color requirements (BARROS et al, 1990). This will make the processing industry less dependent on imports and/or on Valencia juice that has to be stored the previous year to blend with poor-color Hamlin juice.

Ambersweet was released to growers in February 1989. Because it has many desirable qualities and attributes, this most recent released citrus cultivar was rapidly propagated and extensively planted throughout the Florida citrus industry. The inventory at the end of 1992 was estimated at more than five million planted Ambersweet trees (HEARN, 1992).

For the past several years, without taking into consideration tree age, Florida citrus growers, fresh fruit shippers and juice processors have had concerns about the quality of fruit and juice from Ambersweet trees. There has been even a perception about low fruit productivity of Ambersweet trees. In general, Ambersweet has not performed as well as expected for some people involved with the Florida citrus industry and a few growers have removed or topworked their Ambersweet trees.

Several more years of observations are needed to make fair evaluations on the role and performance of Ambersweet trees. Evaluation of Ambersweet trees under different field conditions, cultural practices, and stresses are important to help make wise decisions in managing Ambersweet successfully. Since on-site evaluation has many potential benefits for the grower, a study was initiated to assess the performance of Ambersweet orange trees budded on two rootstocks.

materials and methods

The experiment was conducted in LaBelle, Florida, to compare the effects of Cleopatra mandarin (*Citrus reshni* Hort ex Tan) (CM) with those of Swingle citrumelo [*(C paradisi* (L) × *Poncirus trifoliata* (L) Raf] (SC) on leaf mineral concentration, tree growth, yield, fruit quality, and economics of Ambersweet orange trees.

The trees were planted in December 1989 in such a way that the two rootstocks were side by side in separate rows at a spacing of 3.05 × 6.10 m and at a tree density of 538 trees/ha. The trees were managed according to typical commercial practices. They were irrigated as needed, using a microsprinkler irrigation system with one emitter per tree delivering 40 l/h. Fertilizer was applied at recommended rates for Florida citrus (KOO et al, 1984) and adjusted based on leaf analysis.

The soil was a Boca sand, poorly drained with a sandy surface, subsurface and subsoil layers to a depth of 60 to 90 cm. It is underlain by limestone and has a high water table. The organic matter content and natural fertility of the soil are low. The soil pH is 6.9 and the cation exchange capacity is 3.7 meq/100 g. The experiment was initiated in 1993 and consisted of five replications of four tree plots.

All samplings and measurements were conducted during the first half of November. Trunk circumference (C) was measured annually and trunk cross-sectional area (TCSA) was calculated:

$$TCSA = C^2 / 4 \pi.$$

Tree height (H) and width in two directions parallel (W1) and perpendicular (W2) to the tree row were measured and tree canopy volume (TCV) was calculated based on the assumption that the tree shape was one half prolate spheroid:

$$TCV = \pi/6 \times H \times W1 \times W2.$$

Fruit on each tree were counted. Samples of fifty fruit per plot from experimental and neighboring trees were collected for fruit quality measurements and evaluations. Fruit weight, juice weight, total soluble solids (TSS) and titratable acid concentrations, and juice color number were determined in the laboratory using standard procedures. For each rootstock, average fruit weight, boxes per acre, soluble solids/acid ratio, pounds soluble solids and juice per box (40.8 kg-field box) and per hectare, and yield efficiency were calculated:

Juice (kg/box) = [juice weight (kg) × 40.8 kg/box] / fruit weight (kg)

Solids (kg/box) = [juice (kg/box) × Brix (%)] / 100

Yield (boxes/ha) = [fruit/tree × fruit weight (g) × 538 trees/ha] / 1000 g/kg × 40.8 kg/box

Yield (kg solids/ha) = boxes/ha × solids (kg/box)

Yield efficiency (kg fruit/m^3 canopy) = [fruit/tree × fruit weight (g) × 10^{-3}] / TCV (m^3)

Expenses per acre were analyzed using cost of production or grove care and pick and haul. Costs of pick and haul per box were estimated at $1.80 from 1993 through 1996. Costs involving land investment and grove establishment were not included in the analysis. Returns per acre were computed using yield data and average seasonal prices of soluble solids. Prices of soluble solids per kg were estimated at $1.43, $1.87, $2.31, and $2.20 in 1993, 1994, 1995, and 1996, respectively.

Eighty 4-6-month-old leaves per plot from non-bearing shoots were sampled. Leaf samples were analyzed in the laboratory using standard procedures. They were analyzed for nitrogen (N) by the micro-Kjeldahl method and for the other nutrients by an inductively coupled argon plasma (ICAP) spectrophotometer. With the exception of the data related to economics, statistical analysis was conducted using the *t*-test.

results and discussion

Effects of rootstocks on leaf mineral concentration, growth, yield, fruit size, and quality of citrus scion cultivars have been reported (Gardner and Horanic, 1961, 1966; Rouse and Maxwell, 1979; Monteverde et al, 1988; Continella et al, 1988; Fallahi et al, 1989; Grisoni et al, 1989; Roose et al, 1989; Fallahi and Rodney, 1992; Economides and Gregoriou, 1993).

leaf mineral concentration

Between the two rootstocks, leaf mineral status differed only in Mg concentration. Leaf Mg concentration was significantly lower with SC than with CM (table I). In the fall, leaf Mg deficiency symptoms were visible on trees on SC. Magnesium deficiency symptoms and low leaf Mg concentration of trees on SC might have been aggravated by the K-Mg antagonism and translocation of Mg from leaves to satisfy fruit requirements of a relatively heavy crop for trees on SC rootstock.

Leaf mineral concentration values were compared to Florida citrus leaf standards (Koo et al, 1984). Leaf N concentration was within the optimum range. Leaf P concentration was at the satisfactory to the high level. Leaf K concentration was in the excessive range. It seems that Ambersweet trees accumulate high amounts of K in their leaves. Leaf Ca concentration was within the satisfactory range. Differences in nutritional status among citrus rootstocks have been well documented (Continella et al, 1988; Fallahi and Rodney, 1992; Zekri and Parsons, 1992; Zekri, 1993a, 1993b, 1995). These differences could be attributed to the differential ability of the rootstocks to absorb water and nutrients and to the physical differences between the root systems (Zekri and Parsons, 1989). These differences can further affect growth, yield, and fruit quality of the scion cultivar.

tree size and growth

Rootstocks affected tree shape and growth habit. Trees on CM had a distinctive upright growth habit, while those on SC

Table I
Leaf mineral concentration of Ambersweet trees planted in 1989 and budded on Cleopatra mandarin (CM) and Swingle citrumelo (SC).

Measurement year	*Rootstock*	*Element (%)* Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
1993	CM	2.87	0.18	2.55	0.31	3.19
	SC	2.86	0.17	2.49	0.28	3.26
1994	CM	2.67	0.17	2.78	0.25*	4.07
	SC	2.63	0.18	2.61	0.20	4.32
1995	CM	2.65	0.21	2.71	0.30*	3.42
	SC	2.70	0.22	2.50	0.25	3.41
1996	CM	2.69	0.22	2.42	0.32*	3.20
	SC	2.78	0.22	2.27	0.26	3.19

For each year, mean values with (*) are significantly different for the two rootstocks at the 5% level.

Table II
Trunk cross sectional area (TCSA), tree canopy volume (TCV), fruit weight, yield, and yield efficiency (YE) of Ambersweet trees planted in 1989 and budded on Cleopatra mandarin (CM) and Swingle citrumelo (SC).

Measurement year	*Rootstock*	*TCSA (cm^2)*	*TCV (m^3)*	*Fruit weight (g)*	*Fruit/tree*	*Boxes/ha*	*Solids/ha (kg)*	*YE (kg/m^3)*
1993	CM	31.16	3.27	353	2.57	11.96	18.06	0.28
	SC	27.29	3.12	336	13.19**	58.44**	108.70**	1.42**
1994	CM	55.16	7.61	379**	7.39	36.93	67.21	0.37
	SC	50.84	6.98	304	61.43**	246.25**	571.30**	2.68**
1995	CM	85.75	16.19	392*	9.35	48.33	85.06	0.23
	SC	65.49	14.17	321	124.88**	528.59**	1136.47**	2.83**
1996	CM	110.54*	21.53	368*	13.95	67.69	105.60	0.24
	SC	80.33	20.11	314	155.40**	643.43**	1235.39**	2.43**

[1] field box = 40.8 kg.
For each year, mean values with (*) or (**) are significantly different for the two rootstocks at the 5% or 1% level, respectively.

had a more open and drooping canopy. The more drooping appearance for trees on SC might have been influenced by the relatively heavy crop load. The weight of fruit might have caused the branches to bend downwards which gave the trees on SC a more open spreading canopy shape compared with those on CM.

Trunk cross sectional area (TCSA) and tree canopy volume (TCV) of trees grown on CM tended to be greater than those on SC rootstock, but differences were significant only in 1996 for TCSA (table II). From 1993 through 1995, TCV more than doubled from one year to the next. Canopy sizes of Minneola tangelo, Olinda Valencia, Washington navel (ROOSE et al, 1989) and Valencia (MONTEVERDE et al, 1988) trees on SC were also found similar to those on CM. However, TCSA of Marsh (ECONOMIDES and GREGORIOU, 1993) and TCV and TCSA of Redblush (FALLAHI et al, 1989) grapefruit trees were found to be higher for CM than for SC.

fruit size

Fruit from trees on CM were generally larger and heavier than those from trees on SC (table II). Visually, fruit from trees on CM also had thicker and coarser peel and were greener than fruit from trees on SC. ECONOMIDES and GREGORIOU (1993) reported similar results. However, MONTEVERDE et al (1988) and FALLAHI et al (1989) found similar fruit rind thickness in SC and CM. Fruit weight and size in the present study are not consistent with those of MONTEVERDE et al (1988), FALLAHI et al (1989) and ECONOMIDES and GREGORIOU (1993) which did not detect significant differences between SC and CM. The results of these studies also differ from that of ROUSE and MAXWELL (1979) which showed larger fruit size for trees grown on SC as compared with trees on CM. This conflict between results could be attributed to the young age of the trees and the significant reduction in fruit number per tree for CM. In general, fruit size is negatively correlated with fruit number per tree. The fewer the fruit on the tree, the larger and heavier are the fruit.

fruit yield

Every year, trees on SC produced significantly more fruit than those on CM rootstock (table II). The ratio between SC and CM in terms of kg solids/ha was 6 to 1, 8 to 1, 13 to 1, and 11 to 1 for 1993, 1994, 1995, and 1996, respectively. The mean fruit yield increased with age. From 1993 to 1994, fruit production increased five-fold for SC and less than three-fold for CM. From 1994 to 1995, fruit production doubled for SC, but increased by only 27% for CM. From 1995 to 1996, fruit production increased by 24 and 49% for SC and CM, respectively.

Although trees on both rootstocks bloomed normally, those on CM set less fruit which reduced yield significantly compared with trees on SC. Ambersweet orange trees on SC outproduced trees on CM by a large margin. In the present study, Ambersweet trees on CM rootstock grew well but fruited poorly during these first few years. This is consistent with GARDNER and HORANIC (1961) who concluded that scions on CM were not precocious but produced moderately large crops 10-15 years after planting. Higher yields on SC than on CM were also found for Marsh grapefruit (ECONOMIDES and GREGORIOU, 1993), Minneola tangelo (ROOSE et al, 1989) and Redblush grapefruit (ROUSE and MAXWELL, 1979). However, no differences in yield between SC and CM were reported for Redblush grapefruit (FALLAHI et al, 1989), Valencia orange (MONTEVERDE et al, 1988) and Olinda Valencia and Washington navel (ROOSE et al, 1989). In another study, HEARN (1989) did not find a significant difference in 10-year cumulative yield of Ambersweet trees on four rootstocks including CM. All these results indicated the inconsistency in yield differences as affected by CM and SC rootstocks which could be attributed to differences in scion cultivars, tree age, climatic conditions, and soil characteristics.

fruiting efficiency

In this experiment, yield efficiency (YE) expressed as kg fruit per cubic meter of canopy varied with rootstock (table II). Because trees on both rootstocks were of similar size and trees on SC yielded more than those on CM, trees on SC were more efficient producers. High YE combined with small tree size makes SC a very attractive rootstock for high density plantings. These results agree with earlier reports of higher YE, expressed as kg fruit per unit of TCV and/or TCSA of grapefruit (FALLAHI et al, 1989; ECONOMIDES and GREGORIOU, 1993), tangelo and Olinda Valencia (ROOSE et al, 1989) on SC as compared with trees on CM. In those studies, YE was due to greater production and/or smaller TCV and TCSA with SC as compared to CM. There was, however, no significant difference in YE between SC and CM with Valencia (MONTEVERDE et al, 1988) and Washington navel (ROOSE et al, 1989) because yield and canopy size with the two rootstocks were the same.

fruit quality

Internal fruit quality from trees on SC was superior to that from trees on CM. Percent Brix, pounds solids and juice per box were all significantly higher with SC than CM (table III). Differences between the two rootstocks in internal fruit quality were expected because of unequal fruit size and fruit number per tree. In general, the larger the fruit and the thicker the peel, the lower the juice content and soluble solids are in the juice. Juice content of Marsh grapefruit on SC was also higher than that of fruit from trees on CM (ECONOMIDES and GREGORIOU, 1993). In another study, the Brix levels in fruit from 14-year-old Ambersweet trees on CM, sour orange, and Carrizo citrange were very similar, but higher than from trees on rough lemon rootstock (HEARN, 1989). Other workers also found that fruit quality of citrus scion cultivars was affected by rootstocks (GARDNER and HORANIC, 1961, 1966; CONTINELLA et al, 1988; FALLAHI et al, 1989; FALLAHI and RODNEY, 1992; ECONOMIDES and GREGORIOU, 1993). MONTEVERDE et al (1988), however, found no significant difference in fruit quality between trees on SC and trees on CM probably because yield, fruit number, and canopy volume of trees on the two rootstocks were the same.

Higher total soluble solids and lower titratable acid in the juice significantly increased the Brix/acid ratio with SC compared to CM (table III). FALLAHI et al (1989) reported no differences in percent juice and total soluble solids, but higher acid and a lower ratio with SC as compared to CM. In Florida, Brix and Brix/acid ratio are the main factors judging fruit maturity. The higher the Brix and the Brix/acid ratio, the earlier is fruit maturity. Therefore, SC promoted earlier maturity of Ambersweet orange than CM rootstock, a very important advantage for the fresh fruit market. The earlier the fruit reaches the market, the higher is the return.

juice color

Juice color number or score was higher with SC compared with that for CM (table III). Juice color of the fruit from the scion cultivar can be affected by the rootstock. In early to mid-November, the juice color number ranged from 33.64 to 35.73. A score of 36 is necessary for grade A orange juice and 32 to 35 for grade B juice (STEWART, 1980). The juice from these Ambersweet trees did not meet the minimum color score of 36 needed to make grade A orange juice.

In another study, juice color numbers of fruit from 15-year-old Ambersweet trees ranged from 35.3 to 36.3 in mid-October to mid-November and from 36.5 to 38.0 in early to mid-December (BARROS et al, 1990). These workers concluded that juice color improved as the season progressed and Ambersweet orange was desirable to the processor for blending to improve the color of other orange cultivars. Differences

Table III
Fruit quality of Ambersweet trees planted in 1989 and budded on Cleopatra mandarin (CM) and Swingle citrumelo (SC).

Measurement year	*Rootstock*	*Brix (%)*	*Acid (%)*	*Ratio*	*Juice (kg/box)*	*Solids (kg/box)*	*Color number*
1993	CM	7.60	0.57*	13.33	19.91	1.51	–
	SC	8.75*	0.54	16.20*	21.18*	1.86*	–
1994	CM	8.45	0.54*	15.65	21.50	1.82	33.91
	SC	9.85*	0.49	20.10*	23.56*	2.32*	35.12*
1995	CM	8.33	0.56*	14.88	21.07	1.76	34.36
	SC	9.37*	0.51	18.37*	22.90*	2.15*	35.73*
1996	CM	7.97	0.53*	15.33	19.59	1.56	33.64
	SC	8.83*	0.45	19.62*	21.76*	1.92*	33.95

[1] field box = 40.8 kg. For each year, mean values with (*) are significantly different for the two rootstocks at the 5% level.

Table IV
Financial analysis ($/ha) of Ambersweet trees planted in 1989 and budded on Cleopatra mandarin (CM) and Swingle citrumelo (SC).

Measurement year	*Rootstock*	*Production costs*	*Pick and haul*	*Total expenses*	*Revenue*	*Balance (–)*
1993	CM	1605.50	21.53	1627.03	25.83	1601.20
	SC		105.19	1710.69	155.44	1555.25
1994	CM	1605.50	66.47	1671.97	125.68	1546.29
	SC		443.25	2048.75	1066.33	982.42
1995	CM	1729.00	86.99	1815.99	196.49	1619.50
	SC		951.46	2680.46	2625.25	55.21
1996	CM	1605.50	121.84	1727.09	232.32	1495.02
	SC		1158.17	2763.67	2717.86	45.81

Pick and haul costs are based on $1.80/box. Revenue is based on $1.43, $1.87, $2.31 and $2.20/kg solids of early oranges for 1993, 1994, 1995 and 1996, respectively.

in juice color number results between the present study and that of BARROS et al (1990) could be attributed to differences in tree age and sampling dates.

economics

Financial analysis showed a negative balance for trees on both rootstocks (table IV). At 6 and 7 years of age, Ambersweet orange trees on SC were about to break-even, while on CM they were still losing 1 500 to $1 600/ha. Therefore, there is a financial advantage with SC over CM as a rootstock for Ambersweet orange. The early yield and return with SC rootstock compared with CM are advantageous for the citrus growers.

conclusion

Preliminary results indicate that Ambersweet orange trees performed better on SC than on CM. Trees on SC were more precocious and more productive than those on CM. Based on this study, CM is not a good choice as a rootstock for Ambersweet orange due to its poor yield, fruit quality, and juice. This study is still in progress to find out for how long this trend will hold.

The early yield and return of SC still remain an important advantage over CM although fruit production and quality with CM may improve as the trees get older.

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Efecto comparado de dos portainjertos en el comportamiento del nuevo híbrido de cítricos Ambersweet en Florida.

RESUMEN

INTRODUCCIÓN. En Florida, se evaluó el híbrido Ambersweet, un nuevo cultivar de cítrico, en dos portainjertos: la mandarina Cleopatra (MC) y el citrumelo Swingle (CS). **MATERIAL Y MÉTODOS.** Los dos portainjertos se compararon basándose en su efecto sobre la composición mineral de las hojas, el crecimiento y el rendimiento del árbol, la calidad del fruto y algunos aspectos económicos. Los árboles, plantados en 1989 en una densidad de 538 árboles por hectárea, recibieron los cuidados de cultivo clásicos. La experimentación, constituida por cinco repeticiones de cuatro parcelas, comenzó en 1993 y se continuó hasta 1996. **RESULTADOS Y DISCUSIÓN.** De un portainjerto a otro, la única diferencia significativa relativa al contenido de elementos minerales de la hoja fue la proporción de Mg, inferior en el CS que en la MC. Los frutos producidos por la MC son grandes, de piel espesa y poco coloreada. Respecto a la MC, el portainjerto CS da un mejor rendimiento, una madurez precoz del fruto y mejor calidad tanto de los frutos como del jugo. La relación de los rendimientos de CS y MC, expresados en kg/ha, fue de 6 a 1, 8 a 1, 13 a 1 y 11 a 1 en 1993, 1994, 1995 y 1996 respectivamente. El análisis financiero resultó en un saldo negativo para ambos portainjertos, pero el CS tiene una ventaja respecto a la MC. **CONCLUSIÓN.** Estos primeros resultados indican que el cultivar Ambersweet es más precoz y más productivo en CS que en MC.

PALABRAS CLAVES

Florida, *Citrus*, hibridos, plantas para patrón, ensayos de variedades.