Koo, R. C. J., C. A. Anderson, I. Stewart, D. P. H. Tucker, D. V. Calvert, and H. K. Wutscher, eds. 1984. Recommended fertilizers and nutritional sprays for citrus. Univ. Fl. Ag. Exp. Stn. Bull. 536D.
Marler, T. E., J. J. Ferguson, and F. S. Davies. 1987. Growth of young 'Hamlin' orange trees using standard and controlled-release fertilizers. Proc. Fla. State Hort. Soc. 100:61-64.
Marler, T. E. and F. S. Davies. 1990. Microsprinkler irrigation and growth of young 'Hamlin' orange trees. J. Amer. Soc. Hort. Sci. 115:45-51.
Maurer, M. A. and F. S. Davies. 1994. Leaf nitrogen content effects on freeze hardiness of young 'Redblush' grapefruit trees. Proc. Fla. State Hort. Soc. 107:35-39.
Obreza, T. A. and R. E. Rouse. 1993. Fertilizer effects on early growth and yield of 'Hamlin' orange trees. HortScience 28:111-114.
Obreza, T. A. 1994. Program fertilization for densely-planted 'Hamlin' orange trees. Proc. Fla. State Hort. Soc. 107: 47-50.
Rasmussen, G. K. and P. F. Smith. 1961. Evaluation of fertilizer practices for young orange trees. Proc. Fla. State Hort. Soc. 74:90-95.
Taylor, C. L., J. J. Ferguson, G. D. Israel, and W. R. Summerhill. Citrus young tree care. Univ. Fl. Coop. Ext. Ser. Bull. PE-7.
Willis, L. E., F. S. Davies, and D. A. Graetz. 1991. Fertigation and growth of young 'Hamlin' orange trees in Florida. HortScience 26:106-109.
Zekri, M. and R. C. Koo. 1991a. Evaluation of controlled release fertilizers for young citrus trees. J. Amer. Soc. Hort. Sci. 116:987-990.
Zekri, M. and R. C. Koo. 1991b. Comparative effects of controlled release and soluble fertilizers on young 'Valencia' orange trees. Proc. Fla. State Hort. Soc. 104:199-202.

Proc. Fla. State Hort. Soc. 108:160-164. 1995.

AN ANALYSIS OF HOW PLANTING DENSITY AND ROOTSTOCK VIGOR AFFECT THE ECONOMIC PERFORMANCE OF 'VALENCIA' TREES

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Abstract. **For any given scion/rootstock combination, selecting the proper planting density is essential to maximize economic performance. This was demonstrated by comparing 15-year cash budgets and internal rates of return (IRR) for soluble solids production of trees on vigorous rootstocks (Carrizo citrange and Milam lemon) with those on less vigorous stocks (Swingle citrumelo and Rusk citrange). Data were obtained from long-term *Citrus sinensis* (L.) Osbeck 'Valencia' field trials located in Indiantown, Avon Park, and Babson Park. The analyses included adjustments for tree losses and annual replacement, and were based on current/constant costs applied throughout the 15-year period. Internal rates of return were about 6.5% or less for trees on Carrizo or Milam when grown at planting densities of 102 and 150 trees/acre, respectively. The IRR improved slightly for Milam when planted at 270 trees/acre suggesting that the optimum spacing can be exceeded; for trees on Carrizo planted at 145 trees/acre, the IRR increased to over 13.7%, one of the highest rates in this study. The economic performance of trees on Swingle was relatively poor at the low planting density; however, analyses of trees at actual and hypothetical planting densities in the range of about 218 to 270 trees/acre improved IRR to values greater than 14%.**

The high capital investment of land, irrigation, and establishment costs, along with increasing production, harvesting and regulatory costs, has led Florida citrus producers to seek the most efficient production methods. High tree density plantings (140 to 200 trees per acre) became the standard during the 1980's and early 1990's, enabling more efficient use of limited capital resources by maximizing production during the early development period. Previous economic investment analysis utilizing cash budget analyses have demonstrated the benefits of higher density citrus plantings (Muraro and Fairchild, 1985; Ford et al., 1989). However, these economic analyses assumed an average per tree yield performance without regards to scion/rootstock combination to planting density and to annual tree loss.

Utilizing yield data from three relatively large field experiments (Castle and Muraro, 1992; Wheaton et al., 1995) involving several rootstocks at various planting densities, this paper analyzes the returns of a citrus grove with respect to scion/rootstock combinations at tree densities ranging from 102 to 270 trees per acre. The information presented will demonstrate the economic importance of selecting a tree density with regard to tree vigor (size) that a rootstock may have, along with the effect of the potential tree loss rates associated with a particular rootstock.

Materials and Methods

The Valencia orange grove investment analyses for the ten scion/rootstock combinations and tree planting densities utilized a 15-year cash budget analysis. The actual annual per tree yield data collected from the above mentioned three field experiments were used and adjusted with respect to annual tree losses and additional yield provided by the reset trees (Castle et al., 1993; Castle, 1995; Wheaton et al., 1995). For comparison purposes, the Internal Rate of Return (IRR) was calculated for the ten scion/rootstock and planting density situations. The IRR is a form of discounted cash flow analysis where the annual cash flows are discounted using an interest rate at which the present value of the cumulative cash flows equal the initial capital investment. The initial capital investment was assumed to equal the first year annual net cash flow. The IRR represents an average annual rate of return, or yield, on the investment over the time period of the investment; 15 years in this paper.

Table 1 presents the capital investment costs used in the analysis. Two citrus growing areas in Florida were represented in the three experiments; south Florida flatwoods (Indiantown) and central Florida sand ridge (Avon Park and Babson Park). Land costs differ for each production region. The cost of land for the central sand ridge was assumed to be $2,250 per acre and for south Florida flatwoods $1,450 per acre.

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Table 1. Grove assumptions used in Valencia grove investment analysis.

	Indiantown	Avon Park	Babson Park
Proportion of land planted	85%	95%	95%
Initial capital investment per planted acre:			
Land[z]	$1,706	$2,368	$2,368
Land preparation[y]	1,529	474	474
Irrigation[x]	1,100	1,191	1,191
Total	$4,335	$4,033	$4,033
Trees planted per acre:			
Carrizo citrange	102	145	□
Swingle citrumelo	102/145[w]	145/218[w]	□
Milam lemon	□	□	150/270
Rusk citrange	□	□	150/270
Scion variety:	Valencia orange		
Annual tree loss:	Swingle citrumelo/Rusk citrange	Carrizo citrange	Milam lemon
1 -3 years	0.5%	1.5%	1.5%
4 - 10 years	1.0%	2.0%	2.5%
11 - 15 years	1.5%	3.0%	4.0%
Cumulative 15-year tree loss	16.0%	33.5%	42.0%

[z]Indiantown land cost per acre was $1,450 ÷ .85. Avon Park and Babson Park land cost per acre was $2,250 ÷ .95.
[y]Indiantown land preparation cost per acre was $1,300 ÷ .85. Avon Park and Babson Park land cost per acre was $450 ÷ .95.
[x]Irrigation costs are for microsprinkler systems and include well, pump tubing, sprinklers, and controls. Costs shown represent 102 trees per acre for Indiantown and 145/150 trees per acre for Avon Park and Babson Park. Irrigation costs were adjusted to reflect the higher densities.
[w]Indiantown at 145 trees per acre and Avon Park at 218 trees per acre are hypothetical planting densities.

However, each acre of purchased land cannot be totally planted. The unplanted land must be used for roads, ditches, canals, bedding/mounding, etc. Therefore, it was estimated that only 85% of the Indiantown site was planted and 95% of the Avon Park and Babson Park sites were planted. The actual land acquisition, land preparation and irrigation costs on a planted acre basis totaled $4,335 per acre for Indiantown and $4,033 per acre for Avon Park and Babson Park. The irrigation costs represent 102 trees per acre and 145/150 trees per acre for the two production regions, respectively. The budget analysis was adjusted to reflect the higher irrigation costs for the 218 and 270 trees per acre planting densities.

Table 1 also shows the rootstocks, planting densities and tree loss rates used in the analysis. The rootstocks chosen represent a vigorous and moderate growth/size tree. For Indiantown and Avon Park, Carrizo citrange (vigorous) and Swingle citrumelo (moderate) rootstocks were selected. The two rootstocks used in the Babson Park site were Milam lemon (vigorous) and Rusk citrange (moderate). The scion variety for each rootstock was Valencia orange.

The actual planting densities at the Indiantown and Avon Park sites were 102 (17' × 25') and 145 (12' × 25') trees per acre, respectively. The two actual planting densities selected from the Babson Park site were 150 (15' × 20') and 270 (8' × 20') trees per acre. After observing the trees planted at the lower densities for the scion/rootstock combinations, it was apparent that Swingle at the lower densities was inappropriate. Therefore, in addition to the above tree densities, two hypothetical tree densities were used for Swingle citrumelo rootstock to demonstrate vigor of trees at different spacings; 145 (12' × 25') trees per acre for Indiantown and 218 (10' × 20') trees per acre for Avon Park.

Tree loss rates varied between the four rootstocks and were divided into three age groups—1-3 years; 4-10 years; and 11-15 years. The cumulative 15-year tree loss for the moderate rootstocks (Swingle citrumelo and Rusk citrange) was 16%. The vigorous rootstocks (Carrizo citrange and Milam lemon) 15-year tree loss was 33.5% and 42%, respectively. These cumulative tree loss rates are representative of actual losses experienced for moderate and vigorous rootstocks at the Indiantown and Avon Park sites (Castle, 1995). Table 2 presents the fruit prices and costs used in the investment analysis. The base price per pound solids was assumed to be $0.90 and the harvesting cost was $1.90 per Florida field box. Annual cultural costs for a mature processed orange grove were based on 1994-95 costs published by the University of Florida, IFAS (Muraro et al., 1995a and 1995b). Miscellaneous costs (additional hand tools and labor) and supervision and overhead costs (grove manager, office supplies, telephone, etc.) were included in the total grove care costs. Tree removal and reset costs were in addition to the grove care costs and were based on the annual tree loss rates for each rootstock. However, for the 270 tree per acre density, it was assumed that only one-half of the trees removed would be replaced after year 11. Also, an interest charge on operating grove care costs and annual ad valorem property taxes costs were included in the cash budget analyses.

Results and Discussion

Investment analysis. The 15-year annual cash budgets were calculated to estimate the annual per acre return for each tree density and scion/rootstock situation described above. The breakeven year over all cash expenditures along with the Internal Rate of Return (IRR) were used as the measure for comparing the ten situations.

Referring to Table 3, the breakeven year, at which the first positive net income and the first positive cumulative annual cash flow occurs, is presented. All planting densities had a positive net income within 8 years. Carrizo citrange at 145 trees per acre and Swingle citrumelo at 218 trees per acre reached a positive net income by year 5. Rusk citrange at 270 trees per acre reached a positive net income by year 6. The remaining rootstock and tree density situations reached a net income by year 7 or 8.

Table 2. Prices, harvesting, planting, cultural and other costs used in the Valencia grove investment analysis.

	Indiantown	Avon Park	Babson Park
Price per pound solids	$0.90	$0.90	$0.90
Harvesting costs per box (pick, roadside and haul fruit)	$1.90	$1.90	$1.90
Annual grove care cost for a mature processed orange grove:			
Cultivation and herbicide	$196.05	$200.33	$200.33
Spraying	116.28	134.58	134.58
Fertilization	128.87	142.24	142.24
Hedging	23.05	21.60	21.60
Irrigation/ditch maintenance	161.60	131.38	131.38
Miscellaneous costs (3%)	18.78	18.90	18.90
Supervision and overhead (7%)	45.12	45.53	45.53
Total	$689.75	$694.56	$694.56
Tree removal cost per tree	$5.65	$5.65	$5.65
Tree planting cost (tree, stake, plant, etc.)			
Solidset[z]	$4.50	$4.50	$4.50
Reset trees[z]	$5.75	$5.75	$5.75

Annual grove care cost for young trees:

	Age of trees			
	1	2	3	4
	Per tree			
Solidset[y]	$3.42	$3.81	$3.65	$3.84
Reset tree	$2.63	$2.37	$1.76	□

[z]Includes: "bareroot tree" = $3.00; plant, stake and water solid tree = $1.00; tree wrap = $0.50; and plant, stake and water reset tree = $2.25.
[y]Represents costs for 145/150 trees per acre.

Only eight of the rootstock and tree density combinations had a positive cumulative cash flow after 15 years; e.g., all cumulative costs, including the initial capital investment of land, irrigation, and trees, were recovered. Swingle citrumelo at 218 trees per acre and Rusk citrange at 270 trees per acre had a positive cumulative cash flow by year 11. Carrizo citrange at 145 trees per acre and Rusk citrange at 150 trees per acre had a positive cumulative cash flow by year 12 and 13, respectively. Fifteen was the breakeven year over all cumulative costs for Swingle citrumelo at 145 trees per acre, Carrizo citrange at 102 trees per acre and Milam lemon at 270 trees per acre. However, the breakeven years for the low density Swingle citrumelo at 102 trees per acre and the Milam lemon at 150 trees per acre had not been reached by year 15. Swingle citrumelo at the low density was not appropriate due to the tree vigor associated with this rootstock. Likewise the higher annual tree loss of Milam lemon affected the total annual costs and returns during the last years of the investment analysis.

Referring to Table 4, the IRR's are presented for each tree density and scion/rootstock situation. As can be seen from column one, tree density has a major impact on the grove investment returns. Indiantown plantings at 102 trees per acre showed the lowest IRR; Carrizo citrange at 6.45% and Swingle citrumelo at -1.45%. Even the Indiantown hypothetical Swingle citrumelo tree density of 145 trees per acre, showed an IRR of only 5.45%. Babson Park Milam lemon at 150 trees per acre also had a low IRR at 4.95%. The Milam lemon low IRR was primarily due to the high tree loss rates used in the analysis.

The Avon Park Carrizo citrange at 145 trees per acre and the Babson Park Rusk citrange at 270 trees per acre had the highest IRR at 13.67 and 14%, respectively. Even the moderately vigorous rootstock Swingle citrumelo will provide a favorable IRR at higher tree densities as shown by the Babson Park hypothetical 218 trees per acre situation.

The three situations that provided moderate IRR were all at higher tree densities. Avon Park Swingle citrumelo at 145

Table 3. First positive net annual income and cumulative cash flow occurred for Valencia orange grove investment analysis.

	First positive net income	First positive cumulative cash flow[x]
	Year	
Indiantown		
Carrizo citrange (102 trees/acre)	7	15
Swingle citrumelo (102 trees/acre)	7	?
Swingle citrumelo[z] (145 trees/acre)	7	15
Avon Park		
Carrizo citrange (145 trees/acre)	5	12
Swingle citrumelo (145 trees/acre)	7	14
Swingle citrumelo[z] (218 trees/acre)	5	11
Babson Park		
Milam lemon (150 trees/acre)	8	?
Rusk citrange (150 trees/acre)	8	13
Milam lemon (270 trees/acre)	8	15
Rusk citrange (270 trees/acre)	6	11

[z]Hypothetical tree densities.
[x]Excludes ending grove value in year 15.

Table 4. Internal Rate of Return (IRR) for Valencia orange grove investment analysis showing the sensitivity of grove returns to changes in price, cost and yield.

		% change in price		% change in cost		% change in yield	
	With no change	+15	-15	+15	-15	+15	-15
	Internal Rate of Return (%)						
Indiantown							
Carrizo citrange (102 trees/acre)	6.45	9.92	1.58	4.51	8.30	8.95	3.30
Swingle citrumelo (102 trees/acre)	-1.45	3.12	-10.02	-5.05	1.50	1.89	-6.45
Swingle citrumelo (145 trees/acre)[z]	5.45	8.98	0.40	3.41	7.38	7.98	2.22
Avon Park							
Carrizo citrange (145 trees/acre)	13.67	17.09	9.33	12.17	15.18	16.02	10.91
Swingle citrumelo (145 trees/acre)	9.42	12.81	4.96	7.71	11.11	11.81	6.52
Swingle citrumelo (218 trees/acre)[z]	15.19	18.48	11.10	13.79	16.63	17.48	12.53
Babson Park							
Milam lemon (150 trees/acre)	4.95	8.63	-0.43	2.83	6.96	7.46	1.74
Rusk citrange (150 trees/acre)	9.38	12.78	4.83	7.62	11.09	11.79	8.63
Milam lemon (270 trees/acre)	9.53	12.74	5.25	7.96	11.12	11.67	6.94
Rusk citrange (270 trees/acre)	14.00	17.03	10.22	12.64	15.40	16.14	11.49

[z]Indiantown at 145 trees per acre and Avon Park at 218 trees per acre are hypothetical planting densities.

trees per acre had an IRR of 9.72% and Babson Park Rusk citrange at 150 trees per acre and Milam lemon at 270 trees per acre had an IRR of 9.38 and 9.53%, respectively. Again, Milam lemon at 270 trees per acre had a lower IRR due to the high tree loss rate.

The investment analysis discussed above was also repeated to evaluate the sensitivity that a change in price, cost or yield would have on the grove investment's IRR. Shown in Table 4 are the affects of a + or - 15% change in the price, cost, and yield. The IRR was calculated by increasing, or decreasing, one variable by 15% and keeping the remaining two variables constant. The 15% was chosen as the variable amount and appeared to be reasonable from earlier price forecasts (Brown and Lesser, 1995). For example, at a $0.90 price per pound solids, a 15% increase would result in a price of $1.03 per pound solids; likewise, a 15% decrease would result in a price of $0.77 per pound solids. As can be seen from Table 4, the greatest impact on IRR resulted from a change in price. An increase or decrease in yield showed a moderate impact on IRR, somewhat less than price while a change in cost had the least impact.

Conclusion

This paper compared the breakeven year and IRR of ten scion/rootstock combinations for planting densities ranging from 102 to 270 trees per acre. As shown, lower tree densities (102 trees per acre), even when vigorous rootstocks are used, resulted in a later breakeven year or in a low IRR. Moderately vigorous rootstocks actually result in negative returns on the grove investment. Tree densities of 145 to 270 trees per acre had the earliest breakeven year and the highest IRR for both the vigorous and moderate rootstocks.

Since a citrus grove is a highly capitalized, long-term investment, it is important to evaluate the economic feasibility of scion/rootstock combinations to the planting density being considered. Although in the foreseeable future, few new citrus plantings are expected in Florida, decisions on tree replacement and/or grove rehabilitation should be evaluated with respect to the scion/rootstock combinations and tree planting density. To remain competitive in an international market arena, Florida citrus growers must use efficient production methods to assure maximization of profits and returns.

NOTE: For information on the annual per acre yields and costs and returns, contact the authors of this paper.

Literature Cited

Brown, Mark and Philip Lesser. 1995. Florida citrus outlook 1995-96 season. Univ. of Fla., Fla. Dept. of Citrus, Economic and Market Research Department, Working Paper Series 95-7. 56 pp.

Castle, W. S. 1995. Tree survival in long-term rootstock field plantings. Proc. Fla. State Hort. Soc. (In Press).

Castle, William S. and Ronald P. Muraro. Notebook Entitled: "Financial analyses of 15 years horticultural data obtained from a Valencia orange cooperative field trial involving 12 rootstocks located at Indiantown, Florida." December 1992. 85 pp. (controlled distribution to date).

Castle, W. S., D. P. H. Tucker, A. H. Krezdorn, and C. O. Youtsey. 1993. Rootstocks for Florida citrus. Univ. of Fla., IFAS. SP 42. 92 pp.

Ford, Stephen A., Ronald P. Muraro, and Gary F. Fairchild. 1989. Economic comparison of southern and northern citrus production in Florida. Proc. Fla. State Hort. Soc. 102:27-32.

Muraro, Ronald P. and Gary F. Fairchild. 1985. Economic factors affecting postfreeze production decisions in the Florida citrus industry. Proc. Fla. State Hort. Soc. 98:65-70.

Muraro, Ronald P. and Thomas W. Oswalt. 1995a. Budgeting costs and returns: Central Florida citrus production, 1994-95. Econ. Infor. Rep. EI 95-2, Food and Resource Economics Department, University of Florida. 2[illegible] pp.

Muraro, Ronald P., Robert E. Rouse, and Robert M. Turley. 1995b. Budgeting costs and returns: Southwest Florida citrus production, 1994-95. Econ Infor. Rep. EI 95-3, Food and Resource Economics Department, University of Florida. 37 pp.

Wheaton, T. A., J. D. Whitney, W. S. Castle, R. P. Muraro, H. W. Browning and D. P. H. Tucker. 1995. Citrus tree density and size control: yield, frui quality, and economics. Proc. Fla. State Hort. Soc. (In Press).