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COMPARISON OF YIELDS BY TREE AGE AND ROOTSTOCK IN SOUTHWEST FLORIDA ORANGE GROVES

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Abstract. **A study to provide citrus managers with information on high-density citrus plantings in southwest Florida was initiated in the early 1990s. The first report has been published (Roka et al., 1997), providing yield data for 'Hamlin' and 'Valencia' sweet oranges [*Citrus sinensis* (L.) Osb.] for nine-year-old trees. This paper is a summary of the southwest Florida yield study for trees 13 years of age. Analysis of yield comparisons between Swingle citrumelo (*C. paridisi* × *Poncirus trifoliata*) and Carrizo citrange (*C. sinensis* × *P. trifoliata*) rootstocks found a numerical but not consistent statistical difference under commercial production.**

Citrus acreage in southwest Florida expanded from 72,480 acres in 1985 to 179,093 acres in 1995 (Fla. Ag. Stat. Serv. (FASS), 1986-96). Much of this southern expansion was a result of growers' decisions to achieve a measure of freeze protection. During the 1980s devastating freezes destroyed more than 220,000 acres of Florida citrus, primarily in the northern production region (i.e., Lake, Orange, Marion, and Pasco Counties) (Attaway, 1997).

For many growers, it was their first experience growing citrus under southwest Florida climate and soil conditions. In addition to new growing conditions, tree densities in the new plantings increased from the previous state average of 100 trees per acre in 1988 to more than 150 trees per acre in 1998 (FASS, Commercial Citrus Inventory, 1988, 1998). Southwest Florida growers had little published information to guide them in setting realistic yield expectations. Much of their information was based on yield-age profiles developed by Zach Savage during the 1950s. Savage's yield profiles, however, reflected deep-sand, central ridge growing conditions and tree densities between 48 and 70 trees per acre (Savage, 1960).

In 1990, members of the Southwest Florida Citrus Advisory Committee requested that new yield profiles be developed for the important citrus varieties being grown in the southwest Florida flatwood region. The objective of this paper is to summarize the yield data collected from southwest Florida groves and present yield profiles for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' varieties through thirteen years of age. Further, yield differences between Swingle and Carrizo rootstocks are discussed. This paper updates earlier results reported during the 1996 FSHS conference in Orlando (Roka, et al., 1997).

Materials and Methods

The current study was initiated in 1994 by soliciting grower-cooperators to provide annual yield data from selected blocks. The study blocks had to have been planted since 1985, planted to a single scion-rootstock combination, and managed uniformly. Blocks were chosen to represent "typical" growing conditions within the grove. Neither the best nor poorest blocks were to be included in the study. Block size (net tree acres) was not controlled. By assuming that a block (whatever size) was managed as a single unit, yield data from individual blocks could be reduced to boxes and pounds solids per acre. Further, by not controlling block size, the study did not impose additional record keeping burdens on grove personnel.

After a block was selected, the grove manager filled out a general information sheet, describing block size, planting date, tree spacing, bed configuration, irrigation system, predominate soil types, and general fertilization practices. Annual harvest data were requested from the time the block had been planted. Harvest data included total boxes harvested for the fresh market, boxes harvested for processing, and total pounds solids delivered to the processing plant. Grove managers were also asked to report the number of trees removed and reset annually, whether the block had been hedged or topped, and approximate fertilization rates. Data summary sheets were developed for each block. At the end of each subsequent harvest period, the summary sheets were sent back to the grove managers for updating.

Tree age in this study was referenced against a 1 May planting date. For any block planted prior to 1 May in a given year, the harvest season of that calendar year was counted as "year one." For blocks planted after 1 May, "year one" did not begin until the next calendar year. For example, year-one for a block planted Apr 1993 was the 1993-94 harvest season. Alternatively, year-one for a block planted June 1993 was the 1994-95 harvest period. A 1 May date was selected as a reference planting date because it ensured that all blocks of the same age cohort would have gone through the same number of possible bloom cycles.

Data from the summary sheets were organized into spreadsheets and sorted by scion variety, rootstock, and tree age. Despite being planted in different years, yields of similar aged blocks were grouped and analyzed together. Annual harvest data from the blocks were converted to boxes per acre and pounds solids per box. In this paper, pounds solids per acre were derived by multiplying average boxes per acre by average pounds solids per box. For each sorted group, means and standard deviations were calculated by tree age for boxes per acre and pounds solids per box. Statistical differences in yields among scion varieties and rootstocks were analyzed using the standard T-test.

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Initial study blocks included only four scion variety-rootstock combinations—'Hamlin'/Swingle, 'Hamlin'/Carrizo, 'Valencia'/Swingle, and 'Valencia'/Carrizo. Over the next few years, the range of study blocks expanded to include 'Rohde Red Valencia' and red grapefruit scion varieties. By 1996, the study was tracking 59 blocks, representing nearly 4,000 acres. Other blocks were added to the study in 1999 to increase diversity with respect to tree density and rootstock selection. The results presented in this paper represent almost 6,500 acres of round orange production from 88 individual blocks. Data from an additional 930 acres of grapefruit production were also collected, but this paper discusses only the data collected from round orange production. Table 1 lists the acreage and number of blocks by variety and rootstock. With the completion of the 1998/99-harvest season, fourteen blocks had reached 13 years of age. A few blocks are being tracked that were planted more than 13 years ago. However, a criteria of the study is not to report an annual yield value if there are less than four blocks with data at a given tree age.

Table 1. Number of study blocks, acreage, and participating groves by scion and rootstock.

Variety/Rootstock	Block (no.)	Acreage	Number of groves
Hamlin	29	2,117	12
Swingle	15		
Carrizo	11		
Other[z]	3		
Valencia	45	3,488	17
Swingle	17		
Carrizo	22		
Other	6		
Rohde Red Valencia	14	888	9
Swingle	9		
Carrizo	4		
Other	1		
Total Orange Blocks	88	6,493	
Grapefruit	16	930	8
Swingle	9		
Carrizo	7		
Total Study	104	7,423	

[z] Other rootstocks include, rough lemon (*C. jambhiri*), cleo (*C. reshni*), and sour orange (*C. aurantium*).

Table 2 summarizes the study blocks by scion variety, block size, tree age, and tree density. Blocks ranged from nine to 212 net tree acres. On average, blocks are between 63 and 78 net tree acres. All study blocks are at least six years old and the average tree age for all scion varieties is between 11 and 12 years. A few blocks are as old as 18 years. Tree density averages near 150 trees per acre. Tree density ranges from a 'Hamlin' block of 91 trees per acre to a 'Rohde Red Valencia' block with 277 trees per acre. Coincidentally, the 'Rohde' block with 277 trees per acre is also the youngest block in the study (six years old). All blocks were planted on two row beds and were irrigated. Except for ten blocks, which utilized seep irrigation, low volume micro-jet irrigation systems were in place on the study blocks.

For the most part, the study cooperators are part of large, well-organized citrus operations. These operations perform good grove management practices and keep accurate records of their harvests and production inputs. Therefore, it is expected that the averages reported in this paper would be above state-wide production averages.

Results and Discussion

Variety differences. Average boxes per acre increased through nine years of tree age for each scion variety, regardless of rootstock. Table 3 presents average boxes per acre by tree age for 'Hamlin', 'Valencia', and 'Rohde Red Valencia'. Table 4 presents average pounds solids per acre by tree age for the same three scion varieties. Since tree age cohorts were planted in different years, the values in Tables 3 and 4 should be interpreted as long-run expected averages by tree age. By grouping similar aged blocks planted in different years, seasonal weather and production variability have been averaged.

'Hamlin' blocks peaked at 524 boxes per acre in year ten. By age nine, 'Valencia' blocks produced an average of nearly 400 boxes per acre, while 'Rohde Red Valencia' approached 450 boxes per acre. Between nine and twelve years, production plateaued with 'Hamlin' blocks producing between 502 and 524 boxes per acre and 'Valencia' blocks producing between 342 and 391 boxes per acre. Average production in 13 year old trees dropped to 444 boxes per acre, more than a ten percent decline from the previous year. However, it was unclear whether this reduction is a reflection of a limited number of 13 year old blocks (7 blocks), or whether trees systematically start to

Table 2. Summary statistics describing net tree acres, tree age, and tree density of the study blocks.

Scion (number of blocks)	Units	Avg	Minimum	Maximum
Hamlin (29)				
	Acres	73	18	150
	Tree age (yrs)	12	8	18
	Density (trees/acre)	149	91	189
Valencia (45)				
	Acres	63	9	144
	Tree age (yrs)	12	7	14
	Density (trees/acre)	155	140	198
Rohde Valencia (14)				
	Acres	78	14	212
	Tree age (yrs)	11	6	17
	Density (trees/acre)	164	106	277

Table 3. Average boxes per acre by tree age for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' and indication of statistical significant yield differences between 'Hamlin' and 'Valencia' and between 'Valencia' and 'Rohde Red Valencia' as measured by T-tests.[z]

Tree Age	Hamlin	Valencia	Rohde Valencia	Hamlin vs. Valencia	Valencia vs. Rohde Valencia
		Boxes per acre			
2	57	83	15	ns	ns
3	137	111	120	ns	ns
4	258	202	176	ns	ns
5	355	309	333	ns	ns
6	446	345	332	*	ns
7	468	384	404	*	ns
8	496	387	449	*	ns
9	502	391	447	*	ns
10	524	348	357	*	ns
11	504	381	328	*	ns
12	513	342	387	*	ns
13	444	341	325	*	ns

[z]An '*' indicates the difference between the two means is significant at the 95% confidence level.
An 'ns' indicates no significant difference between the two means.

decline. Thirteen year old 'Valencia' and 'Rohde Red Valencia' blocks appeared to be maintaining their production levels. Again, however, both scion varieties have a limited number of blocks at that age, five and two blocks, respectively.

From three years of tree age onward, 'Hamlin' blocks produced more boxes per acre than did 'Valencia' blocks. These yield differences became statistically significant by six years of tree age when 'Hamlin' blocks produced between 100 and 120 more boxes than 'Valencia' blocks. Statistically significant yield differences between standard 'Valencia' and 'Rohde Red Valencia' blocks were not found among the respective study blocks. An important caveat to note is that scion clone identification numbers were not collected with the study block data. Data from the Southwest Florida Budwood Foundation Grove have indicated wide production variability among Rohde clones (Rouse and Youtsey, 1993; Rouse, 2000).

Pounds solids per box increased through the first ten years of tree age for all scion varieties (Table 4). Pounds solids per box appeared to reach a plateau between ten and thirteen years of tree age. At every tree age, more pounds solids per box are produced from 'Valencia' than from 'Hamlin' trees. The differences were statistically significant after four years. Eight year old 'Hamlins' produced 5.23 pounds solids per box. Eight year old 'Valencias' produced 6.51 pounds solids per box, 1.3 pounds solids per box more than 'Hamlins'. Pounds solids per box were not significantly different between standard and 'Rohde Red Valencia' clonal selections through 13 years of tree age.

Multiplying average boxes per acre with average pounds solids per box provided an estimate of pounds solids per acre by tree age. While a statistical test was not possible, it appears that after age five, 'Hamlin' blocks consistently yield more pounds solids per acre than do 'Valencia' blocks (Table 5). Average 'Hamlin' blocks peaked at more than 3,000 pounds solids during year ten, while maximum pounds solids production on a 'Valencia' was 2,550 during year nine. Between seven and thirteen years of age, 'Rohde Red Valencia' blocks produced between 2,200 and 2,800 pounds solids per acre, annually. There does not seem to be any clear year-to-year pattern when pounds solids production from Rohde blocks were compared against standard 'Valencia' blocks.

Rootstock differences. The study blocks were further sorted and analyzed to determine whether Carrizo and Swingle had an effect on production. A stated hypothesis among growers and researchers is that Carrizo, a more vigorous rootstock, would produce greater yields. To some extent, yield averages

Table 4. Average pounds solids per box by tree age for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' and indication of significant yield differences between 'Hamlin' and 'Valencia' and between 'Valencia' and 'Rohde Red Valencia' as measured by T-tests.[z]

Tree Age	Hamlin	Valencia	Rohde Valencia	Valencia vs. Hamlin	Valencia vs. Rohde Valencia
		Pounds solids per box			
2	4.75	5.06	na	ns	ns
3	4.95	5.30	4.98	ns	ns
4	5.16	5.61	4.40	ns	ns
5	5.03	5.85	6.12	*	ns
6	5.39	6.15	5.64	*	ns
7	5.44	6.03	6.25	*	ns
8	5.23	6.51	6.23	*	ns
9	5.37	6.23	5.93	*	*
10	5.81	6.69	6.71	*	ns
11	5.69	6.57	6.59	*	ns
12	5.56	6.86	6.35	*	ns
13	6.09	6.67	6.82	*	ns

[z]An "*" indicates the difference between the two means is significant at the 95% confidence level.
An 'ns' indicates no significant difference between the two means.

Table 5. Estimated average pounds solids per acre by tree age for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' variety in southwest Florida.[z]

Tree Age	Hamlin	Valencia	Rohde Valencia
	Pounds solids per acre		
3	677	587	595
4	1,332	1,130	775
5	1,790	1,809	2,054
6	2,406	2,125	1,872
7	2,546	2,317	2,522
8	2,592	2,521	2,799
9	2,696	2,550	2,651
10	3,046	2,326	2,394
11	2,867	2,502	2,165
12	2,855	2,342	2,457
13	2,704	2,270	2,218

[z]Table values derived by multiplying corresponding values from Tables 3 and 4 (box/acre * ps/box).

presented in Table 6 confirm this belief. In nine out of ten years, the average yields from 'Hamlin' blocks with Carrizo rootstocks were numerically greater than blocks with Swingle rootstocks. On 'Valencia' varieties, Carrizo blocks outperformed Swingle blocks six out of ten years. Figures 1 and 2 illustrate the numerical differences in mean production between Carrizo and Swingle rootstocks over the age profile.

When statistical tests were applied, however, data from the study blocks failed to show any statistically significant yield differences between Carrizo and Swingle rootstocks both in terms of year-to-year comparisons and in terms of cumulative yield comparisons (Table 6). This "statistical insignificance" contradicts the common perception by suggesting that the observed yield differences between the two rootstocks are due more to chance than real horticultural effects. Perhaps soil and grove management practices, which this study cannot fully isolate, are masking production effects from these two rootstocks. Alternatively, the rootstock effect may be real, but its overall effect on commercial yields is small.

While the study blocks may not indicate a significant production effect from rootstocks, translating yield differences into economic terms suggest that growers do, in fact, see an economic gain from planting trees with Carrizo rootstocks. As an exercise, it was assumed that paired blocks of 'Hamlin' and 'Valencia' were planted to Swingle and Carrizo rootstock in 1986 and began to bear fruit during their third year, 1988. The yield differences, shown in Table 6, were valued using the early/mid and late season average on-tree prices reported by the Florida Agricultural Statistics Service (FASS, 1986-96). The right-hand columns of Table 6 show the annual monetary value of having planted Carrizo rootstock. Over the ten-year period, from 1986–1996, annual per-acre gross revenues from a 'Hamlin' block planted on Carrizo would have been $228 higher than a 'Hamlin' block planted on Swingle. The differences were not as dramatic with 'Valencia' varieties, but revenues from Carrizo blocks were on average $38 per acre higher than revenues from Swingle blocks.

Conclusions

The Southwest Florida Citrus Yield Study is an ongoing project to develop yield-age profiles for selected citrus scion varieties and rootstocks in southwest Florida. This paper pre-

Table 6. Monetary valuation of yield differences between Swingle and Carrizo rootstocks for 'Hamlin' and 'Valencia' sweet orange trees.

Age	Carrizo bx/acre	Swingle bx/acre	Production Difference bx/acre	Season avg price[z] $/bx	Annual value[y] $/acre	Cum. value $/acre
Hamlin			(Carrizo – Swingle)			
3	151	125	26	6.69	$174	$174
4	329	216	113	6.01	$679	$853
5	387	335	52	5.38	$280	$1,133
6	510	416	94	5.44	$511	$1,644
7	521	437	84	3.23	$271	$1,916
8	535	490	45	3.76	$169	$2,085
9	545	470	75	3.25	$244	$2,328
10	549	509	40	3.62	$145	$2,473
11	451	546	-95	3.18	-$302	$2,171
12	535	497	38	2.81	$107	$2,278
				Annual Avg $/acre	$228	
Valencia						
3	103	121	-18	8.41	-$151	-$151
4	216	175	41	6.53	$268	$116
5	299	292	7	6.58	$46	$162
6	356	311	45	6.65	$299	$462
7	367	397	-30	3.88	-$116	$345
8	406	389	17	4.61	$78	$424
9	376	420	-44	4.41	-$194	$230
10	339	357	-18	5.57	-$100	$129
11	405	370	35	4.07	$142	$272
12	351	329	22	4.88	$107	$379
				Annual Avg $/acre	$38	

[z]Season average on-tree prices for early/mid and late season varieties as reported by Fla. Agricultural Statistic Service from 1988/89 through 1998/99 season.
[y]Annual value equals the season average on-tree price multiplied by the yield differences between Carrizo and Swingle blocks.

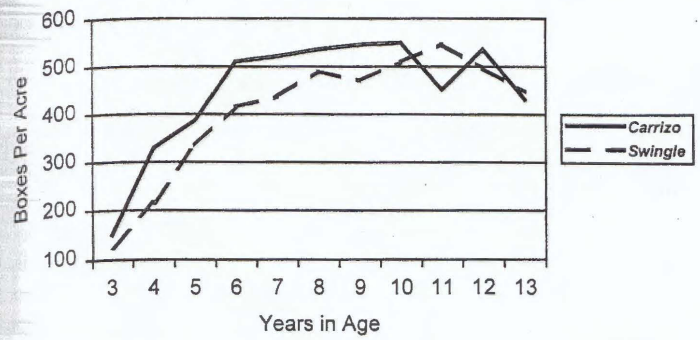

Figure 1. Estimated boxes per acre for 'Hamlin' by tree age and sorted by Swingle and Carrizo rootstocks.

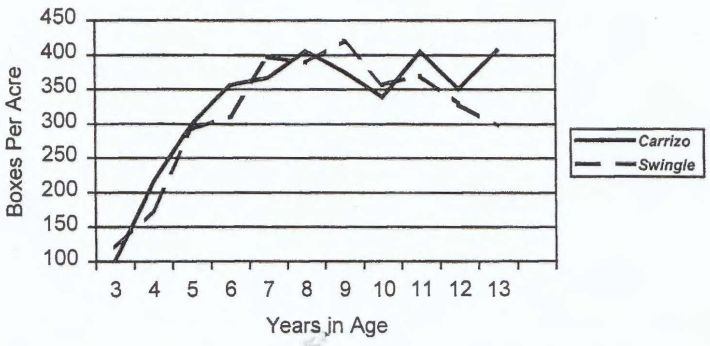

Figure 2. Estimated boxes per acre for 'Valencia' by tree age and sorted by Swingle and Carrizo rootstocks.

sents average yields for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' scion varieties through 13 years of tree age. 'Hamlin' blocks generally outperform 'Valencia' blocks in terms of boxes and pounds solids per acre. The reverse is true in terms of pounds solids per box, where 'Valencia' scion varieties produce more than 'Hamlin' scion varieties. While these results may confirm what growers already knew, this study provides growers with a benchmark from which to evaluate the performance of their own groves. Given the above average level of management among the growers who are participating in this study, the average yields reported from this study are likely to be higher than a region-wide average. However, long-term success will require a grower to set production goals at a level higher than a region-wide average. Therefore, the benchmark provided by this study should help growers achieve long-term success.

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EVALUATION OF ORANGE TREES BUDDED ON SEVERAL ROOTSTOCKS AND PLANTED AT HIGH DENSITY ON FLATWOODS SOIL

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Abstract. **The performance of 'Valencia' orange trees on Swingle citrumelo (Swi), Cleopatra mandarin (Cleo), Milam lemon (Mil), and Volkamer lemon (Volk) rootstocks was evaluated on the flatwoods soil of southwest Florida. Leaf mineral concentration, growth, fruit production and quality were measured four and seven years after planting in a closely-spaced setting (19 ft by 9 ft) in a commercial grove. Compared to Florida citrus leaf standards, leaf mineral concentration values were within the optimum to the high range. Yield efficiency expressed as lb solids/yard^3 of canopy and juice quality in terms of juice content, Brix, and lb solids/box increased with tree age. Tree and fruit size were the highest for Volk and the lowest for Cleo. Fruit yield was the highest for Volk. However, yield expressed in lb solids/acre was not significantly different between Volk and Swi due to the higher solids/box for Swi. Yield efficiency was also higher for Swi than for Volk. Juice content and soluble solids in the fruit were higher for Swi and Cleo than for both lemon rootstocks. Financial analysis showed that at high density planting, trees on Swi were the most profitable.**

Citrus is of major economic importance in many counties of Florida, with a total economic impact exceeding $8 billion a year. In Florida, citrus groves occupy approximately 845,000 acres with over 107 million trees (Florida Agricultural Statistics Service, 1999). Rootstocks have had a substantial role in the development of the Florida citrus industry. Prior to about

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