Proc. Interamer. Soc. Trop. Hort. 48:40-42. *Fruit/Frutales - October 200*

Citrus Mechanical Harvesting: Balancing Production Goals with Harvesting Efficiency

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Abstract. *Global competition with orange juice producing countries is pushing the Florida citrus industry to develop mechanical harvesting systems to reduce costs. Currently, a Florida grower pays between $1.40 and $1.80 per box to pick and deliver fruit for the processed market. Mechanical systems are projected to reduce harvesting costs by more than 50%. Incumbent, however, upon success of mechanical harvesting is a significant change in culture for the Florida grower. The flexibility of hand harvesting crews allows a grower to design and maintain a grove in any configuration that meets production goals. With mechanical systems, a grower will be forced to make accommodations in tree and grove design to promote harvesting efficiency. This paper presents expected benefits and costs from mechanical harvesting systems. Data describing performance statistics of harvesting systems is related to tree characteristics. Trade-offs between production goals and harvesting efficiency are outlined.*

Resumen. *La competencia global con los paises productores de de naranja está estimulando la industria de frutas cítricas en el s la Florida para desarrollar sistemas de cosecha mecánica reduzcan los costos. Actualmente, un cultivador de la Florida entre $1.40 y $1.80 por la caja de fruta seleccionada para el mer de fruta procesada. Los sistemas mecánicos son proyectados reducir los costos de cosecha a 50%; sin embargo, el éxito de sistema ha creado un cambio significativo en la cultura del cultiva de la Florida. La flexibilidad de este tipo de cosecha y los equip permiten que el cultivador diseñe y mantenga un cultivo en cualqu configuración para resolver metas de producción. Con los sistem mecánicos, forzaran al productor para acondicionar el árbol y diseño del cultivo para mejorar la eficiencia de la cosecha. Es trabajo presenta ventajas y los costos previstos de sistemas mecanic de cosecha. Los datos se describen estadísticamente sobre funcionamiento de los sistemas de cosecha y se relacionan con l características del árbol. Las compensaciones entre las metas de producción y eficacia de la cosecha son comparadas.*

Citrus fruit in Florida is harvested by hand, as it is harvested in any other part of the world where citrus is grown. Even for processed fruit, where the cosmetic appearance of the peel is not important, a human hand touches every piece of harvested fruit. The greatest benefit of a hand harvest system is the flexibility it affords a grower. First, harvest costs are not incurred until the crop is picked. If a freeze, hurricane, or bad market conditions render the crop uneconomical to pick, no additional harvest costs have to be expended. Second, a hand harvest system allows the grower to manage production independent of harvest considerations. Decisions on grove design and tree architecture can be made to maximize yield or improve fruit quality. Hand harvesting crews are able to adapt to a wide variety of tree and grove situations.

Florida growers are beginning to question whether they can continue to afford the attributes of flexibility hand harvest crews provide. San Paulo, Brazil is the world's largest producer of oranges for the juice market. Brazilian growers are able to grow, harvest, and process oranges into juice at lower costs than Florida growers. The cost advantage is most pronounced in the area of harvesting. Brazilian fruit can be harvested at less than 50 cents (US) a box, while Florida growers pay at least $1.50 per box. If Florida is to continue as an important orange production region, cost reductions have to occur and mechanical systems may offer the best opportunity to dramatically reduce harvesting costs. Mechanical harvesting is not a new endeavor for the Florida citrus industry. Considerable time and effort on mechanical harvesting systems was expended between 1960 and the early 1980s. During this period, the primary motivation for mechanical harvesting was concern over an adequate supply of harvest labor. The devastating freezes of the 1980s removed labor availability as a primary concern, and interest in mechanical harvesting waned. During the early 1990s the competitive cost position of Florida citrus eroded to a point where interest in mechanical harvesting was resurrected.

Commercial harvesting systems:

During the 2003-04 harvest season, 7,154 ha (17,600 acres) of citrus in Florida were mechanically harvested. Most of the acreage was harvested by one of two systems. The first is called a trunk-shake-catch system (TSC). Two independent machines work on opposite sides of a tree. The shaker unit clamps around the trunk of a tree and shakes the tree for between 5 and 10 seconds. Detached fruit is deflected into a receiver unit, which conveys fruit into a trailing cart. The cart holds between 70 and 90 boxes (40.9 kg/bx) before being off-loaded into a field truck (called a "goat") and transported to the bulk trailers at the edge of the grove or block. The TSC system requires a team of three people, two operators and a goat driver.

The second system is called a continuous-canopy-shake-catch (CCSC). Unlike a TSC system, a CCSC system moves continuously down a tree row at speeds between 0.83 and 2.08 kilometers per hour (0.5 and 1.5 mph). Fruit is removed by vibrating tines attached to a harvesting drum, or whirl. Two self-propelled units work together on opposite sides of the tree line. Detached fruit falls to a catch surface at the base of each harvester and is conveyed into a field truck (goat) following behind each harvester. A CCSC system requires a team of six people, two operators and four goat drivers. The additional set of goat drivers allows the harvesters to keep harvesting while the first set of goats delivers fruit to the bulk trailers.

Table 1 summarizes the important performance statistics that have been compiled through field observations of the harvesting systems. The performance statistics for the 2002-03 harvest season closely follow data that has been

collected since 2000-01. Both TSC and CCSC systems remove an average of 95% of the available fruit and deliver, or recover, 90% of available fruit to a bulk-hauling trailer. On average, mechanical systems do not harvest between 4-6% of the fruit. Around 5% of the fruit that is removed misses the catch frames and falls to the ground. At the present time, nearly all growers who utilize mechanical harvesting systems insist that gleaning (i.e. hand harvesters) crews follow the mechanical harvesters to collect most of the crop missed by the mechanical system. Harvesting speed of a CCSC system is significantly faster than a TSC system. However, since a CCSC system employs twice as many people as a TSC system, harvest labor productivity is very similar. When actively harvesting, both systems allow labor productivity to be around 100 boxes per labor-hour, more than a 10-fold improvement over hand harvesting crews.

Adjustments to Grove and Tree Design

If TSC and CCSC systems are to achieve their full cost reduction potential, grove design and tree architecture will have to be adjusted. Some groves can be "retrofitted" relatively easily to fit either TSC or CCSC system. These groves are fairly uniform with respect to general tree configuration. Tree preparation includes pruning, skirting, brush clearing, and placement/adjustments of irrigation sprinklers. Lower scaffold limbs need to be pruned to secure a clear trunk height of at least 45 cm, necessary for a TSC system to adequately shake a tree. Skirt heights of at least 75 cm at the drip line are necessary for effective operation of the catch frames on both TSC and CCSC systems. Overall tree height should be no taller than 5.5 meters (18 feet) to avoid excessive fruit splitting as detached fruit hits the catch frame.

Costs of retrofitting mature trees range from $250 to $500 per hectare. Table 2 provides a breakdown of costs. These are one-time costs, the most significant of which may be the value of lost fruit during the pruning and skirting operations. Many groves in Florida are irrigated with micro-sprayers. To prevent damaging the jets, they should be repositioned away from the trunk and placed equidistant between trees and in the tree row. Pruning and skirting mature trees generates a lot of limb trash. Brush removal or mower chopping is necessary. After establishing a new tree shape, annual "maintenance" skirting is required. Maintenance skirting typically costs about $25 per hectare.

Older groves are usually very non-uniform because of the number of resets. Varying tree heights and ages make efficient operation of shake and catch systems very difficult, if not impossible. For these groves the only access to either the TSC or CCSC systems will come after the grove has been replanted to the specifications outlined previously. Replanting a block is a significant capital expenditure. In all likelihood, such a decision will not be driven solely by mechanical harvesting considerations, but rather in conjunction with varietal/rootstock changes and/or improvements in the grove infrastructure.

Table 1: Average performance statistics for the trunk-shake-catch (TSC) and the continuous canopy-shake-catch (CCSC) systems, 2002-03 harvest season.

		2002-03 TSC	CCSC
Removal	%	94	95
Recovery	%	89	91
Harvest speed	Tree/hr	185	310
Labor productivity	Bx/man-hr	100	100

Table 2: Costs of retrofitting mature trees for either the TSC or CCSC systems.

	$/ha
Initial skirt	$25-50
Pruning lower limbs	$75-100
Brush removal / mow	$25-100
Micro-sprayer placement	$75-100
Value of lost fruit (2-5% loss, 1,000 bx/ha, $3/bx on-tree)	$50-150
Total cost of tree preparation	$250-500

Criteria for Adoption

Florida citrus growers will embrace mechanical harvesting only if they realize sufficient reductions in net harvesting cost. It is important to emphasis the word "net" because all costs and potential ramifications on the production operations have to be considered if mechanical harvesting is to be economically sound. Grower benefits are measured in terms of lower harvesting costs. For example, if pick and roadside costs go from $1.50 (hand harvest) to $1.00 (mechanical) and the mechanical system picks 1,000 boxes per hectare, the grower realizes an increase in on-tree revenues of $500/ha. From this amount, a grower must deduct all costs associated with mechanical harvesting, such as pro-rated costs of initial tree preparation, annual maintenance skirting, and the on-tree value of fruit not recovered by the mechanical system.

While mechanical harvesting can break limbs and cause some defoliation, neither University of Florida research nor grower experiences indicate any reduction in crop yields or increases in tree mortality from mechanical harvesting. Despite these reassurances, many growers remained concerned about tree health and the long-term productivity impacts

from mechanical harvesting systems. From an economic perspective, such concerns can be built into the adoption calculation. The more a grower is uncertain about tree health issues, the higher the cost savings will have to be before he or she adopts a mechanical harvesting system.

Change of Culture

Mechanical harvesting represents a major cultural change for the Florida citrus growers. A hand harvest system allows a citrus grower the flexibility of keeping production decisions independent from harvesting considerations. If a mechanical harvesting system is to achieve the full measure of cost reduction, accommodations will have to be made in the production arena. Skirting and pruning decisions will be made on the basis of increasing harvesting efficiency, not solely for production goals. Tree resetting strategies may have to be modified to preserve more uniformity within a block, again to enhance machine performance. This will require nursery trees with straight trunks and higher heights of initial scaffold branches to accommodate harvesting equipment under the tree. Grower on-tree returns will be the measure of accountability and success of mechanical harvesting systems. A successful system will be one that increases on-tree returns to the grower. In other words, if the savings in harvest costs from mechanical systems more than offset the costs of tree/grove preparation, and even perhaps lower crop yields, mechanical harvesting will be a success.

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