Citrus Mechanical Harvesting Systems--Continuous Canopy Shakers[1]

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Introduction

Mechanization has been the hallmark of American agriculture. Nearly 100 percent of the agronomic crops grown in the United States are plowed, planted, and harvested with mechanical equipment. Mechanical harvesting equipment for sweet oranges has been studied extensively since the 1970s and during the 2005/06 harvest season, trunk and canopy shakers harvested more than 36,000 acres of Florida citrus. Mechanically harvested citrus acreage, however, has decreased significantly since 2005. During the 2012/13 season, less than 9,000 acres were mechanically harvested (FDOC 2013). Nevertheless, development and adoption of mechanical harvesting technology is important to the long-term economic sustainability of the Florida orange juice processing industry. This article describes canopy shakers and a companion article (FE950) discusses trunk shakers. To view the machinery in action, click on https://www.youtube.com/watch?v=WuPIUS6bShY

Continuous Shaker Systems

Two types of continuous canopy shaker systems have been used to harvest sweet oranges for processed juice. One type is commonly referred to as a self-propelled continuous shake and catch (CSC) system. The CSC system uses two independently operated machines on opposite sides of a tree row that shake the fruit from the trees onto a catch frame (Figures 1 and 2). The second type is commonly referred to as a tractor-drawn continuous canopy shake (TD-CS) system (Figure 3). The TD-CS system shakes the fruit to the ground, where a crew collects the fruit by hand and places it into tubs.

Both systems improve harvesting efficiencies by reducing the amount of labor required to harvest the fruit as

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compared with hand harvesting. Whether self-propelled or tractor-drawn, the core unit of a continuous canopy harvester is a series of rods stacked horizontally on top of each other in a whirl pattern. The rods, generally called tines, are six feet long and two inches in diameter. The tines are connected to a central drum, and penetrate into the tree canopy, shaking the canopy in a reciprocating horizontal pattern to remove fruit.

The shaking frequency of the tines can vary depending on the force needed to remove the fruit. The operator of the shaker assembly can adjust the angle and depth of the tine penetration to match the angle of a hedged tree. A machine can harvest fruit up to 18 feet high, but it is recommended that trees be topped at 16 feet to minimize damage to fruit falling to the catch frames or the ground. Hedged trees and uniform tree canopies are essential to achieve the maximum performance efficiency from a continuous canopy shaker. Trunk alignment in the row, a clear trunk height of 18 inches to the first branches, and long tree rows also improve harvesting efficiency. A canopy skirt height of 30 inches above the ground allows for the catch frame to easily travel under the tree canopy, which minimizes lower limb damage and maximizes fruit recovery.

Figure 1. Continuous canopy shake and catch (CSC) system, Oxbo Freedom 3220 (Photo courtesy of Barbara Hyman, UF/IFAS)

Self-Propelled Continuous Shake and Catch (CSC) Systems

The self-propelled harvesters work in pairs, one unit for each side of the tree (Figure 2). Each unit has a hydraulic leveling system, which allows the paired units to work effectively in bedded groves and moderately sloping terrain. The paired units travel down the tree row at ground speeds between one-half and two miles per hour, which allows between 200 and 400 trees to be harvested per hour. Each unit catches and separates the fruit from leaves and stems, thereby reducing the amount of trash in a harvested load. Fruit is conveyed directly to a field truck that follows behind each harvester. The catch frames of the self-propelled units can hold up to 60 boxes before the fruit has to be off-loaded to the field trucks. The field trucks for the CSC harvesters are similar to a conventional harvesting truck (also called a goat) but slightly larger with a capacity of between 130 and 150 90-lb boxes. These field trucks transport fruit and offload it into semi-trailers, which in turn transport the fruit to a juice processing plant.

Figure 2. CSC system (Photo courtesy of Paul Meador, Everglades Harvesting, LaBelle, FL)

When canopy shakers were studied extensively between 2000 and 2004, fruit recovery was measured to be consistently above 90 percent. Uniform and continuous tree canopies are essential to achieving a high percentage of fruit recovery. Another important condition for high fruit recovery is that both harvesting units are driven in alignment with each other. Any misalignment causes detached fruit to fall to the ground. A gleaning crew follows behind the harvesters to collect undetached fruit or wholesome fruit on the ground that missed the catch frame. With gleaning crews, total fruit recovery approaches 98 percent.

One self-propelled CSC system uses a crew of six workers (two harvester operators and four field truck drivers). Overall, individual harvest labor productivity approaches 100 boxes per hour (600 boxes per hour for one complete system), a tenfold increase over what hand harvesters can accomplish.

Tractor-Drawn Continuous Canopy Shaker (TD-CS) System

The tractor-drawn continuous canopy shaker (Figure 3) does not come with a catch frame and can accommodate uneven tree canopies. This shaker has demonstrated good fruit removal among trees that have not been skirted to the first scaffold branches.

Figure 3. Tractor-drawn continuous canopy shaker (TD-CS) system, Oxbo 3210 (Photo courtesy of Barbara Hyman, UF/IFAS)

The tractor-drawn continuous canopy shake (TD-CS) harvesting system works in a similar fashion to the self-propelled CSC harvesting system. Tines mounted to a central drum remove the fruit from the tree by a reciprocal horizontal shaking action and fruit falls to the ground. As with the self-propelled CSC unit, the TD-CS operator can adjust the tilt and elevation of the drum that contains the series of stacked whirls. Harvesting area is limited to the height of 18 feet. With an experienced TD-CS operator and in trees less than 18 feet tall, 95 percent of the crop can be removed from the tree.

A hand crew must follow behind the TD-CS system to gather fruit shaken off the tree by the harvesting unit. Worker productivity behind a TD-CS system has been documented to be twofold higher than hand harvesting crews. The tractor-drawn harvester can travel between one-half and one mile per hour and has the capacity to harvest between 100 and 200 trees per hour. The capacity of the tractor-drawn harvester is limited by the size of the pickup crew. Typically, the machine operator harvests only the amount of fruit that can be picked up within a day.

A fruit pickup crew working behind a TD-CS system gathers fruit into eight- or ten-box tubs, which are then loaded into conventional high lift trucks, or goats. Because hand crews glean most of the remaining tree fruit, a TD-CS system can deliver up to 99 percent of the available crop.

With the TD-CS system, trees should be hedged to maintain a canopy diameter of no more than 16 feet. Trees should be topped to a height of no more than 18 feet. Multi-stemmed tree trunks or low-hanging branches do not decrease harvesting efficiency with the tractor-drawn system as significantly as they do with the self-propelled system.

Harvesting Costs

In 2012, the cost to hand harvest sweet oranges for processed juice was between $1.90 a box in December/January (early-season fruit) to more than $2.20 a box in May/June (late-season fruit) (Muraro 2012). The cost to hand harvest citrus likely will increase as the Florida minimum wage rate continues to rise. Effective January 1, 2014, the Florida minimum wage increased to $7.93 per hour. A citrus harvester whose average productivity was eight boxes per hour had to be paid nearly $1.00 a box simply to cover the minimum wage threshold. Together with roadside charges, costs to hand harvest citrus will likely be more than $2.25 a box throughout the 2013/14 season.

Harvesting and roadside costs during the 2011/12 season for continuous canopy shakers ranged between $1.25 and $1.75 per 90-pound box. The lower cost range reflected well-prepared, high-yielding trees that were harvested with the self-propelled CSC system (machine and catch frame). The cost per box of the TD-CS system (tractor-drawn and no catch frame) was higher due to the additional labor requirements to gather the fruit from the ground. Actual harvesting costs will depend on specific grove conditions and gleaning requirements of the grower (Roka and Hyman 2013).

The unit costs of mechanical harvesting should be lower on higher-yielding blocks because the fixed costs of ownership and operation are spread over more boxes per hour. In addition, larger blocks or tracts in close proximity to the operator's base of operations should command a lower price because the time and energy spent to get the harvesting equipment to the trees and back is reduced, so that the harvest is more efficient and of longer duration. Whatever the cost of a mechanical harvesting system, the relative comparison a grower needs to consider is the price a hand crew would charge to pick and roadside the same block of trees. Between 2002 and 2012, growers who mechanically harvested their fruit reported cost savings of between 25 and 30 cents per box from what they would have paid to hand harvest the same fruit. These cost savings included gleaning fruit behind the machines to ensure at least 98 percent total fruit recovery.

Tree Health Effects

Horticulturalists and engineers from the University of Florida, the United States Department of Agriculture and the Florida Department of Citrus conducted several field trials between 1970 and 2005 to investigate whether mechanical harvesting equipment adversely affected fruit yield and long-term tree health. Except for the case of late-season Valencia oranges, the results of these field trials showed *no* short-term or long-term adverse effects (Whitney 2003; Hedden, Churchill, and Whitney 1988). Instead, the research suggested that well-nourished trees before and after mechanical harvesting recovered from all harvest-related stresses. A more recent study that analyzed grower yield data between 1998 and 2008 with and without mechanical harvesting showed no evidence of shortened tree life or reduced yields (Roka, House, and Mosley 2014).

Late-season Valencia oranges present a different and difficult challenge for mechanical harvesting. Valencia orange trees carry two fruit crops during the entire harvest season (March–June), that is, this year's mature fruit and next year's emerging fruitlets. The late-season harvest period begins when the emerging fruitlets grow to more than one inch (3 cm) in diameter. Mechanically shaking Valencia trees during the late season may cause upwards to a 50 percent yield reduction in the next year's crop (Coppock 1972). While growing conditions change each year, fruitlets typically grow to a one-inch diameter by mid-May. Consequently, most growers stop harvesting Valencia trees by early May.

Despite lower harvesting costs and research that indicated no adverse effects on tree health from mechanical harvesting, Florida citrus growers have yet to embrace mechanical harvesting. Citrus greening (HLB) became widespread after 2006 and its effects have drastically affected the use of canopy shakers. During the 2012/13 harvest season, 9,000 acres of sweet oranges were harvested with continuous canopy shakers, a decrease from the 2005/06 harvest season when more than 36,000 acres of sweet oranges were mechanically harvested. Trees infected with HLB cannot withstand shaking well, and many growers who were mechanically harvesting prior to 2006 either stopped or significantly scaled back on their mechanical-harvesting efforts as they sought to minimize any physiological stress on their HLB-infected trees. HLB also has compromised the overall efficiency of continuous canopy shake and catch systems because it has increased the percentage of resets or missing spaces within blocks that had been mechanically harvested in years before HLB. Whereas between 2000 and 2004, overall fruit recovery was consistently more than 90 percent, operators of the continuous shake and catch systems reported that fruit recovery has fallen below 80 percent in many blocks previously mechanically harvested because of tree skips and resets. An open space in the middle of a row creates space for more interior fruit in the adjacent trees, and the self-propelled CSC system cannot reach interior fruit.

In recent years, managing HLB-infected trees has significantly increased citrus production costs. While growers are rightfully concerned about the health of their HLB-infected trees, more study and consideration should be given to mechanical harvesting. The costs to grow and harvest citrus have been escalating significantly since 2006, and the cost savings potential from mechanical harvesting technologies can help Florida growers sustain their economic viability.

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