A Double-Sided Rake-Pickup Machine for Citrus

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ABSTRACT

A self-propelled rake pickup machine was designed and built to pick up fruit from the ground by making one pass down the center between two tree rows when the fruit was windrowed at the tree drip-line. Rod draper chain was used for pickup and a double belt trash eliminator system was used for separating out the trash. Fruit was loaded directly into a high-lift grove truck towed behind the pickup machine. The average pickup rate and ground speed were 490 kg/min and 0.46 km/h, respectively. Fruit recovery efficiency was 92 percent.

INTRODUCTION

Research and development of gathering and picking equipment for citrus has been under investigation in Florida for about 15 years. For the last several years, the research has concentrated on mechanizing the complete harvest system. Usually abscission chemicals are used with mechanical harvesting to loosen the fruit before shakers drop the fruit to the ground (Coppock, 1969; Whitney and Sumner, 1977; Sumner and Churchill, 1977; Wilson et al., 1977). The oblique rake and rod draper chain pickup are a combination that has been predominant for raking and picking up oranges in Florida (Sumner and Churchill, 1977).

Previous research has shown the advantages and disadvantages of particular gathering and pickup methods. A commercial system (Sumner and Churchill, 1977) was tried which gathered and picked up oranges at the center between two rows. One pass with the pickup machine required two passes with the windrower. Fruit raked in the first pass must be in a compact windrow to allow the rake to straddle the windrow on the second pass down the row. In high yielding groves fruit was often damaged when it was raked to form a compact windrow or when placed into a double windrow on the second pass. A commercial rake and pickup operation indicated a need for improvements in gathering the fruit into a tight windrow for one pass with the pickup machine, thus reducing fruit damage from dragging the tractor drawbar through the windrow. Two of the most recent reports (Churchill and Sumner, 1977; Churchill, 1981) described the design and performance of the drip-line rake-pickup system. The system was designed to gather and pick up oranges without moving them to the center between two rows. The objective of the double-sided rake pickup design was to minimize fruit damage caused in forming a compact windrow and reduce the possibility of running over fruit on the ground with harvesting equipment.

In 1974, a grant was given to a commercial company by the Department of Citrus to design and construct a self-propelled pickup machine for citrus. The purpose of this machine was to gather and pick up oranges from two drip-line windrows in a single pass down the middle between two rows of trees in an effort to minimize fruit damage. Due to financial reasons, the gathering device was never completed.

In 1980, the USDA research team at Lake Alfred agreed to redesign and complete the machine. A program was set up to finish the machine, field test and compare it with the drip-line system. The design of the double-sided rake-pickup machine is discussed in this paper.

MACHINE DESIGN

Design requirements were established by incorporating previous research work into the design of the double-sided rake-pickup machine.

Specific design parameters were:

1. Self-propelled with power steering on front and rear axles for maneuverability in the grove.
2. Four-wheel hydraulic drive for traction in sand.
3. Low profile gathering system for operating under tree canopy.
4. Rake, pickup, and direct-load fruit with one pass from two drip-line windrows using a total operating width of 6.3 m.
5. Operator cab to reduce noise and dust exposure to an acceptable level and provide windrow visibility from the cab.
6. Fold up rake assemblies for transport and turning at row ends.
7. Provisions for trash removal.
8. Rake and pickup speed of 0.65 km/h in a fruit load of 27 kg/m of windrow.

The rake assemblies were located in front of and on either side of the pickup assembly. These devices consisted of a three-bar oblique type rake with gauge wheels at both ends of the rake frame for height adjustment. The rake assemblies were lifted hydraulically for turning at row ends and positioning for transport.

Fig. 1 shows the fruit flow diagram of the double-sided self-propelled rake pickup machine. Engineering specifications are given in Table 1.

The pickup assembly consisted of two rod draper chain assemblies placed side by side to form a pickup width of 1.5 m. A flapper cylinder assembly 1.5 m long by 36 cm in diameter was mounted just above and in front of the pickup chain to assist in loading the fruit onto the pickup chain. The pickup conveyor was inclined at 38 deg from the horizontal and used a draper belt assembly which applied pressure to the fruit to prevent

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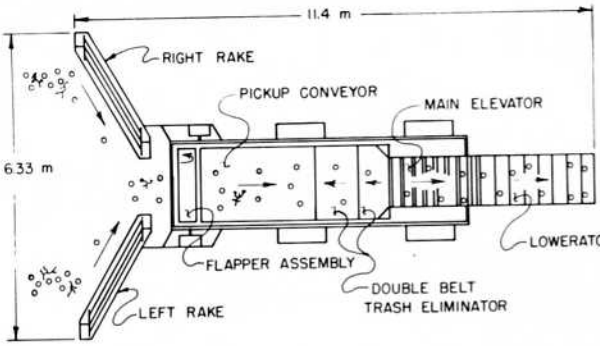

Fig. 1—Plan view with arrows showing fruit flow through double-sided rake pickup machine.

roll back. Weights were placed on top of the belt to hold the fruit against the rod draper chain. Gauge wheels were mounted on either side of the pickup frame to provide depth control in following the ground contour.

From the pickup chain the fruit fell onto a double belt trash eliminator system, as shown in Fig. 2. The top trash belt assembly was mounted at an incline of 20 deg from the horizontal and rotated in the opposite direction of fruit flow. The bottom trash belt assembly was inclined 15 deg from the horizontal and also rotated in the opposite direction of fruit flow. The fruit rolled down both trash eliminator belts and dropped onto the main elevator. The elevator (inclined at 45 deg) raised the fruit to the lowerator conveyor between 5 cm x 15 cm x 100 cm long wood flights spaced 38 cm apart. The 102 cm wide x 2.5 m long cleated belt lowerator emptied into the high-lift grove truck. The lowerator height was adjustable for uniformly distributing the fruit in the truck.

TABLE 1. DESIGN SPECIFICATIONS OF DOUBLE-SIDED PICKUP MACHINE

Overall specifications:		
Width of machine (transport position)		3 m
Width of machine (operating position)		6.3 m
Length of machine (transport position)		9.1 m
Length of machine (operating position)		11.6 m
Height of machine (transport position)		4 m
Height of machine (operating position)		3.4 m
Wheel base		2.7 m
Weight		7.48 t
Component specifications:		
Pickup conveyor	2.9 m long x 1.5 m wide	45 m/min
Pickup flapper assembly	1.5 m long x 35.6 cm dia	65 rpm
Top trash eliminator belt	1.2 m long x 1.5 m wide	25 m/min
Bottom trash eliminator belt	1.2 m long x 1.5 m wide	25 m/min
Main elevator	3.7 m long x 1 m wide	30 m/min
Lowerator	2.4 m long x 1 m wide	0-140 m/min
Engine	Cummins Diesel V-3781, V6 rated at 108 kW intermittent duty at 3,000 rpm and 93 kW continuous duty at 2800 rpm.	
	(a) Front axle - Rockwell 6.72:1 2 Char-Lynn 4,000 series motor, 0.23 L/rev.	
	(b) Rear axle - Timken 6.75:1 1 Char-Lynn 10,000 series motor, 0.48 L/rev.	
Tires - Four	38 x 20.00 - 16.1, 4 ply rating	
Hydraulic pumps	(a) Ground drive - Hydreco gear, 0.10 L/rev.	
	(b) Auxilliary - 2 Hydreco gear 0.06 L/rev.	
Steering	Power steering on front and rear axles.	
Raking Component Specifications:		
	Raking width	205 cm
	Raking height	71 cm
	Tooth circle dia.	41 cm
	Bar length	228 cm
	Teeth/bar (no.)	34
	Tooth spacing	6.4 cm
	Tooth length*	25 cm
	Tooth speed	0-150 rpm

*Rubber-mounted hay rake teeth

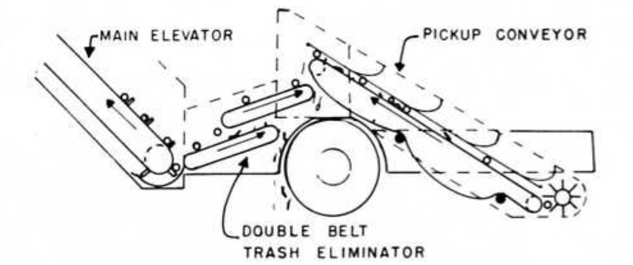

Fig. 2—Double-belt trash eliminator system on double-sided rake pickup machine. Arrows indicate direction of conveyor travel.

Prime Mover

The engine selected for this machine delivered 93 kW for continuous duty at 2800 rpm and was mounted between the front and rear axles above the trash elimination section. Power was transmitted through a 1:1 double output gearbox mounted directly on the engine bellhousing to a 98.3 cm^3/rev variable displacement hydrostatic pump, to provide a continuous variable ground speed drive.

The front and rear axles were both 2½ ton military truck front drive axles which permitted four wheel drive and power steering. Two 229.5 cm^3/rev motors were coupled to either side of the front axle differential and one 478.9 cm^3/rev motor was coupled to the rear differential. The rear wheels were equipped with locking hubs which could be used for positive traction in loose sand.

Two hydraulic pumps, each 76 L/min at 1800 rpm provided oil for all other machine functions. They were mounted together and directly to the 1:1 ratio engine mounted gearbox. Each pump output was further divided into two equal circuits. The two circuits from the front pump were (a) pickup conveyor and (b) lowerator cylinder, main elevator cylinder, pickup head depth control cylinder, left and right rake and flapper motors, and the cylinders for raising and lowering the rakes. The rear pump circuits were (a) front and rear power steering and (b) main elevator conveyor and lowerator conveyor.

The operator's cab was mounted over the entrance to the pickup conveyor and as low as possible to provide good visibility of the gathering rakes and pickup chain. It also protected the operator from some of the engine noise. Outside mirrors assisted the operator in viewing toward the rear of the machine. All the controls were located inside the cab. A ventilation blower was mounted on top of the cab to keep out dust and provide air movement for the operator.

PERFORMANCE

Prime Mover

The double-sided rake-pickup machine was tested during the 1982 harvest season in a Hamlin variety orange grove that averaged 490 kg per tree with a tree spacing of 7.6 m x 7.6 m. Due to the severe freeze on January 12, 1982, no additional testing was done.

Maneuverability of the pickup machine in the grove was satisfactory and with the large tires, flotation in loose sandy soil was no problem. However, turning at row ends required a large area and it was difficult for the operator to see the position of the rear wheels when backing up. The hydrostatic hydraulic system functioned satisfactorily. No problems were encountered in moving

Fig. 3—Double-sided rake pickup machine in field operation.

through loose and sandy conditions.

The location of the cab provided good visibility for the operator. However, it was difficult to determine the position of the pickup chain. With the fan circulating air in the cab, dust was not a problem for the operator but it would build up on the outside of the glass. Insulation installed around the control valves reduced the heat from the hydraulic system coming in the cab.

Fruit Gathering and Pickup

A tractor-drawn rake (Sumner and Hedden, 1981) was used to gather the fruit from around the base of the tree and place it in a windrow at the tree drip-line. Low tree limbs had to be removed to enable the equipment to operate under the tree skirts since the grove was being harvested mechanically for the first time. Some fruit damage occurred in the initial raking operation. Prior to harvesting, the grove was disked to minimize splitting of the oranges when they hit the ground. The loose soil condition caused the rake to dig in excessively and consequently, more soil was moved along with the fruit than desired. Fig. 3 shows the fruit in the windrows ready for the pickup operation.

The location of the windrow was satisfactory for the pickup machine and the row width of 7.6 m caused no problems. The average ground speed was 0.46 km/h with a down-the-row fruit pickup rate of 490 kg/min.

The machine was further modified by relocating the head shaft on the top trash eliminator belt to improve recovery efficiency. After relocating the top trash eliminator head shaft, the system worked satisfactorily, separating trash and unwholesome fruit from good fruit. However, the machine was tested under only one trash condition and additional testing under other conditions is needed. Trash discharging on top of the front axle built up to the bottom of the belting and had to be cleaned off by hand periodically. Some fruit was lost over the top of the rakes and some rolled back outside the side board of the pickup frame width because of the large fruit load. Fruit recovery efficiency averaged 92%. The initial drip-line gathering operation which moved the fruit from the center between two rows formed a trough in the center between the two rows. This condition occasionally caused the gauge wheels to ride higher, preventing the pickup head from getting under the fruit and some fruit was missed.

In comparison with drip-line pickup system, the self-propelled machine had more problems making it less efficient. The wheel base was short and required a flat surface for a smooth operation. The rakes were not able to handle the large fruit load of 32.14 kg/min and some fruit had to be abandoned. The drip-line pickup system operating in the same grove had a fruit recovery efficiency of 95%.

CONCLUSIONS

The double-sided rake-pickup machine has several advantages in that it makes only one pass down the middle between two rows and the possibility of the drive wheels running over fruit was eliminated. However, the machine is large and heavy and requires additional space for turning around at row ends. Its high capacity would make it attractive to certain operators or large growers. Compared to the drip-line pickup system the double-sided rake-pickup machine is more restricted to specific grove conditions.

In general, the fruit gathering and pickup efficiency was less than expected. The double-belt trash elimination system did a satisfactory job in separating fruit from trash and was not a limiting factor in the pickup capacity.

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