A New System for Raking and Picking Up Oranges

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DURING the 1974-75 season Florida produced over 7.1 million tonnes of oranges (Fla. Agri. Statis. 1975). Approximately 90 percent of this crop was processed into products. The oranges were harvested almost entirely by hand labor. Harvesting in Florida is a major problem because the industry depends on seasonal labor and there is a decline in the number of workers willing to do this type of work. Labor cost has been increasing much faster than the cost of production. Mass removal systems for mechanical harvesting of citrus have been under development since 1961 (Coppock 1969). These systems require machines with the capacity to handle a large volume of fruit. An air shaker concept of removing oranges from the tree has been under development since the early 1960's (Whitney and Patterson 1972). A trunk shaker (Whitney 1975) and limb shaker (Sumner and Hedden, 1975) have been used to drop the fruit on the ground. With most mass removal systems an abscission chemical is used to loosen the fruit. Such a chemical causes a large preharvest fruit drop making a ground fruit handling system desirable.

After fruit has been dropped to the ground, it must be moved to a location for pickup. Citrus pickup equipment developed since 1967 was reported by Churchill et al. (1976). An experimental machine, designed by Marshall and Hedden (1970) picked up oranges from the ground midway between two rows. A combination rake-pickup machine, designed by Sumner and Hedden (1974), used oblique rakes to move the fruit to this center area for pickup. A commercial rake and pickup machine is now available that uses a self-propelled oblique rake to move the oranges from the tree line to midway between two rows and a tractor-drawn pickup machine to pick up the fruit. Observations indicate that in high yielding groves severe damage occurred to the fruit when it was raked into a windrow midway between two rows. In an effort to minimize fruit damage during raking and picking up, a system that raked and picked up the fruit at the drip line on each side of the tree was developed. The design and performance of this harvest system is given in this paper.

DESCRIPTION OF HARVEST SYSTEM

Rake

Fruit flow through the rake and offset pickup machine is shown in Fig. 1. The rake was mounted on a 65-hp hydrostatic drive tractor and consisted of three oblique rake assemblies and one brush rake. The front rake was a four-bar rake that was mounted in front of the tractor for moving the oranges from the row middle to the drip line. The inside rake was a four-bar rake with a gauge wheel on the outer end of the rake frame for height adjustment. A three-bar side shift rake was mounted on the slide rails of the main frame and had a side shift of 76 cm (2.5 ft) for moving in and out of the tree row. A flat, circular, horizontal brush rake mounted at the outside end of the side shift rake served as a height gauge adjustment for the rake and also removed the oranges from around the tree trunk. The front and inside rakes had 16 cm (6.5 in.) long rubber mounted tines spaced 6.4 cm (2.5 in.) apart on the rake bars, and the side shift rake had 14 cm (5.5 in.) long rubber mounted tines spaced 5.72 cm (2.25 in.) apart. The rakes formed a 102 cm (40 in.) wide windrow at the tree drip line on each side of the tree. Two passes were required to form the two windrows. A wheel sweep assembly was mounted ahead of the left front tractor tire to move the fruit in the path of the wheel. The wheel sweep was a cylinder made up with eight-flaps of 0.48 cm (3/16 in.) belting 13 cm (5 in.) wide.

The frame on which the other two rake assemblies were mounted was attached to the right rear tractor axle and transmission housing. The attaching frame had a pivot tube parallel to the direction of travel, 51 cm (20 in.) above the ground and 41 cm (16 in.) outside the rear tractor tire. This tube enabled the rake assemblies to pivot up 1.9 rad (110 deg) for transport position. The complete raking system was hydraulically powered by a 1515 cm^3/s (24 gpm) pump driven directly off the front crankshaft of the tractor. Fig. 2 shows the hydraulic diagram of the tractor mounted rake system. The engineering specifications of the rake are given in Table 1. Fig. 3 shows the field operation of the rake.

Offset Pickup

The offset pickup machine was designed to pick up fruit from a windrow at the tree drip line. This machine combined several proven principles from previous machines, into a tractor drawn pickup with a steerable axle. Fig. 4 shows the offset pickup machine in field operation.

The fruit pickup assembly was made up of two rod draper chain assemblies side by side to form a 1.14 m (45 in.) wide pickup frame. A 36 cm (14 in.) O.D. x 112 cm (44 in.) long flapper cylinder assembly was mounted just in front and above the pickup chain to assist in loading the oranges onto the chain. The side boards on the pickup frame extended 79 cm (31 in.) beyond the chain and were flared at the end to give a 127 cm (50 in.) pickup width. Two gauge wheels, just

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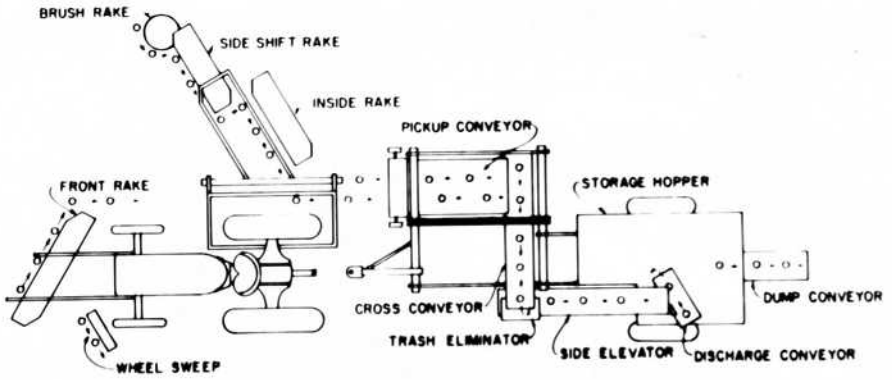

FIG. 1 Plan view showing fruit flow through rake and offset pickup machine for drip line operation.

in front of the flapper assembly, controlled the depth of the pickup frame by following the ground contour. The overall height of the pickup frame was 61 cm (2 ft) to allow clearance of foliage at the tree drip line.

Oranges were discharged from the pickup chain onto a rod draper chain cross conveyor. From the cross conveyor the fruit dropped onto a trash eliminator belt that separated the trash from the fruit and discharged the fruit onto the side elevator. From the side elevator, the fruit fell onto a discharge conveyor that dropped the fruit into the 1225 kg (2700 lb) storage hopper. The storage hopper was the "lift-and-dump" type with a cleated belt conveyor attached at the end for loading into high-lift grove trucks. The engineering specifications of the offset pickup machine are given in Table 2. Two hydraulic pumps, 1388 cm^3/s (22 gpm) and 379 cm^3/s (6 gpm) driven directly from the tractor power take-off provided all the hydraulics for the pickup machine. The hydraulic diagram of the offset pickup machine is given in Fig. 5.

The pickup frame was attached to the main frame through a pivot tube for raising the assembly into the transport position.

PERFORMANCE OF THE SYSTEM

The drip line rake and pickup system was tested during the 1975-76 harvest season under a variety of grove conditions while it raked and picked up 9500 boxes of early, midseason, and 'Valencia' variety fruit. Minor changes and modifications were made on the equipment throughout the harvest season.

The rake was tested for its ability to move fruit into a compact windrow under various grove conditions. The pickup efficiency and the ability of the trash eliminator to separate trash and unwholesome fruit from good fruit at different pickup rates were determined. The ability to transport and maneuver the equipment in the grove and during travel were observed. Speeds of the various components and rates of the machines were recorded.

Test results for the rake and offset pickup system are given in Table 3. The average ground speed of the rake was 1.6 km/h (1 mph) while the average ground speed of the pickup machine was 1.0 km/h (0.64 mph). The maximum fruit pickup rate for one side of a row consisting of fortyfive trees was 6 kg/s (792 lb/min) while the average rate was 4.5 kg/s (594 lb/min).

TABLE 1. ENGINEERING SPECIFICATIONS OF RAKE.*

	Height		Length		Effective raking width		Speed	
	cm	(in.)	cm	(in.)	cm	(in.)	m/s	(fpm)
Front sweep	33†	(13)	97	(38)	91	(36)	2.3	(460)
Front rake	56	(22)	259	(102)	229	(90)	2.6	(513)
Inside rake	64	(25)	107	(42)	94	(37)	3.2	(623)
Shift rake	41	(16)	117	(46)	107	(42)	2.0	(401)
Brush	41	(16)	91†	(36)	46	(18)	4.8	(943)

*Dimensions of machine in operating position: 5.2 m (17 ft) long x 5.5 m (18 ft) wide.
†Diameter.

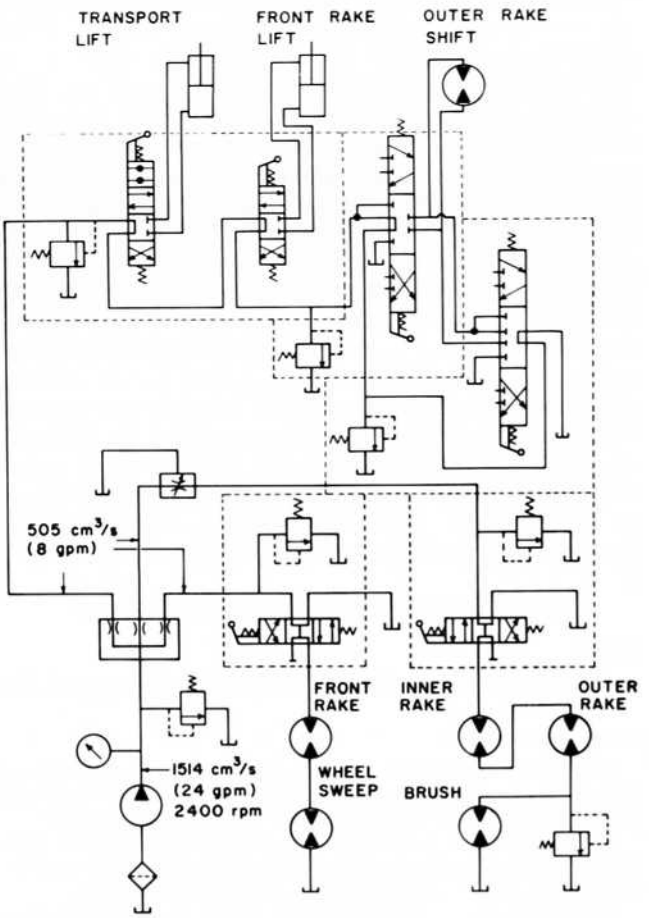

FIG. 2 Hydraulic diagram of the tractor mounted rake.

FIG. 3 Field operation of rake.

FIG. 4 Field operation of offset pickup machine.

The oblique rakes did an adequate job of gathering the fruit and forming a compact windrow at the tree drip line. Forming the windrow at the tree drip line minimized the distance the fruit was moved compared with the present system which requires the windrow to be located in the center between two rows.

In unlevel groves, the cross conveyor on the pickup machine dragged on the ground and stopped the rod draper chain because of excessive power requirements. One test was conducted in a grove with a large amount of dead wood which slowed down the raking and pickup operation. The rod draper chain in the pickup conveyor easily broke up small pieces of wood 1.27 cm (0.5 in.) in diameter and less. The flapper assembly in front of the pickup chain reduced the power requirement of the pickup chain by 40 percent. Also, it enabled the recovery of all the oranges at the end of the row.

The rake and pickup machines were independent units and could be operated at different speeds, directly behind one another. Both units were highly maneuverable and were one and two man operations, respectively. The second man on the pickup machine removed trash and unwholesome fruit that was missed by the trash eliminator.

Preharvest pruning and hedging was desirable before the oranges were dropped on the ground. In the 'Valencia' tests, the grove had been hedged and disced, and the tree skirts were raised to a minimum height of 61 cm (24 in.).

TABLE 2. ENGINEERING SPECIFICATIONS OF OFFSET PICKUP MACHINE.

Overall specifications:		
Width of machine (operating position)	4.2 m	(13 ft 10 in.)
Length of machine	8.23 m	(27 ft)
Height of storage hopper	2.29 m	(7.5 ft)
Capacity of storage hopper	1225 kg	(2700 lb)
Tire size	26.67 x 45.72 cm	(10.5 x 18 in.)
Weight (empty)	3250 kg	(7165 lb)
Draw bar weight (empty)	1180 kg	(2501 lb)
Component specifications:		
Pickup conveyor—		
rod draper chain	1.11 x 53.34 x 3.96 cm	(7/16 x 21 x 1-9/16 in.)
Frame width	114.3 cm	(45 in.)
Frame height	60.9 cm	(24 in.)
Normal angle of incline	0.35 - 0.44 rad	(20-25°)
Conveyor speed	0.97 m/s	(190 fpm)
Cross conveyor —		
rod draper chain	0.95 x 53.34 x 5.08 cm	(3/8 x 21 x 2 in.)
Frame width	55.9 cm	(22 in.)
Conveyor speed	0.56 m/s	(110 fpm)
Trash eliminator-belt		
Frame width	60.9 cm	(24 in.)
Frame length	76.2 cm	(30 in.)
Conveyor speed	0.79 m/s	(156 fpm)
Side elevator—		
rod draper chain	0.95 x 53.34 x 5.08 cm	(3/8 x 21 x 2 in.)
Frame width	55.9 cm	(22 in.)
Frame incline	0.79 rad	(45°)
Conveyor speed	0.49 m/s	(90 fpm)
Discharge conveyor-belt		
Width	45.7 cm	(18 in.)
Length	132.1 cm	(52 in.)
Conveyor speed	0.46 m/s	(90 fpm)
Dump conveyor-belt		
Width	60.96 cm	(24 in.)
Length	213.36 cm	(84 in.)
Conveyor speed	0.79 m/s	(156 fpm)

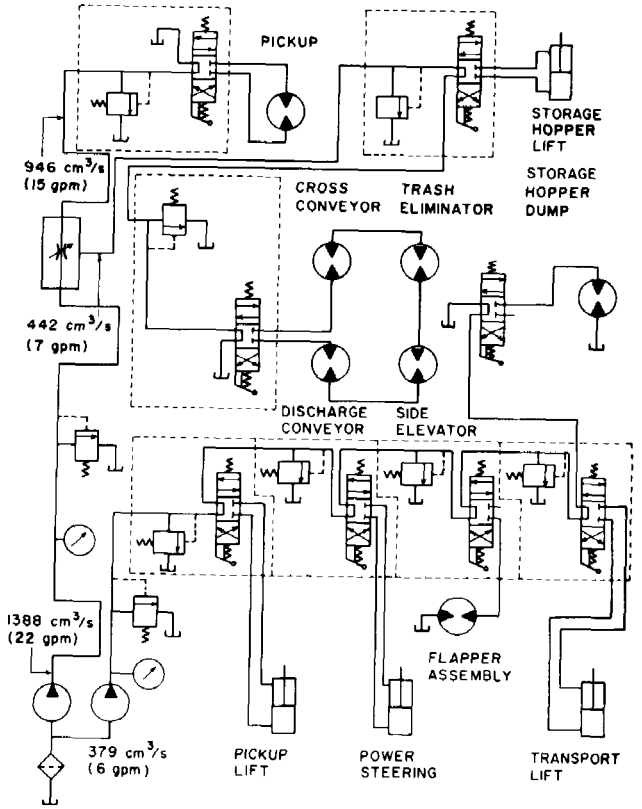

FIG. 5 Hydraulic diagram of the offset pickup machine.

SUMMARY

The new drip line rake and offset pickup system performed satisfactorily in 7.6 m (25 ft) and 9.1 m (30 ft) row spacings. With the drip line rake and pickup system the average ground speed for raking was 1.6 km/h (1 mph) and for picking up, 1.0 km/h (0.64 mph). Both the rake and pickup units were highly maneuverable in and out of the grove. The flapper cylinder assembly located in front of the pickup chain enabled recovery of all the fruit at the end of the row and reduced the power requirement on the pickup chain. Raking and pickup rates were influenced by grove preparation.

TABLE 3. TEST RESULTS WITH THE DRIP LINE RAKE AND OFFSET PICKUP SYSTEM.

Test No.	Variety	Tree spacing m (ft)	Yield kg/tree (lb/tree)	Avg. ground speed *rake* km/h (mph)	Avg ground speed *pickup* km/h (mph)	Pickup rate kg/s (lb/min)
1	Hamlin	7.6 x 7.6 (25 x 25)	225 (495)	1.6 (1)	1.2 (0.75)	5 (657)
2	Pineapple	7.6 x 7.6 (25 x 25)	204 (450)	1.95 (1.21)	1.2 (0.75)	5.5 (594)
3	Pineapple	7.6 x 7.6 (25 x 25)	204 (450)	1.95 (1.21)	1.2 (0.75)	5.5 (594)
4	Pineapple	7.6 x 7.6 (25 x 25)	204 (450)	1.6 (1)	1.2 (0.75)	5.5 (594)
5	Queen	4.6 x 9.1 (15 x 30)	143 (315)	1.6 (1)	0.8 (0.5)	3.5 (462)
6	Hamlin	7.6 x 7.6 (25 x 25)	265 (585)	1.2 (0.75)	0.8 (0.5)	3.9 (515)
7	Hamlin	7.6 x 7.6 (25 x 25)	265 (585)	1.2 (0.75)	0.8 (0.5)	3.9 (515)
8	Valencia	7.6 x 7.6 (25 x 25)	269 (594)	1.6 (1)	1 (0.63)	3.9 (515)
9	Valencia	7.6 x 7.6 (25 x 25)	253 (558)	1.6 (1)	1 (0.63)	5 (654)
10	Valencia	7.6 x 7.6 (25 x 25)	245 (540)	1.6 (1)	1 (0.63)	4.8 (634)

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