A Tractor-Drawn Rake for Oranges

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ABSTRACT

DESIGN requirements established over four harvest seasons, with two tractor-mounted raking systems were used to develop a tractor-drawn rake that gathered oranges into a windrow for pickup. The constructed unit used three oblique rakes and a horizontal brush to gather fruit into a windrow at the tree dripline or at the center of the row for pickup. Fruit recovery averaged 99 percent in citrus groves suitable for mechanical harvesting at raking speeds of 0.8-1.6 km/h (0.5-1 mph) in an average fruit load of 22 kg/m (15 lb/ft) of windrow. Fruit damage, recovery, and raking speed were influenced by grove conditions.

INTRODUCTION

Mechanical systems to harvest Florida oranges destined for processed products have been under development for over 2 decades. The most widely used method is mechanically shaking limbs for mass fruit removal after the fruit has been sprayed with abscission chemicals to reduce the fruit detachment force. These chemicals almost always cause preharvest fruit drop which results in fruit on the ground at harvest time. Research and development of machines to gather fruit which has fallen or been shaken onto the ground has been underway for the past decade (Sumner and Hedden, 1972; Churchill et al., 1976).

Preliminary rake design requirements were established by using a tractor-mounted oblique citrus rake that moved fruit to the row middles for pick up (Sumner and Hedden, 1972). The pickup and raking units were also combined into a single unit for testing a complete system (Sumner and Hedden, 1974). In high-yielding groves, however, moving large fruit loads to the center of the row caused excessive fruit damage. Therefore, a system was developed that picked up fruit from a windrow at the tree dripline approximately 1.8 m (6 ft) from the tree trunk to reduce the damage to fruit by reducing distance and amount of fruit moved in one direction (Churchill and Sumner, 1977).

MACHINE DESIGN CRITERIA

Machine design criteria were established over four harvest seasons (1975-78), with two tractor-mounted rake systems that move fruit into a windrow. The first system, used in 1975, consisted of three oblique rakes mounted to a 48 kW (65 hp) hydrostatic drive tractor (Fig. 1). A 2.4-m (8-ft)-long, four-bar, oblique rake mounted to the front of the tractor raked the fruit from the row middle to the dripline of the tree. A 1-m (3½-ft)-long, three-bar, oblique side shift rake with rubber teeth raked the oranges from around the tree trunk, shifting in and out as it passed each tree. Fruit from the shifting rake was discharged in front of a 1.2-m (4-ft)-long, four-bar, oblique inside rake with rubber-mounted steel teeth that raked the oranges into a 102-cm (40-in)-wide windrow at the tree dripline 2 m (6½ ft) from the tree trunk. A 33-cm (13-in.) wheel sweep made of rubber flaps that rotated at 100 RPM was mounted ahead of the left front tractor wheel to remove the fruit in the path of the wheel. The side shift and inside rakes were mounted on long tubes that pivoted near the front wheel of the tractor. The amount of rake overlap was adjusted by hydraulic cylinders that powered the pivot tube in and out. Two caster wheels mounted behind each rake controlled rake depth. For transport, the rakes were retracted onto a carrier bar attached to the three-point hitch of the tractor.

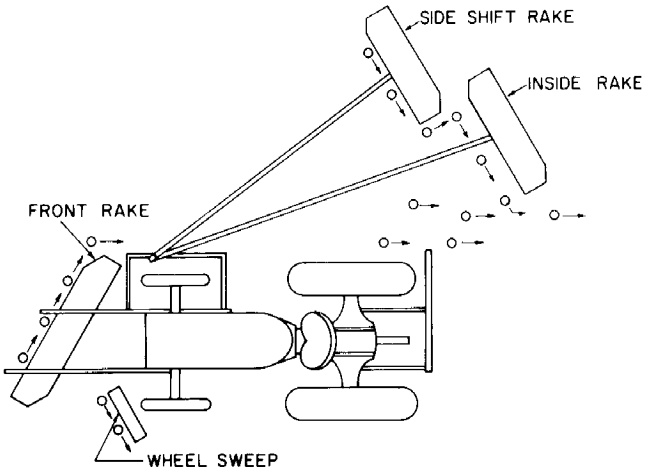

FIG. 1 Plan view of fruit flow through the first tractor-mounted dripline rake system.

This mounting arrangement of the side shift and inside rakes provided adequate rake flotation over uneven ground at speeds up to 1.6 km/h (1 mph). However, when the side shift rake was shifted in and out, it became unstable (tipped up at one end) and missed fruit. Also, the transport system for carrying the rakes was not satisfactory for turning at row ends since the tractor had to be moving forward for the rakes to retract onto the carrier bar.

For the 1976 harvest season, the mounting for the side shift and inside rakes (that gathered fruit from under the tree to the windrow) was redesigned. The frame for the inside rake was attached to the right rear tractor axle and

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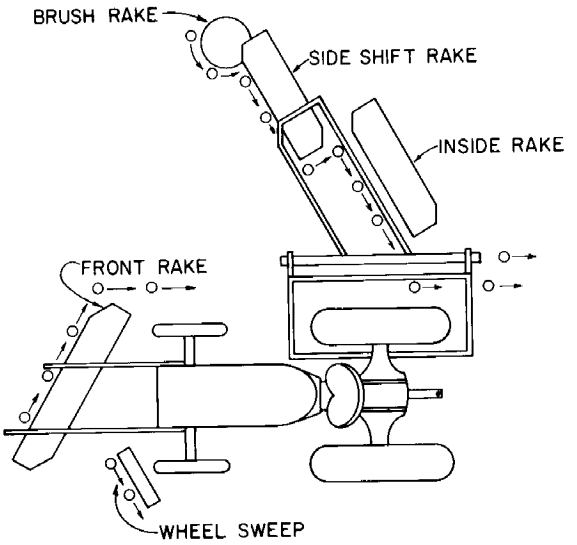

FIG. 2 Plan view of fruit flow through the second tractor-mounted dripline rake system.

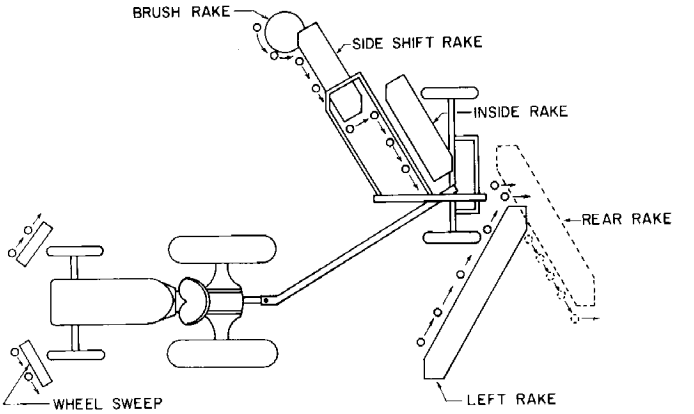

FIG. 3 Plan view of fruit flow through tractor-drawn rake forming windrow at dripline. Superimposed rear rake shown in position for providing windrow in the center of the row.

transmission housing and pivoted about a line parallel to the direction of travel, 51 cm (20 in.) above the ground, and 41 cm (16 in.) from the outside of the rear tractor tire (Fig. 2). A gauge wheel on the outer end of the frame provided depth control. The side shift rake was mounted on slide rails of the frame to provide for a side shift of 91 cm (36 in.). A 91-cm (36-in.)-diameter brush was attached to the outer end of the side shift rake to brush the fruit from around the tree trunks and serve as a depth control for the outer end of the rake. The main frame for the brush and two rakes pivoted 110 deg upward for transport. Churchill and Sumner (1977) described this rake system in detail.

This second tractor-mounted system gave the operator good control of the rakes, thereby increasing raking speed and efficiency as compared with the first system. Raking speeds of 2.4 km/h (1½ mph) were possible under several grove conditions, and averaged 1.4 km/h (¾ mph) in most groves. The transport position for the rakes was much better than the previous front-pivot arrangement.

The second tractor-mounted rake system was used to windrow approximately 40,000 boxes of oranges from 1976-1979 in tests in various groves throughout Florida. It performed adequately in gathering fruit and forming a windrow at the tree dripline (Churchill and Sumner, 1977). However, because the rakes were not easily removed from the tractor, the tractor could be used only for the windrowing operation. Thus a tractor-drawn rake system was needed, so that the tractor could be used for other functions in the harvest operation to reduce harvest machine investment costs.

OBJECTIVE

The objective of the research was to develop an oblique rake system for citrus that could be pulled by a conventional grove tractor. This paper describes the development and performance of such a system to windrow oranges for pickup either at the tree dripline or in the center of the row.

Specific design objectives were to provide:

1 Easy attachment and detachment of rake system to a grove tractor (approximately 37.3 kW (50 hp).

2 Steerable axle for maneuverability at row ends and around tree trunks.

3 Low profile for clearance (under 76.2 cm (30 in.) at the tree dripline) under tree canopy.

4 Ability to gather the fruit into a windrow at the tree dripline 1.8 m (6 ft) from the tree trunk or in the center between two rows.

5 Rakes that fold to less than 2.4 m (8 ft) wide for transport and turning at row ends.

6 Trailable machine behind tow truck at 81 km/h (50 mph).

7 Side shift of rake and brush around the tree trunk.

8 Free floating of the rake height for automatic control of raking depth to allow the operator to concentrate on side shifting of the rake.

9 Adjustable machine to operate in row middles 7.6-or 9.1-m (25- or 30-ft).

10 Safety break-away on the side shift rake.

11 Self-contained hydraulic system driven from the tractor power-take-off.

12 Rake speed of 0.8 km/h (0.5 mph) in fruit density of 30 kg/m (20 lb/ft) of windrow.

DEVELOPMENT

The rake arrangement, outer brush, flotation, and side shift components were similar to those of the tractor-mounted rake (Figs. 3 and 4). The left rake or rear rake was operated behind the trailer wheels instead of on the front of the tractor. An adjustable position hitch allowed for positioning the tractor in the center between rows while the inside and side shift rake assemblies operated under the tree canopy. Two sweeps, 0.9 m (3 ft) wide, ahead of the front tractor wheels kept that area free of fruit. The arrangement of the rakes as shown in Fig. 3 places the fruit windrow at the tree dripline.

To gather fruit into a windrow in the center between two rows, the left rake was removed and a rear rake was mounted behind the right inside rake as shown by the dashed lines in Fig. 3. The tractor-drawn rake could be changed from gathering fruit at the dripline to gathering fruit at the center between rows or vice-versa in approximately 3 man-hours.

Power to operate the rake is supplied through a PTO-mounted, 91 L/min (24 gpm) hydraulic pump on the tractor. Fig. 5 shows a schematic diagram of the hydraulic system. The rake and component specifications are given in Table 1.

TABLE 1. DESIGN SPECIFICATIONS OF THE TRACTOR-DRAWN RAKE

Overall Specifications:				
Width of machine (transport position)			2.4 m	(8 ft)
Width of machine (operating center of row system)			3.8 m	(12.5 ft)
Width of machine (operating dripline system)			5.6 m	(18.5 ft)
Rake shift distance			76.0 cm	(30 in.)
Length (transport and operating position)			4.9 m	(16 ft)
Height (transport position)			3.4 m	(11 ft)
Height (operating position)			63.5 cm	(25 in.)
Height (tire)			76.0 cm	(30 in.)
Weight			1380 kg	(3030 lb)
Tire size (2)			28-38 cm	(11L-15)
Axle (power steering)				
Hitch (adjustable)				
Rake Component Specifications:	Inside rake	Shift rake	Left rake	Rear rake
Raking width, cm (in.)	94.0 (37.0)	94.0 (37.0)	234.0 (92.0)	165.0 (65.0)
Raking height, cm (in.)	66.0 (26.0)	48.0 (19.0)	71.0 (28.0)	71.0 (28.0)
Tooth circle DIA., cm (in.)	36.0 (14.0)	25.0 (10.0)	42.0 (16.0)	41.0 (16.0)
Bar length, cm (in.)	107.0 (42.0)	107.0 (42.0)	259.0 (102.0)	183.0 (72.0)
Teeth/bar (No.)	16.0	15.0	36.0*	34.0
Tooth spacing, cm (in.)	3.8 (1.5)	3.8 (1.5)	3.8 (1.5)	3.8 (1.5)
Tooth length†, cm (in.)	25.0 (10.0)	18.0 (7.0)	25.0 (10.0)	25.0 (10.0)
Side shift (rpm)	0	86.0 (34.0)	0	0
Tooth speed (rpm)	150.0	150.0	150.0	150.0

*Plus four rubber teeth
†Rubber-mounted hay rake teeth

The rakes were lifted for transport by two hydraulic cylinders. A complete transport system was arranged by loading the tractor onto a flatbed truck and hitching the rake behind the truck (Fig. 6).

PERFORMANCE

Adjustment of the trailer wheel steering and the adjustable hitch allowed the side rakes to operate at a 65 deg rake angle from the direction of travel. The rake angle could be increased to 75 deg to provide a wider raking width, but raking efficiency was reduced in heavy fruit loads.

Operator visibility with the tractor-drawn rake was not sufficient, since the leading edge of the brush and side shift rake were almost to the right of the tractor operator. Care had to be taken to drive the tractor straight down the tree row at the proper distance from the tree trunk. The steerable axle of the trailer allowed the rakes to be steered away from the tree trunk to miss low hanging limbs. The steerable axle was also essential for maneuvering at row ends. A safety break-away system to allow the side rake to move back when the tree trunks were bumped was not needed, since the entire rake would pivot about the tractor hitch point and swing away from the tree, and get the rake aligned properly when starting down a new row.

The tractor-drawn windrow rake was used to rake 9000 boxes of oranges into a dripline windrow in three groves to determine if the design objectives had been met. Fruit recovery averaged 99 percent or greater in groves that were considered suitable for mechanical harvesting (level and free from excessive trash). A few fruit were lost at the tree trunks, near exposed tree roots, and in tall grass and weeds.

The windrow rake operated at 0.8-1.6 km/h (0.5-1 mph). Raking speed depended on field conditions and fruit load. Fruit density of 22-30 kg/m (15-20 lb/ft) of windrow was the maximum that could be raked without excessive fruit damage. Densities above 30 kg/m would require a side shift rake diameter larger than 25 cm (10

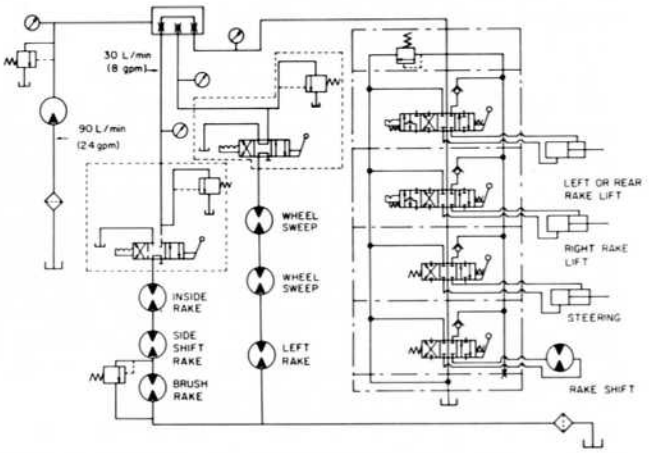

FIG. 5 Hydraulic schematic diagram for tractor-drawn windrow rake.

FIG. 4 Tractor-drawn rake in final stages of construction.

FIG. 6 Transport system for tractor-drawn windrow rake (dripline arrangement).

in.). Trash in the grove will reduce raking speed and increase fruit damage.

Field efficiency (raking time ÷ total time) of the rake was approximately 80 percent. The operator spent down time removing dead limbs, rocks and other trash from the path of the rake. In tall grass, long runners that entwined the rake bars and bearings had to be removed periodically. Replacement of rake teeth bent or broken when they struck rocks and exposed tree roots accounted for most of the repair time.

Approximately 1000 boxes of fruit were windrowed for center row pickup, with all three oblique rakes moving fruit to the left. Side draft was not excessive. The trailer wheels on the rake were turned to the right 2 deg to 5 deg to maintain correct frame position of the rake. The 61-cm (24-in.) "overlap" adjustment of the rear rake provided positioning to allow the windrow of fruit to be discharged in the center of the row for single or double windrow pickup. The capacity and performance of the center windrow rake arrangement was approximately the same as with the dripline windrow arrangement.

SUMMARY

A tractor-drawn windrow rake for oranges was designed, constructed, and tested to meet established design objectives. The unit used three oblique rakes and a horizontal brush to gather fruit into a windrow at the tree dripline or at the center of the row for pickup. A 37.3-kW (50-hp) grove tractor provided sufficient power in the Florida grove conditions tested. At operating speeds of up to 1.6 km/h (1 mph) in a fruit load of 22 kg/m (15 lb/ft) of windrow, fruit recovery was 99 percent in groves suited for mechanical harvesting.

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