DEVELOPMENTS IN CITRUS PICKUP EQUIPMENT

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DEVELOPMENTS IN CITRUS PICKUP EQUIPMENT

By D. B. Churchill, H. R. Sumner, and S. L. Hedden\textsuperscript{1}

ABSTRACT

Numerous fruit pickup concepts have been investigated, but none found entirely successful under the wide range of existing citrus grove conditions. Machines range from comparatively simple tractor-pulled windrow pickup units to elaborate self-propelled machines that gather fruit from a wide area, remove trash, and store the fruit until a truckload is accumulated. A straight-through windrow pickup machine using a rod draper chain and loading directly into a grove truck has been most successful and is commercially available.

INTRODUCTION

Each year, Florida faces the continuing problem of obtaining enough hand labor to harvest its orange crop. Florida orange production is expected to increase from 6.4 million tons in 1972–73 to 8.6 million tons in 1979–80.\textsuperscript{2} For the past 12 years, work has been under way to develop mechanical harvesting systems for citrus fruits in Florida.\textsuperscript{3} A common approach is to remove all the fruit, drop it on the ground, and then pick it up with some mechanical equipment. A number of such pickup devices were tested and observed by personnel of the Agricultural Research Service; the results obtained are the subject of this report.

\textsuperscript{1} Agricultural engineers, Agricultural Research Service, U.S. Department of Agriculture, Lake Alfred, Fla. 33850.


PICKUP MACHINES TESTED

In 1967, a vacuum pickup unit, shown in figure 1, was designed and built at the Agricultural Research and Education Center, Lake Alfred, Fla. The vacuum source for the pickup unit was an 18-inch-diameter centrifugal fan rated at 2,000 cubic feet per minute of air at 20 inches water-column static pressure and a speed of 3,600 revolutions per minute. Air-volume flow rate for this system was 546 cubic feet per minute through the pickup tube. Pickup was made by hand-manipulating a 4-foot-long rigid tube over each fruit, which was then conveyed through a 4-inch-I.D., 19-foot-long, flexible vinyl hose to an air lock, where it was discharged into a storage box. The duct work of this system was designed to separate the fruit from the trash by allowing the trash to follow the airflow through the transition and blower, while the fruit fell into an air lock. The air-lock system separated the fruit from the trash using a double set of doors (fig. 2). The upper doors closed off about 80 percent of the cross-sectional area, which provided sufficient vacuum retention, and yet when the lower door closed, equalization of pressure allowed the fruit to fall through the upper doors. The operator, with practice, could pick up two
fruit per second, disregarding breakdown or unplugging time (a pickup rate of 20–30 pounds per minute). Tests with this unit showed that the minimum acceptable ratio of fruit diameter to duct diameter was 2:3. Because of the low potential capacity, excessive horsepower requirements, noise, dust, and fan-wear problems, this method of pickup was abandoned after the initial design information was obtained.

Initial tests with a USDA-developed tung nut pickup machine in 1967 showed promise for picking up citrus fruit. This unit (fig. 3) had a 34-inch-diameter, double-pitch, spiral brush 7 feet long. The brush, mounted at a 70° angle from the direction of machine travel was made up of 1-inch-diameter, smooth-finished rubber fingers 5 inches long. The cleaning and conveying components used for tung nuts were removed and fruit-handling conveyors added. No attempts were made to remove any trash other than that which fell through the open wire mesh conveyor.

Fruit was either handpicked and dumped from field boxes in the center of the row to form a windrow, or a limb shaker shook the fruit to the ground and the machine simply picked up fruit in its path. On a continuous run of 23.5 minutes, including basket changes, a pickup rate of 210 pounds per minute was obtained. With a forward travel speed of one-half mile per hour, the average pickup rate of the unit was 408 pounds per minute, excluding basket change time.

The tung nut pickup machine was not designed for use in soft, sandy soils, and the tractor-front-mounted unit did not maneuver well. However, this concept for citrus pickup showed promise for development into a useful system.

The manufacturer of the tung nut harvester, Gotcher Engineering and Manufacturing, Clarksdale, Miss., intended to modify the standard pickup for use in citrus groves. However, they were unable to find citrus growers willing to contract to purchase unproven equipment and abandoned the development of this machine.

In 1967, Continental/Moss-Gordon, Inc. (CMG), a private manufacturing company in Prattville, Ala., built an experimental tractor-mounted citrus pickup machine (fig. 4), which was a modification of a commercial nut pickup

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machine (Bush-Hog). The pickup head was a paddle wheel consisting of 36 bars carrying heavy belting flaps (4 by 6 inches) that pulled the fruit rearward and up a grate to a cross conveyor behind the paddle wheel, approximately 12 inches above the ground. Rotating flap reels were later mounted on the sides of the pickup head to help gather the fruit in the pickup unit. The front-mounted unit proved so difficult to maneuver in the sandy Florida soils that pickup rates were not obtained.

In early 1968, CMG designed and built, to the specifications of the Florida Citrus Industry Harvesting Committee, a self-propelled pickup machine with a paddle-wheel pickup head similar to that described above. This machine (fig. 5) was designed to pick the fruit up from a windrow. It had an 8-foot pickup width, including the two 11/2-foot gathering augers, and was designed to pick up fruit at 500 pounds per minute and discharge it into a grove truck at 1,500 pounds per minute.

The pickup head had an automatic height adjustment, activated by floating skids that followed the ground contour. However, the 8-foot wheel base of the machine proved too short. When the front wheels were on a ridge and the rear wheels were in a depression, the pickup head could not be lowered enough to reach the windrowed fruit, even at its maximum vertical adjustment.

After the fruit was picked up, it was conveyed by a bucket elevator and dumped onto a sloping trash conveyor. The fruit rolled off the belt and fell into a storage hopper, while the trash was discharged off the end of the conveyor onto the ground. The discharge of the fruit hopper was similar to the loading operation. Fruit was elevated out of the storage hopper by a bucket elevator and discharged onto a bulk loader conveyor. This machine was designed to unload as it continued to pick up fruit.

Each front wheel of the CMG pickup machine was powered by a separate hydrostatic system; steering was controlled by changing the speed of individual wheels. The rear wheels were castered and smaller than the traction wheels. This arrangement resulted in poor steering control, particularly when traveling between grove sites at speeds above 2 miles per hour.

The paddle-wheel pickup onto the grate worked well in level, sandy grove conditions at speeds up to approximately one-half mile per hour. The grate did not work in sod or trashy conditions because of clogging; it was replaced with small-diameter, powered steel rollers. CMG changed ownership, and due to the incomplete success of the pickup machine, further development was discontinued.

Figure 6 shows the USDA citrus pickup machine which was designed and built at Lake Alfred in 1967–68. This self-propelled machine moved the fruit from a 91/2-foot-wide path into line with the pickup conveyor, picked up the fruit, and passed it over a cleaning belt into a 60-box-capacity holding bin.

A Florida citrus field box has a volume of 4,800 cubic inches and holds 90 pounds of oranges.
on the conveyor, with a belt speed of 100 feet per minute gave best separating results.

During the 1968–69 season, modifications were made on a standard potato harvester to design it into a citrus pickup unit (fig. 8). The conveyors were removed except for the digger chain. The digger chain head shaft was lowered to decrease the slope to approximately 18°. A cross-conveyor belt was added for trash removal at the discharge end of the pickup chain. An elevator and bulk loader conveyor were added to carry the fruit from the trash-elimination belt into a high-lift grove truck.
The initial pickup head (not illustrated) was a 24-inch-wide belt conveyor with 1 3/4-inch-high flights; it used gathering augers 6 feet long and 36 inches in diameter to load the fruit onto the conveyor from the side, much like the tung nut pickup machine previously described. This pickup method was not satisfactory, since sand would fill the area inside the belt and stop the conveyor. The front of the pickup conveyor was shortened and changed to rod draper chain, and a straight blade from a potato harvester was mounted to run 1 to 2 inches below the ground surface in front. A small paddle wheel was installed above the digger blade, to help load the rod draper chain conveyor.

Final changes as shown in figure 7 were made on this pickup head. The digger blade, gathering augers, and paddle wheel were removed, and a 28-inch-diameter belt flap reel was installed above the pickup point to load the fruit onto the rod draper chain. These modifications eliminated the excessive trash buildup encountered with the blade, reduced fruit damage caused by the paddle wheel, and allowed the rod draper chain to operate satisfactorily at ground level in all grove conditions. An average ground speed of 0.55 miles per hour and an average pickup rate of 579 pounds per minute were obtained. An oblique rake 4 feet long was attached to the right side of the pickup machine to provide a pickup width of 6 1/2 feet.

A rough-top trash eliminator belt conveyor on this machine was effective in removing leaves, sticks, bottles, weeds, and sand from the fruit being picked up. Fruit fell onto the top of the
In 1970, the FMC Corporation started development of a citrus pickup machine and a commercial model was available in 1972. This unit was a tractor-drawn version of the modified potato harvester, with a power-steering rear axle. It had a pickup width of 5 feet and used 7/8-inch-diameter by 1 1/2-inch-pitch rod draper chain for fruit pickup and the initial elevator. No rod or blade was used in front of the pickup chain; however, a new horizontal section 1 foot long at the pickup joint alleviated the trash buildup problem. The fruit dropped from the pickup chain onto a counterrotating cleaning belt and rolled into an elevator that carried it up to the loader conveyor, where it was discharged into a high-lift grove truck being towed behind the pickup machine. Figure 9 shows the commercial machine as it is being used today.

Data were collected on one FMC pickup machine in operation during the 1972-73 harvest season. In five different grove sites, including the above, a total of 2,594 tons was picked up in 143.5 hours, for an average pickup rate of 602.5 pounds per minute. In one grove, 1,689.6 tons of windrowed fruit was picked up in 75 hours of operation, an average pickup rate of 750.9 pounds per minute. Fruit was acceptable at the processing plant.

The Harvey Harvester Division of Koehring Corporation brought their pickup machine to Florida in 1970 (fig. 10). This offset, tractor-drawn machine was a commercial version of a machine developed by Agricultural Research Service at East Lansing, Mich., for picking up apple drops. A cylindrical drum, studded with 41/2-inch-long rubber fingers, rotated in the direction opposite tractor travel to lift and convey the fruit over the drum and between the top shroud and deposit it onto a conveyor elevator. Most citrus groves would not accommodate the 30-inch height of the offset drum under the tree skirt, however, and pickup capacities were not obtained. The machine was modified to elevate the fruit to the rear into a pallet box rather than to the side. This machine did not pick up fruit well, however, unless it was one layer deep on the ground.

In 1972, the Citrus Systems Division of Upjohn Company adapted the Koehring machine as a front-mounted pickup on an agricultural tractor as shown in figure 11. The pickup drum rotated in the direction of travel to sweep the windrowed fruit off the ground, across a grate, and onto a cross conveyor. The fruit was transferred to an elevator, running the length of the tractor, and stored in a surge bin mounted on a three-point hitch lift mast.

A combination rake-pickup machine, shown in figure 12, was designed and built by Agricultural Research Service in 1971 to incorporate both the rake and pickup operations into one self-propelled unit requiring one operator. Oblique raking was used since it was a method for windrowing fruit. Three oblique rakes were mounted at 65° from the direction of travel and

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arranged to provide a 14½-foot raking width.

The front rake moved the fruit from ahead of the front wheels and pickup chain. The outside rake (along the tree line) had a 3-foot side shift for moving in and out of the tree row. A safety “breakaway” was built in to allow the rake to move back 12 inches, if it struck low-hanging limbs or large tree roots. The inner rake moved the fruit from both rakes to the inside of the pickup chain, which was a rod draper chain 29 inches wide with a 2-inch pitch. This chain formed a track on the ground, which moved in the direction opposite travel at twice the ground speed of the machine. Fruit was conveyed on the pickup chain and discharged into a 36-inch-diameter drum onto a cross conveyor. From the cross conveyor, the fruit discharged into a side elevator and into a 30-box holding bin. The pickup chain and rake were made to float freely over uneven ground, by the use of depth control wheels. This unit had a pickup rate of 378 pounds per minute; its capacity was limited by its raking ability.

The first design had no cleaning capacity except that of the rod draper chain; some trash, such as hedge trimmings, dead wood, and cans, was loaded into the storage bin with the fruit. To improve its cleaning capacity, a draper-chain side elevator was substituted for the closed side elevator; a cleaning belt was added at the end of the cross conveyor; and a sorting belt was added at the discharge end of the side elevator. A pickup rate of 689.4 pounds per minute was obtained, but the cleaning belt could handle only 472.5 pounds per minute. Because of space limitations, the cleaning belt became the limiting factor in the pickup rate of this machine.

**SUMMARY AND DISCUSSION**

Citrus pickup equipment can be divided into three categories: the vacuum system, which picks up one fruit at a time; the paddle wheel pickup, which rotates either with or against the direction of travel, depending on where the fruit is to be discharged; and the chain method, which makes use of some type of chain to pick up the fruit (such as a rod draper chain used on potato harvesters).

Several pickup methods have been and still are being investigated. Of the prototype machines discussed in this report, some were complex and would be too costly. At the time some of these machines were being developed, industry was not interested in purchasing unproven pickup machines; in addition, fruit removal devices for putting fruit on the ground were not fully developed.

Advance preparation is necessary in most groves for the pickup machines to perform satisfactorily. Low-hanging limbs need pruning, and some preraking and pickup is required to remove excessive trash and decayed fruit, before fruit is shaken to the ground. Throughout the testing of pickup-machine concepts, the industry has tended to be reluctant to make necessary grove modifications and preparations to enable the machines to do an acceptable job.

At the present time, the acceptance of pickup equipment by industry has changed because a simple pickup machine has been developed and offered for sale at a reasonable cost by a local manufacturer, there has been an occasional shortage of pickers and an increase in picking costs, fruit removal devices have been developed.
which give high rates of removal when used with newly developed abscission chemicals, and harvest demonstrations in groves prepared and suited for pickup have educated the industry as to what can be done under proper conditions. Therefore, industry and research groups have been encouraged to continue the development of pickup equipment.

The present commercially available pickup machine is simple and has gained some acceptance by industry. It picks fruit up from a windrow, drops it onto a cleaning belt, and discharges it into a grove truck. Approximately 15 machines were used during the 1973-74 season and are doing an acceptable job of picking up fruit in several grove conditions.

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