Proc. Fla. State Hort. Soc. 122:122–126. 2009.

Citrus Production Systems to Survive Greening: Economic Thresholds

Fritz Roka[1*], Ronald Muraro[2], R. Allen Morris[2], Peter Spyke[3], Kelly Morgan[1], Arnold Schumann[2], William Castle[2], and Ed Stover[4]

[1]*University of Florida, IFAS, Southwest Research Education Center, Immokalee, FL 34142-9515*

[2]*University of Florida, IFAS, Citrus Research and Education Center, Lake Alfred, FL 33850*

[3]*Arapaho Citrus Management, Inc., 13300 Okeechobee Road, Ft. Pierce, FL 34945*

[4]*U.S. Department of Agriculture, Agricultural Research Service, Horticultural Research Laboratory, 2001 South Rock Road, Ft. Pierce, FL 34945*

Additional index words. net present value, yields, planting density, costs, efficiency

Advanced production systems (APS) and open hydroponic systems (OHS) are proposed strategies for citrus production that could increase early production and sustain production at higher levels through at least the first 15 years of grove life. Higher tree densities, automated irrigation, and intensive nutrient management will increase costs per acre for establishment and annual cultural care. Estimated cost increases are based on the APS/OHS specifications outlined in a companion paper (Morgan et al., 2009). This paper utilizes net present value (NPV) as a framework to evaluate the costs and benefits of AP/OH systems. Per acre yields must increase sufficiently to cover establishment costs. Sufficiently increasing yields within the first 5 to 7 years of a new grove could make it more likely that an AP/OH system will return positive profits over a wider range of fruit prices.

Situation

The costs of citrus production in Florida have increased by nearly $1000 per acre in the past 5 years, from an estimated $775 per acre during the 2002–03 season to more than $1750 during the 2007–08 season (Muraro, 2009). Prices for petroleum based inputs, especially fertilizers, have surged more than 190% and have increased production costs by more than $350 per acre since 2002. The presence of two diseases, canker (*Xanthomonas axonopodis*) and huanglongbing (greening; *Liberibacter asiaticus*), have accounted for nearly $500 per acre increase in costs. Greening is a particularly ominous disease because under standard cultural practices, an infected tree can become nonproductive within a few years after it begins to express symptoms. The disease's vector, the Asian citrus psyllid, is endemic throughout Florida and the latency period between when a tree becomes inflected to when it expresses symptoms makes the effectiveness of rouging infected trees an uncertain disease control strategy. If, in fact, the average expected life of a citrus grove decreases, annual unit costs of production will increase because fewer boxes are produced over the life of the grove to balance the initial planting and general overhead costs.

Citrus growers need to develop new production strategies to offset increases in production costs. Advanced production systems (APS), which include open hydroponic systems (OHS), are proposed strategies that, if designed properly, could accelerate and increase early fruit production. Morgan et al. (2009) and Stover et al. (2008) outline the basic horticultural principles behind APS and OHS. High density planting and more intensive management of nutrition and irrigation inputs are key features of these systems. Planting densities of up to 360 trees per acre (TPA) are being tested and would constitute a more than 2-fold increase in the number of trees per acre from a current typical planting density of 150 TPA. Strategies for nutrient and water management include controlled release fertilizers, computerized fertigation systems, and ET-based models for irrigation scheduling.

Increasing production efficiency is a necessary condition for the adoption of APS/OHS designs. Production efficiency is measured as a ratio of input to output quantities. The ratio gets smaller as production efficiency improves. For example, if 200 lb of nitrogen per acre from a "standard" fertilizer yields 500 boxes of oranges, the production efficiency is 0.4 lb N per box of oranges. If by using a controlled release fertilizer (CRF) total applied nitrogen decreases to 150 lb/acre with no adverse effect on fruit yields, production efficiency with respect to fertilizer inputs would increase by 25%, or 0.3 lb N per box of oranges.

Higher production efficiency is a *necessary* condition for the adoption of a new technology such as CRF, but improved economic efficiency is the *sufficient* condition before which a new technology can be commercially viable. Changes in "unit costs" measure changes in economic efficiency. Unit costs are the ratio of dollars spent (costs) to total output (units). When economic efficiency improves, unit costs decrease. If nitrogen from a "standard" fertilizer costs $0.50 per pound and 200 lb/acre are applied, then the economic efficiency measure for the "standard" nitrogen program would be $0.20 per box of oranges. In order to improve economic efficiency with CRF, the maximum cost of nitrogen per pound of CRF is $0.66. A price any higher than this threshold would adversely affect economic efficiency. For example, if the price per pound of nitrogen from CRF were

*Corresponding author; email: fmroka@ufl.edu; phone: (239) 658-3400

$0.80, total fertilizer costs would increase to $120 per acre ($0.80 × 150 lb) and unit costs with respect to nitrogen would increase from $0.20 to $0.24 per box of oranges.

The purpose of this paper is to outline a framework by which to evaluate changes in economic efficiencies from APS/OHS grove designs. Although cost and yield data used in this paper are from published sources, the analysis should be regarded as hypothetical. Cost and yield data will be refined as more trial plantings are started and maintained over an extended number of seasons. The ultimate analysis of economic efficiency will depend on actual production budgets and realized fruit yields, both of which will vary by grower and growing conditions.

Cost and production assumptions

Shifting from current production systems to APS or OHS involves increasing tree densities. The added costs to establish an APS or OHS with 360 TPA are nearly $5500 per acre higher than if a block is replanted to a more typical density of 150 TPA (Table 1). Most of the higher costs are attributable to buying and planting 210 more trees per acre. Since 2004 the cost of citrus nursery trees has more than doubled as a result of new regulations requiring that all tree propagation to be done within protected structures. APS and OHS may require some additional investment into the existing irrigation infrastructure and beds may have to be reshaped to accommodate the higher tree density (Spyke, 2009).

Table 1. Cost assumptions to establish an APS or OHS system with 360 trees per acre (TPA) as compared to a standard planting of 150 TPA.

		150 TPA	360 TPA	Difference
New trees	$9.00/tree	$1350	$3240	$1890
Planting costs	$3.50/tree	$525	$1260	$735
Irrigation/bed preparation		$1000	$1300	$300
Young tree management (years 1–3)		$2320	$4875	$2555
Added costs by YR3				**$5480**
Mature grove care	$1400/acre			
Harvest and haul	$2.10/box			

Source: Muraro, 2008.

Costs to grow young trees at a higher density increase by $2500 per acre over the first 3 years of a new block (Muraro, 2008).

Given the higher initial costs to establish an APS or OHS, the economic efficiency criteria must be met by increasing per acre fruit production. It is important to evaluate not only the increased cumulative production from APS or OHS, but also the extent to which production from young trees can be enhanced. Tree yields increase with age. Maximum yield potential of an individual tree depends on a number of factors but can be limited by planting density. Individual tree yields increase with age so long as their expanding canopy volume is not impeded by neighboring trees. Consider Figure 1, which presents three scenarios of individual tree production by tree age. The solid lines represent two planting densities, 150 (blue line) and 360 (red line) TPA. For the first and second scenario, it is assumed that up until age 5 trees planted to either density are managed identically and hence per tree yields are expected to be the same. After the fifth year, trees planted at 360 TPA begin to hedge together and yield per tree levels off. In fact, yield per tree may even decrease over time as individual tree canopies become more overlapped. Trees planted at 150 TPA continue to increase per tree production through year 10 (Roka et al., 2000). The dashed red line in Figure 1 (360+) represents a third production scenario where enhanced fertilizer and irrigation management from an APS or OHS accelerates and increases production from young trees. For a hypothetical scenario labeled "360+", production begins in the second year with 0.2 boxes per tree. Production in the third and fourth year increases by 0.25 and 0.30 boxes per tree, respectively, from the 150 and 360 TPA plantings. By the fifth year, trees planted at 360 TPA have started to canopy together implying that their individual tree production potential had reached the maximum.

More trees per acre translate to more boxes per acre, at least during the initial years of young tree production. Between the third and fifth year of tree age, production from a 360 TPA planting is more than double the production from a 150 TPA planting (Fig. 2). Even after accounting for decreasing tree yields after the fifth year, per acre production from 360 TPA should remain higher than a 150 TPA planting. Higher production from young trees, as shown in the 360+ scenario, results in an additional 289 boxes per acre being harvested through year 4 (Fig. 2, dashed red line).

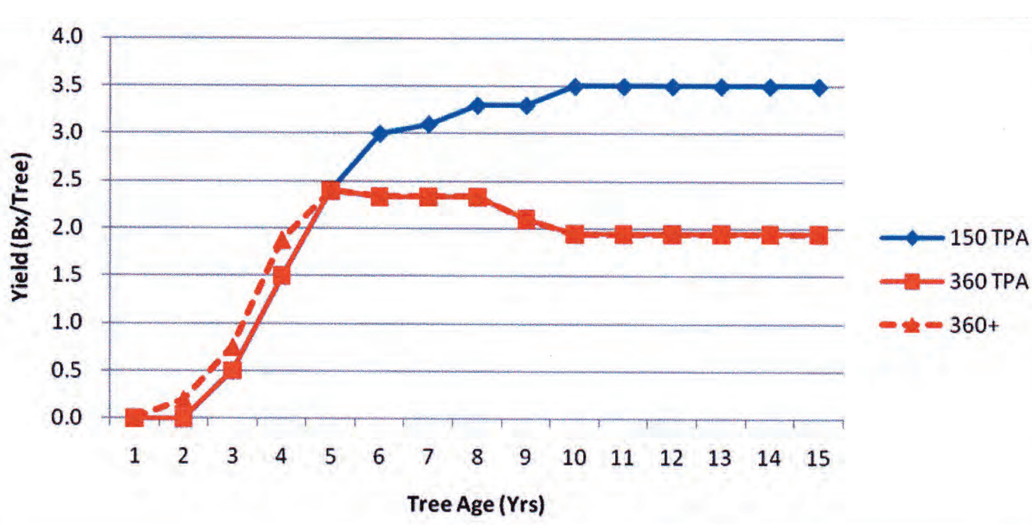

Fig. 1. A hypothetical example of citrus yields per tree by tree age, two tree density plantings [150 and 360 trees per acre (TPA)], and for enhanced nutrient and irrigation management to increase young tree yields (360+).

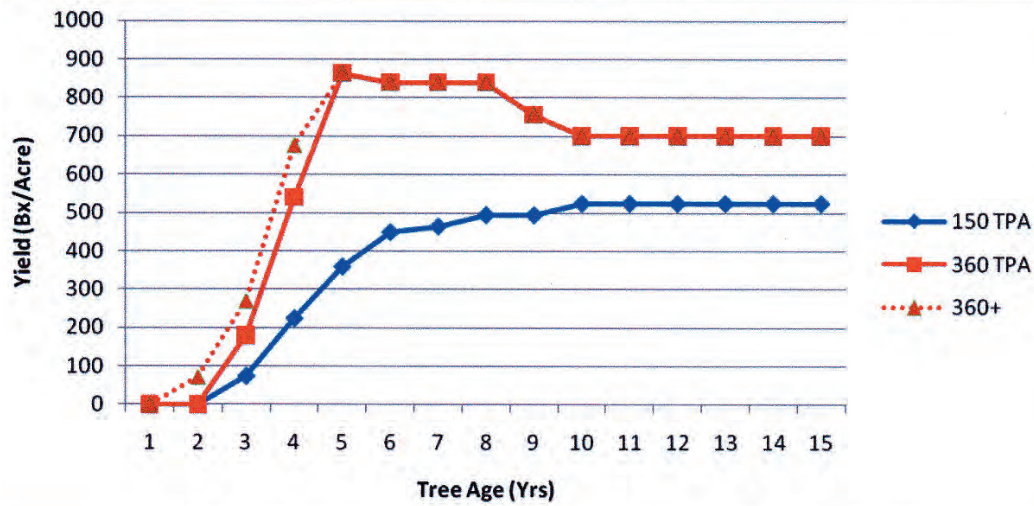

Fig. 2. Production per acre by tree age, two tree densities, and enhanced early fruit production (360+) using tree yields presented in Figure 1.

Table 2. Summary and comparison of net present value calculations of standard and high density plantings over 15 years and at a delivered-in price of $1.20 per pound-solids at tree densities of 150 and 360 trees per acre (TPA).

Year	Discount factor (10%)	Standard density (150 TPA) Net present value ($/acre)	High density (360 TPA) Net present value ($/acre)	High density + management (360+ TPA) Net present value ($/acre)
0	1.0000	($2875)	($5800)	($5800)
1	0.9091	($1089)	($1976)	($1976)
2	0.8264	($971)	($1752)	($1434)
3	0.7513	($413)	($465)	($104)
4	0.6830	($136)	$1013	$1512
5	0.6209	$324	$1995	$1995
6	0.5645	$566	$1742	$1742
7	0.5132	$556	$1583	$1583
8	0.4665	$580	$1439	$1439
9	0.4241	$527	$1118	$1118
10	0.3855	$541	$901	$901
11	0.3505	$492	$819	$819
12	0.3186	$447	$745	$745
13	0.2897	$407	$677	$677
14	0.2633	$370	$616	$616
15	0.2394	$336	$560	$560
Total 15 year NPV ($/acre)		($337)	$3217	$4395

Net Present Value Analysis

Given the upfront costs presented in Table 1 and yield scenarios presented in Figures 1 and 2, a grower must determine whether it is in his or her financial advantage to invest in a high-density APS or OHS. NPV analysis provides a way to compare the cumulative stream of annual net returns between the two tree densities and a third scenario where early tree production is increased in conjunction with higher tree density. Table 2 presents annual net returns for 15 years by planting scenario, 150, 360, and 360+ TPA. The initial year (Year 0) includes grove set-up and new tree planting costs. Subsequent years include grove care costs of young and mature trees, overhead, harvest, and fruit hauling costs. Starting in the third year for the 150 and 360 TPA scenarios and in the second year for the 360+ scenario, revenues from fruit sales are calculated by assuming each box produces 6.2 pound-solids. Fruit prices are held constant at $1.20 per pound-solids.

A "discount factor" is included in Table 2 and is based on an interest rate of 10%. The discount factor reflects the *time value of money*, which simply means that "a dollar today is worth more than a dollar tomorrow." The discount factor in the i^{th} year (D_i) is calculated as:

$$D_i = 1 \div (1 + r)^i$$

where "r" is the interest rate and "i" is the number of years into the future. The choice of an interest rate is somewhat arbitrary because it is based in large part on an individual's subjective perception of risk. The interest rate increases with higher perceptions of risk. At a minimum, the interest rate of the discount factor should be the rate of return an individual can reasonably expect from his or her next best investment opportunity. For a given interest rate, the annual discount factor decreases with time, reflecting the time value of money. A higher interest rate would account for a higher level of risk and hence, a lower annual discount factor. The NPV of returns in any given year (*i*) is the calculated net returns for that year multiplied by the corresponding discount factor for that year.

Over a 15-year horizon and a constant delivered-in price of $1.20 per pound-solids, the cumulative NPVs for the generic example are a positive $3217 per acre for a 360 TPA planting and a negative ($337) per acre for a 150 TPA planting (Table 2). In this example, the higher annual yields for the 360 TPA more than offset the higher costs to establish the APS or OHS. If, in fact, the APS or OHS could have increased young tree production as shown in scenario 360+ (Fig. 2), the cumulative NPV would have increased by more than 36% to $4395 per acre. The NPV analysis is repeated for delivered-in prices ranging from $1.00 to $1.40 per pound-solids (Fig. 3). Given the costs and production values used in this example, a 360 TPA planting always returns a higher 15-year cumulative NPV than a 150 TPA planting. The higher returns from a 360 TPA affords a grower a greater cushion against low market prices than a 150 TPA. At prices below $1.25, returns from a 150 TPA planting are negative. Negative returns for a 360 TPA do not occur until prices fall below $1.05 (Fig. 3).

Babson Park Yield Data

The NPV analysis described in the previous section was applied to yield data collected from Babson Park (Muraro, 2007). In 1980, a long-term variety/rootstock trial was planted in a commercial grove near Babson Park. Three tree densities, 150, 270, and 360 TPA, were incorporated in the trial. Production data for ‘Valencia’ on Rusk citrange rootstock were collected until 1993. Annual production per acre for the 150 and 360 TPA plantings are shown in Figure 4. Production did not begin until the fifth season, after which the 360 TPA produced more boxes

Fig. 3. Comparison of the cumulative net present value over 15 years vs. delivered-in prices from 150 and 360 TPA planting densities.

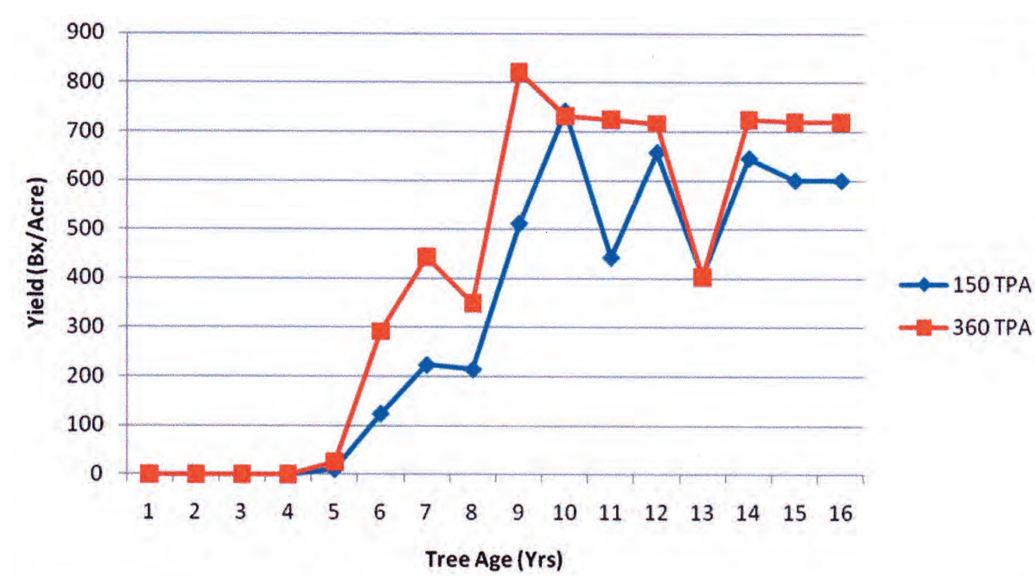

Fig. 4. Yield data from two planting densities versus tree age in the Babson Park, FL, trial, ‘Valencia’ on Rusk citrange rootstock, 1978 to 1993. (Note yield loss after 1989–90 freeze in year 13). Source: (Muraro, 2007).

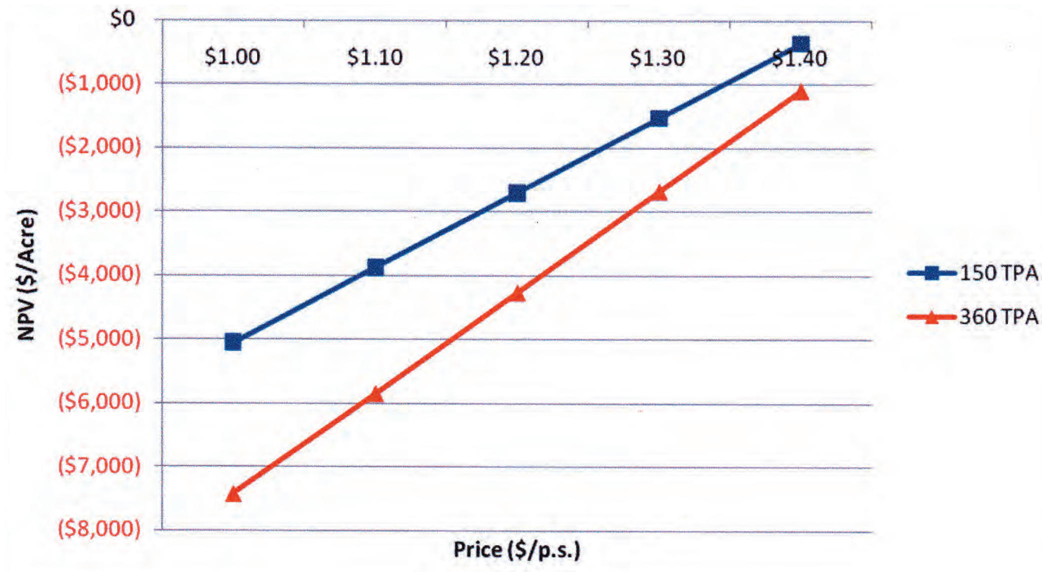

Fig. 5. Cumulative 15-year net present value based on the Babson Park yield data and cost assumptions in Table 1 for two tree densities (150 and 360 TPA) at fruit prices ranging from $1.00 to $1.40 per pound-solids.

per acre than did the 150 TPA planting. Over the 12 years of fruit production, one acre of the 360 TPA planting produced 6668 boxes while the 150 TPA produced almost 1500 boxes less, or 5178 total boxes per acre.

A 15-year cumulative NPV analysis was conducted with the above yield data for delivered-in prices ranging from $1.00 to $1.40 per pound-solids. The costs to establish 150 and 360 planting densities were assumed to be the same as shown in Table 1. NPV results by fruit price and planting density are summarized in Figure 5. The additional cumulative production from the 360 TPA planting was not sufficient to offset the higher costs associated with the higher density planting. The 15-year NPV from a 360 TPA planting was lower than from a 150 TPA planting. For a delivered-in price or $1.20 per pound-solids, the 15-year NPV of the 150 TPA planting was –$2704. The higher planting density (360 TPA) received a substantially lower cumulative NPV of –$4262 per acre. As fruit prices increase, the difference in NPVs between the two planting densities narrows. Once fruit prices exceed $1.60 per pound-solids, the 360 TPA would yield a higher 15-year NPV.

Conclusions

The added costs associated with citrus greening and a general inflation of input prices are forcing citrus growers in Florida to reexamine the way they grow citrus and look for new production strategies that will help enhance their overall economic efficiencies. APS and OHS are two related systems that are receiving some attention among growers and researchers. Both systems require an initial investment that probably will amount to several thousand dollars per acre. For either system to be commercially viable, higher fruit production per acre is required. NPV analysis was used in this paper to compare different cash flow streams over time. A lower planting density (150 TPA) requires lower start-up costs, but a high planting density (360 TPA) should generate higher revenues in the future.

Almost by definition, higher tree densities should produce more boxes of fruit per acre. The economic question becomes, what minimum increase in production is necessary to cover initial investment costs under a reasonable range of expected fruit price? Not only is cumulative production important, but also increasing production from young trees. Enhancing production from young trees carries two benefits, 1) more total boxes of production over time, and 2) increasing net returns earlier in the cash flow stream when discount rates are relatively higher. A final conclusion of the NPV analysis in this paper was that any investment in future citrus production requires adequate market prices.

Literature Cited

Morgan, K.T., A.W. Schumann, W.S. Castle, E.W. Stover, D. Kadyampakeni, P. Spyke, F.M. Roka, R. Muraro, and R.A. Morris. 2009. Citrus production systems to survive greening: Horticultural practices. Proc. Fla. State Hort. Soc. 122:114–121.

Muraro, R.P. 2009. Florida processed orange cost dynamics. PowerPoint presentation to the Gulf Citrus Growers Assn. Mtg., 4 Feb. 2009, LaBelle, FL.

Muraro, R.P. 2008. Summary of 2007–08 citrus budget for the Southwest Florida production region. <http://www.crec.ifas.ufl.edu/extension/economics/pdf/SW_Budget_Summ_2007_2008.pdf>.

Muraro, R.P. 2007. Economics of planting densities in Florida citrus. PowerPoint presentation at the 2007 Citrus Expo, 23 Aug. 2007, Ft. Myers, FL.

Roka, F.M., R.P. Muraro, and R.E. Rouse. 2000. Comparison of yields by tree age and rootstock in Southwest Florida orange groves. Proc. Fla. State Hort. Soc. 113:115–119.

Stover, E., W.S. Castle, and P. Spyke. 2008. The citrus grove of the future and its implications for huanglongbing management. Proc. Fla. State Hort. Soc. 121:155–159.

Spyke, P. 2009. Open hydroponics vs. conventional grove—Trial grove "what-if" analysis, instructions. Arapaho Citrus Mgt., Ft. Pierce, FL, 19 Jan. 2009.