

Development of an Auger Picking Head for Selectively Harvesting Fresh Market Oranges

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THE Florida citrus industry harvested 144 million boxes of oranges (1) during the 1966-67 season. The large amount of hand labor required to harvest this crop is more difficult to recruit each year. An inertia tree-shaker and catching-frame system for harvesting citrus was developed in 1966 by Coppock and Hedden (2). This system is suitable for harvesting early and mid-season oranges utilized for processing, but it damages too much such fruit that is to be shipped fresh, and it decreases the yield of "Valencia" oranges — the only late season variety — by removing the young fruit that is developing for the following season's crop. A harvester for Valencia oranges, which make up 50 percent of the Florida orange crop, must remove the mature fruit without damaging or removing the green fruit from $\frac{1}{4}$ to 2 in. in diameter which is on the tree at harvest time. Research on an auger picking head has been aimed at developing a harvest system for Valencia oranges and for fruit that is to be shipped fresh.

Research on the auger picking head was originally started by Coppock (3), who tested a bank of sixteen, 4-in. diameter augers spaced $4\frac{1}{2}$ in. apart on a square spacing. These augers were fabricated of 35 to 45 durometer $\frac{1}{4}$ -in. thick sheet neoprene cemented together. The augers were very time consuming to make, they were not durable enough for extensive testing. The auger flights deflected primarily at the roots of the flight in the glued joint, and, for that reason, it was not certain that these augers closely simulated a molded auger. Only molded augers would be durable enough for a commercial harvest machine.

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* Numbers in parentheses refer to the appended references.

The work reported here progressed from a study of the individual auger characteristics to a study of auger arrangements to a test of a prototype auger bank. Part I, "Auger Shape, Hardness, and Diameter," reports on the effects of auger characteristics on fruit removal and foliage entanglement. Part II, "Auger Bank Configurations," reports on the effects of auger spacing, of rods between the augers, and of square and triangular auger arrangements. Part III, "Prototype Auger Bank," reports on the speed of picking and the percent of fruit removed with a 5-ft square prototype auger bank.

PART I. AUGER SHAPE, HARDNESS, AND DIAMETER

Work to optimize the auger shape and diameter necessitated development of a method to fabricate a number of different shaped augers at reasonable cost. Although it was not necessary that these augers be extremely durable, it was important that they closely simulate a molded auger.

A number of recently developed room-temperature vulcanizing (RTV) elastomers can be cast in plaster-of-Paris molds, and two of these elastomers, polyurethane and polysulfide rubber, were found suitable for casting prototype augers (Fig. 1). The molds themselves were cast in three sections using an auger of $\frac{1}{4}$ -in. thick neoprene cemented together for a pattern. Each mold was durable enough to be used for casting at least 20 augers. Silicone rubber compounds made by three different companies were tested but their tear strength was much too low to be used for casting experimental augers.

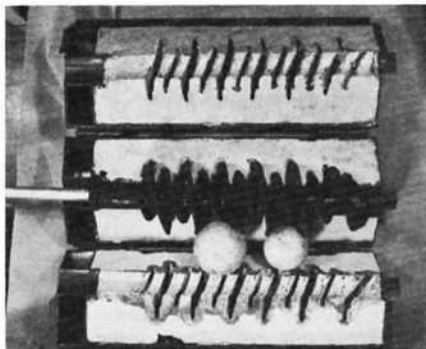


FIG. 1 A three-section plaster of Paris mold used to cast room temperature curing polyurethane augers.

Procedure

Augers of each type shown in Figs. 2 and 3 with the dimensions given in Table 1 were tested to develop an auger shape and diameter which did not entangle the foliage, would remove fruit effectively and convey it to the back of the auger bank without damage. Five different types of $5\frac{3}{4}$ -in. diameter augers (Fig. 2) were tested to determine the effect of auger hardness and shape. One type each of the $3\frac{7}{8}$ -in. diameter, $8\frac{1}{8}$ -in. diameter, and $9\frac{1}{8}$ -in. diameter augers were tested to determine the effect of auger diameter.

The $5\frac{3}{4}$ and $3\frac{7}{8}$ -in. diameter augers were both tested in auger banks of 16 augers in a triangular arrangement. The $5\frac{3}{4}$ -in. diameter augers were spaced 7 in. apart (Fig. 4c) in the auger bank and the $3\frac{7}{8}$ -in. diameter augers were spaced $5\frac{1}{2}$ in. apart (Fig. 4f). Ten of the $8\frac{1}{8}$ (Fig. 4b) and $9\frac{1}{8}$ (Fig. 4a) — in. diameter augers were spaced $10\frac{1}{2}$ in. apart in an auger bank with a triangular arrangement.

The banks with $3\frac{7}{8}$ and $5\frac{3}{4}$ -in. diameter augers had a similar amount of space — $2\frac{7}{16}$ -in. diameter — for an orange between each set of three augers. The space between each set of three $8\frac{1}{8}$ -in. diameter augers was $3\frac{1}{2}$ in. in diameter and the $9\frac{1}{8}$ -in. diameter augers had a space 3 in. in diameter between them.

The auger shafts were 10 in. longer than those tested by Coppock so that the augers protruded 40 in. from the drive unit. More fruit could be reached with the longer auger shafts; however, the augers usually ran into a limb or became entangled before penetrating their full length. At least one tree was picked with augers of each type after

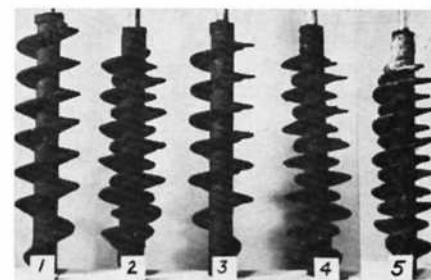


FIG. 2 Five different types of $5\frac{3}{4}$ -in. diameter augers tested. Types 1 and 2 were cast out of polysulfide rubber (30 durometer hardness) types 3, 4, and 5 were cast out of polyurethane (60 durometer).

TABLE 1. SALIENT DIMENSIONS OF EXPERIMENTAL PICKING AUGERS TESTED

Auger No.	No. of auger flights	Durometer hardness	Pitch of flights	Major diameter of largest auger flight	Major diameter of smallest auger flight	Minor diameter
(Fig. 2)						
1	1	30	2 3/4	5 3/4	---	2
2	2	30	2 3/4	5 3/4	3 3/4	2
3	1	60	2 3/4	5 3/4	---	2
4	2	60	2 3/4	5 3/4	3 3/4	2
5	2	60	2 3/4	5 3/4	4 3/4	2
(Fig. 3)						
6	1	60	2 1/2	3 3/4	---	1 1/2
7		(Same as No. 4 in Fig. 2)				
8	4	60	5	8 1/8	7	2 3/4
Not shown	4	60	5	9 1/8	7	2 3/4

* There were two flights of both diameters of this auger.

they had been adjusted to run at their optimum rotational speed. Each was evaluated for its effectiveness in removing the fruit and the extent to which it entangled the foliage.

The auger bank was positioned and then moved into the tree radially with a "scissors" positioner while the augers all rotated in the same direction (CCW looking at the front of the auger bank). The augers were then pulled out of the tree as they were rotated in the opposite direction and repositioned to enter the tree again.

Results and Discussion

Effect of Auger Hardness Auger types 1 to 5 are arranged in Fig. 2 according to the degree that they tended to entangle the foliage. Type 1 entangled the foliage most often, and types 4 and 5 entangled the foliage the least often. The softer (30 durometer) polysulfide rubber augers (Types 1 and 2, Fig. 2) did not slip through the tree foliage as easily as the harder (60 durometer) polyurethane auger (types 3, 4 and 5). The foliage tended to cling and wrap around the polysulfide augers.

The hard and soft augers removed the fruit equally well. In fact, all five of the 5 3/4-in.-diameter auger types removed nearly 100 percent of the fruit once the fruit was entrained within the bank of augers. Each of these auger types appeared to grasp the fruit equally well, and each was equally aggressive in pulling the fruit into the bank of augers.

Effect of Auger Shape Auger shapes having a second smaller diameter flight between the main flight (Types 2, 4 and 5) entangled the foliage less than the single-flight augers. This effect was much more pronounced when the two auger shapes made of the polysulfide rubber were compared. The smaller flight increased the effective diameter of the auger shaft as "seen" by the foliage, and a large diameter shaft has less tendency to wrap up in the foliage than a small diameter shaft.

Auger shape did not have any effect on fruit removal. However, auger type 5 with the largest second flight did not convey the fruit to the back of the auger bank as well as the other two shapes of polyurethane augers (Types

3 and 4). The large fruit was often in firm contact with three augers all of the time and consequently would simply idle in one place. Apparently it is necessary that the fruit have some room to "fall" for the fruit to be conveyed.

The two most effective 5 3/4-in. diameter auger shapes tested (No. 3 and 4, Fig. 2) were compared in two additional tests. Sixteen augers of each type were tested with a 7 1/2-in. center distance between the augers in a triangular auger arrangement. At the time of the first test (October 4, 1967), the fruit was small and had a high removal force. This fruit tended to wedge between the flights of the single-flighted auger (Type 3) causing the foliage to be twisted around the auger. The smaller flight of the double-flighted augers (Type 4) prevented the fruit from wedging between the flights and, consequently, these augers removed much less foliage. At the time of the second test (November 3, 1967), the larger fruit with a lower removal force prevented the fruit from wedging between the flights of the single-flighted augers and resulted in both types of augers entangling the foliage about the same amount. Usually there was little difference between the operation of these two auger shapes; however, the double-flighted auger always operated as well if not better than the single-flight auger.

Effect of Auger Diameter Increasing the size of the augers caused them to crowd the foliage and entangle it. The 9 1/8-in. and 8 1/8-in. diameter augers entangled the foliage so severely that they were not rated for fruit removal even though there was more room between these augers for the fruit. Instead of going into the foliage, larger augers would push it to one side and remove only a small portion of the fruit. Any foliage pulled into the bank of augers was usually damaged and entangled to a much greater extent than with the smaller augers.

The 5 3/4-in. diameter augers entangled the foliage once every six or seven times they were extended into the tree but could effectively be used to remove the fruit. The smallest augers (3 3/8-in. diameter) very seldom entangled the foliage and effectively removed the fruit.

PART II. AUGER BANK CONFIGURATIONS

Using the optimum 5 3/4-in. diameter augers tested (Fig. 3) and the 3 3/8-in. diameter augers, a number of different auger bank configurations (*i.e.*, spacial arrangements of the augers) were tested. These configurations included triangular and square arrangements of the augers, three different auger spacings, and the placing of rods between each three augers in the triangular arrangements (Fig. 4). The 8 1/8 and 9 1/8-in. diameter augers were not used in this test but are included in Fig. 4 so as to show all the configurations that were ever tested. One-half a tree was picked with each auger bank of sixteen augers and the auger configuration rated for fruit removal, foliage entanglement, aggressiveness, and conveying of the fruit.

In these tests, the augers were rotated in the same direction all of the time the auger bank was moving in and out of the tree. Previously the augers were often reversed when pulled out of the tree to untangle the foliage. This was time consuming, and one of the primary objectives was to develop a configuration that would remove the fruit without entangling the foliage. The 5 3/4-in. diameter augers were rotated at approximately 250 rpm or 376 surface feet per minute and the 3 3/8-in. diameter augers worked best at 330 rpm or 334 surface feet per minute.

The auger configurations were defined as being closely spaced, intermediately spaced, or loosely spaced as determined by the amount of space between the augers for the fruit. A 2 7/16-in. diameter cylinder was the largest that would fit between the closely spaced augers; a cylinder between

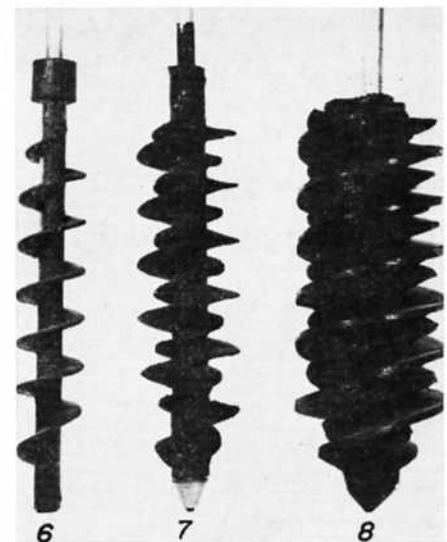


FIG. 3 Three different sizes of augers tested: a 3 3/8-in. diameter auger; the optimum type of 5 3/4-in. diameter auger, and an 8 1/8-in. diameter auger. A fourth size, 1 in. larger in diameter than the largest auger shown, was also tested.

TABLE 2. OPERATING CHARACTERISTICS OF AUGER CONFIGURATIONS TESTED

Auger diameter, in.	Auger center distance,° in.	Fruit removal	Entanglement of foliage	Aggressiveness	Conveying of fruit
5 3/4	7 tri (C)	Excellent	Substantial	Excessive	Good
5 3/4	7 1/2 tri (D)	Satisfactory	Negligible	Satisfactory	Good
5 3/4	8 tri (E)	Poor	Negligible	Satisfactory	Poor
3 3/8	5 1/2 tri (F)	Excellent	Negligible	Satisfactory	Good
3 3/8	6 tri (G)	Satisfactory	Negligible	Satisfactory	Good
3 3/8	7 tri (H)	Very poor	Negligible	Satisfactory	Poor
3 3/8	4 1/2 sq (I)	Excellent	Substantial	Satisfactory	Good
3 3/8	4 15/16 sq (J)	Satisfactory	Negligible	Satisfactory	Fair
5 3/4	8 tri (K)†	Satisfactory	Negligible	Too little	Poor
3 3/8	7 tri (L)†	Satisfactory	Substantial	Too little	Poor

° Center-to-center distance between augers. "Tri" indicated triangular auger arrangement with three-point fruit contact; "Sq" indicates square auger arrangement with four-point fruit contact. The letter in parenthesis is the number of the configuration shown in Fig. 4.

† These arrangements had 3/4-in. diameter rods centered between each three augers.

2 7/8 and 3 in. in diameter would fit between the intermediate spaced augers, and a cylinder 3 1/2 in. in diameter would fit between the loosely spaced augers.

Results and Discussion

Auger Spacing Fruit removal was inversely related to the space between the augers through which the fruit could slide out of the auger bank. Closely spaced auger configurations C, F, and I (Fig. 4) removed all of the fruit which entered the auger bank (Table 2). Closely spaced configuration K (Fig. 4) did not remove all of the fruit, probably because of insufficient auger contact on the fruit. Configurations D, G, J, and L (Fig. 4) with intermediate spacing removed most (90 percent or more) of the fruit which entered the auger bank but did not remove the fruit as quickly as the closely spaced configurations. The loosely spaced configurations E and H (Fig. 4) removed only about two-thirds of the fruit which entered the auger bank.

The maximum triangular spacing of any size augers between 3 3/8 and 5 3/4 in. in diameter which will result in most of the fruit being removed is given by the following equation:

Auger spacing = (Auger diameter + 3 in.) cos 30 deg. This equation was derived from the geometry of configurations D and G (Fig. 4) and simply gives the spacing which will allow a 3-in. diameter cylinder to be placed between the augers.

Too close spacing of augers caused them to entangle foliage. Closely spaced 5 3/4-in. diameter augers entangled the foliage because there was not enough room between the augers for the foliage. Crowding of the foliage was also evidenced by a greater amount of power required to drive the closely spaced 5 3/4-in. augers than the intermediate or loose spacing. Neither the intermediate nor the loose spacings of the 5 3/4-in. augers entangled foliage.

The auger configurations, which crowded the foliage, entangled the foliage less if the augers were extended into the tree very slowly. This gave them a chance to pull the foliage to the back of the auger bank and straight-

en it out thus resulting in less foliage crowding. Moving the augers radially into the tree also decreased the foliage entanglement. Any branches crossways of the augers had much more tendency to entangle.

The aggressiveness of an auger bank was defined as the tendency of the

auger bank to pull foliage into it. Auger aggressiveness was generally related to how crowded the foliage was in the auger bank. Both the 5 3/4-in. augers on a close triangular spacing and the 3 3/8-in. augers on a close square spacing were aggressive auger banks.

Effect of Auger Arrangement and Rods Between Augers Fruit removal was affected relatively little by whether the auger configuration included rods or whether the augers were arranged in a triangular or square pattern. Configurations with 3 3/8-in. augers removed the fruit slightly slower than configurations with a similar spacing of 5 3/4-in. augers, probably because of a smaller area of contact between rotating augers and the fruit. For this reason, the 3 3/8-in. diameter augers in a triangular arrangement did not remove the fruit as rapidly as the square arrangement, and

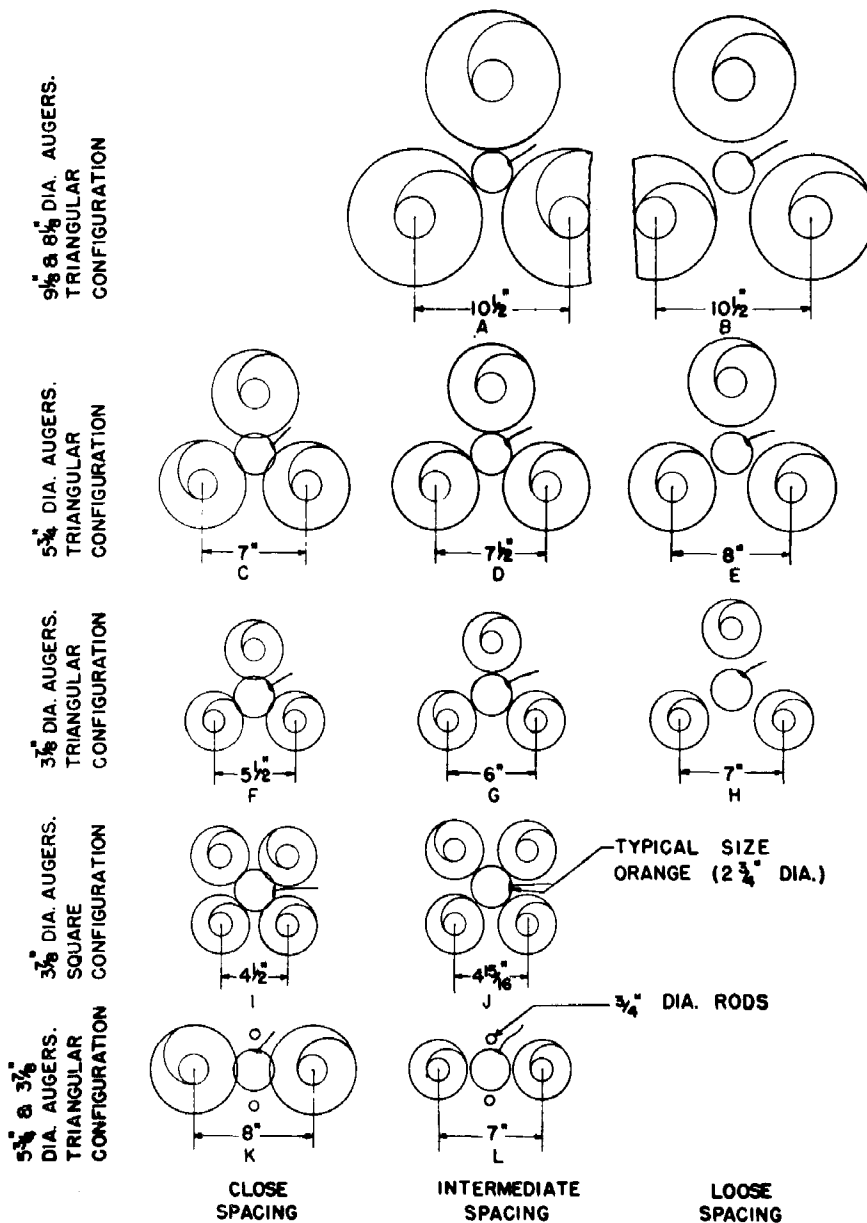


FIG. 4 Schematic drawing of the different auger configurations tested. Each schematic represents one of the fruit-removing "holes" in an auger bank. In a particular auger bank, all of the "holes" were the same geometrically, but some of the holes would be oriented differently than others.

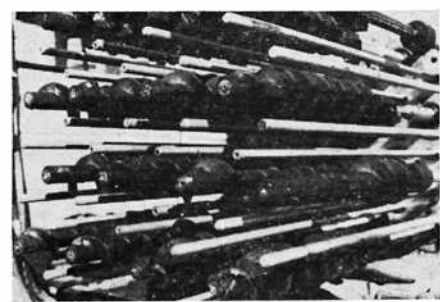


FIG. 5. Augers 3 7/8 in. in diameter with a nonrotating rod centered between each of the three augers. Auger banks with rods were much more difficult to work on than auger banks without rods.

the 5 3/4-in. diameter augers in an 8-in. triangular configurations with rods (Fig. 4k) did not remove the fruit as rapidly as the 5 3/4-in. augers in a 7-in. triangular arrangement without rods (Fig. 4c).

Closely spaced 3 7/8-in. diameter augers arranged in a square configuration crowded the foliage in the auger bank resulting in entangling the foliage while the same augers closely spaced in a triangular configuration did not crowd the foliage or entangle it.

Placing rods between each three augers decreased the aggressiveness of the augers substantially. Configurations K and L (Fig. 4) were the least aggressive of those tested. The foliage had to be pushed into these auger banks.

Selection of an Auger Bank Configuration

Configurations D, G, J, and K removed most of the fruit and entangled very little foliage. Configuration F removed all of the fruit which entered the auger bank and still entangled very little foliage. All of these configurations would be satisfactory as far as operating characteristics are concerned; however, there are definite engineering advantages to some of the configurations.

The two configurations with rods were slower to operate because they had so little aggressiveness. Also, the rods added a great amount of complexity and clutter to the auger bank (Fig. 5). It was impossible to reach into either auger bank that contained the rods to remove twigs and trash.

A minimum of augers for a specific size auger bank is desirable to reduce its weight and complexity. Using configuration D (Fig. 4), an auger is required for each 48.7 sq in. of auger bank area, configuration G requires an auger for each 31.1 sq in. of auger bank area, and J requires an auger for each 24.4 sq in. of auger bank area.

PART III. PROTOTYPE AUGER BANK

A bank of 16 augers was satisfactory for determining the optimum auger shape, spacing, and arrangement; how-

ever, tests to determine the fruit removal or picking time that could be expected with a larger bank of augers were not reliable. A larger auger bank would affect both picking time and fruit removal in two ways.

An auger bank must overlap the areas of the tree it picks in order that fruit which are pushed to one side on one pass will be picked in the next pass into the tree. This would not reduce the effective picking area of a large auger bank as much as it would for a smaller bank. Thus, the picking time for a large bank might be reduced less than expected from the ratio of the areas of the large and small banks.

Conversely, the unevenness of the tree canopy might prevent the total area of a large bank from being used effectively and might even decrease the fruit removal with a large auger bank because of fruit which it could not reach and the small auger bank could. To determine reliably the picking time, fruit removal, and fruit damage that could be expected with a larger machine, an auger bank approximately 5 ft square and with 80 augers was built.

Equipment

Configuration D altered slightly was selected for the 5-foot square bank of 80 augers. The spacing was reduced from 7 1/2 to 7 1/4 in. for design purposes, and the auger diameter reduced correspondingly to 5 3/8 inches.

Room temperature vulcanizing polyurethane was a satisfactory auger material for comparing different styles of augers and evaluating different configurations using a 16-auger bank. However, the RTV polyurethane augers tore too easily to be satisfactory for an 80-auger bank. One RTV polyurethane auger had to be replaced and the tears in several others trimmed each hour of operation on the 16-auger bank. A tear in an auger catches the foliage causing it to wrap around the auger.

An aluminum mold (Fig. 6) was machined for molding augers at a temperature of 320 F and pressure of 1,000 to 2,000 psi normally used to mold rubber. Using such a mold, augers could be made of a number of elastomers tougher than RTV polyurethane.

A bank of 80 augers was built using augers molded of 50 durometer neoprene. The top three rows of augers protruded 39 in. from the drive housing, the next 3 rows 37 1/2 in., and the bottom four rows protruded 36 1/2 in. from the drive housing. The bottom row of augers had 22 in. of flights and the remaining augers had 15 in. of flights. A triangular spacing was used with the augers spaced 7 1/4 in. apart.

The augers were similar in shape to No. 4, Fig. 2. The large auger flight

was 5 3/8 in. in diameter, the smaller auger flight was 3 1/2 in. in diameter, the minor diameter (diameter of the core between the flights) was 2 in., and the flight pitch was 2 7/8 in. The larger auger flight was approximately 3/8 in. thick at the root of the flight and tapered to 1/4 in. at the outside edge. The aluminum shafts were 1 in. in diameter and the augers were driven at 275 rpm.

A picking-head positioner shown in Fig. 7 was used to position the augers and to extend them into the tree. This positioner has a vertical travel of 21 ft and can turn from an angle of 30 deg with the direction of travel to an angle of 150 deg with the direction of travel (Fig. 7). The scissors mechanism on the picking-head positioner extends to a maximum length of 16 ft which enables the augers to be extended into the tree approximately perpendicular to the surface of the tree and collapses to a length of 1 ft 8 in. to pick the side of the tree closest to the transport unit (Fig. 7).

Procedure

Tests were run in three groves to determine fruit removal and picking rate of the augers under different grove conditions (Table 3). Fruit samples were taken in each of the groves to determine the effect on fruit decay of mechanically harvesting with the augers. Tests in the Lake Alfred grove were specifically designed to determine the amount of green fruit removed by the augers at various times during the season. As these tests progressed, the equipment was modified to improve its operation and, consequently, the procedure of each test was slightly different.

Five of the trees in Test 1 (Table 3) were picked with a set of fruit-collecting rods and a collecting bag mounted on the auger bank (Fig. 8). The last five trees were picked with the collecting rods and bag removed, letting all of the mechanically picked fruit fall to the ground. After each of the first five trees were mechanically picked, the fruit caught in the bag, the fruit which missed the collecting bag and fell on the ground, and the fruit left on the tree were measured

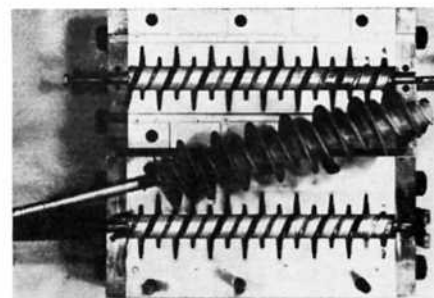


FIG. 6 Completed aluminum mold with one of the rubber augers molded with it.

separately in 90-lb field boxes. The fruit was similarly measured after picking each of the second five trees, except of course all of the mechanically picked fruit fell on the ground.

After test No. 1, the auger bank was altered by removing the collecting rods and installing one rod in the center of each space in the bottom row of augers (Fig. 8). This also allowed the collecting bag to be raised $4\frac{1}{2}$ in.

Test 2 was the same as Test 1 except the small green fruit removed with the augers was collected and counted on a canvas placed under the tree. Also, fewer trees were picked (Table 3), and when the bag was removed, the rods were left in the spaces between the bottom row of augers.

All of the trees in tests 3, 4, and 5 were picked with the collecting bag on the auger bank. Fruit collected in the bag, fruit which missed the bag, and fruit left on the tree were all measured in field boxes in the same manner as for the first five trees of test No. 1 above.

Decay tests were run on the fruit from each test. Two box samples of the hand-picked fruit and of the fruit caught in the bag were taken for all tests. In Tests 1 and 3 a sample of the fruit picked without the bag was taken and in Tests 4 and 5 two box samples were taken from the fruit which missed the bag. One box of each treatment and the check (handpicked) were washed and waxed and the other box stored as grove run (not washed or waxed) at 70 F. The number of decayed fruit was counted at the end of 7 days, 14 days, and 21 days.

RESULTS: PROTOTYPE AUGER BANK

Collection of Fruit Collection of the fruit is an important part of any system to be used for harvesting fresh fruit.

Collecting rods $\frac{3}{4}$ in. in diameter and spaced $2\frac{1}{4}$ in. apart center to center with a bag placed below the augers (Fig 8) were used to collect the fruit in the first test, but the rods pushed the foliage ahead of the augers and made it much more difficult to extend the augers into the tree without breaking limbs. For this reason, removal of the rods during the first test enabled the operator to pick the last 5 trees in 14 min per tree instead of the 17 min per tree required for the first 5 trees (Table 3).

Installing a rod between each two augers in the bottom row of augers caused the bottom row of augers to effectively convey the fruit to the back of the auger bank into the collecting bag. The rods between the augers did not push the foliage nearly as much as the collecting rods below the augers. There was very little difference in the operation of the auger bank with and without the collecting bag. Either system (rods below the bank or rods between the augers) collected approximately 70 percent of the fruit which was picked (Table 3). This is not very good but would be difficult to improve on because most of the fruit not collected is knocked off outside of the auger bank.

Fruit Removal Fruit removal was nearly the same in all of the tests — from 60 to 65 percent. The Lake Wales grove was not severely hedged and appeared to have a lot of inside fruit. Fruit removal averaged only 62 percent for the ten trees mechanically picked. The Fort Pierce trees were very symmetrical and lightly hedged with what appeared to be only a small amount of inside fruit. However, again only 60 percent of the fruit was removed. Possibly there appeared to be a smaller

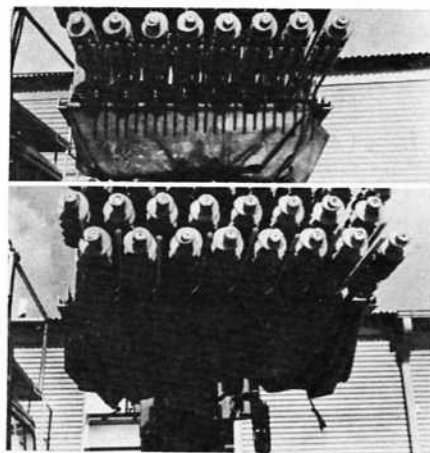


FIG. 8 Rods between the lower group of augers shown collected the fruit as effectively as those below the augers in the upper group.

amount of interior fruit because of the smaller yield of these trees. The Lake Alfred trees (Tests 2 and 4) were large trees that had been severely hedged on three sides. They appeared to be only fairly suited for the augers. However, the removal in tests 2 and 4 still averaged 63 percent.

After test 4, the trees at Lake Alfred were hedged on two sides (every other middle was hedged in both directions), including the side which had not previously been hedged. This was a severe hedging on the fourth side of these trees and removed approximately two boxes of mature fruit on the outside of the tree which could have been easily picked with augers. However, the removal in test 5 was still 63 percent.

Most of the fruit that was not removed was in the center and tops of the trees. When the trees were viewed from the outside, they looked like they had been well picked. This indicates that any stripping device, which does not penetrate further than 3 ft into the canopy of the tree and does not have any provision for reaching down into the top of the tree, probably will not remove more than 60 or 65 percent of the fruit from mature Valencia orange trees.

Rate of Picking The average picking time per tree in each of the tests was from 13 to 14 min, with the exception of the first test when the collecting rods were on the auger bank and test No. 3 in which the trees were slightly smaller and much more symmetrical. The picking time did not include the time to move from one tree to the next one or dumping the fruit out of the collecting bag. The rate of picking (boxes per hour) depended primarily on the yield of the tree since the picking time per tree and percent fruit removed remained almost constant. This indicates the importance of relatively high-yielding trees for the

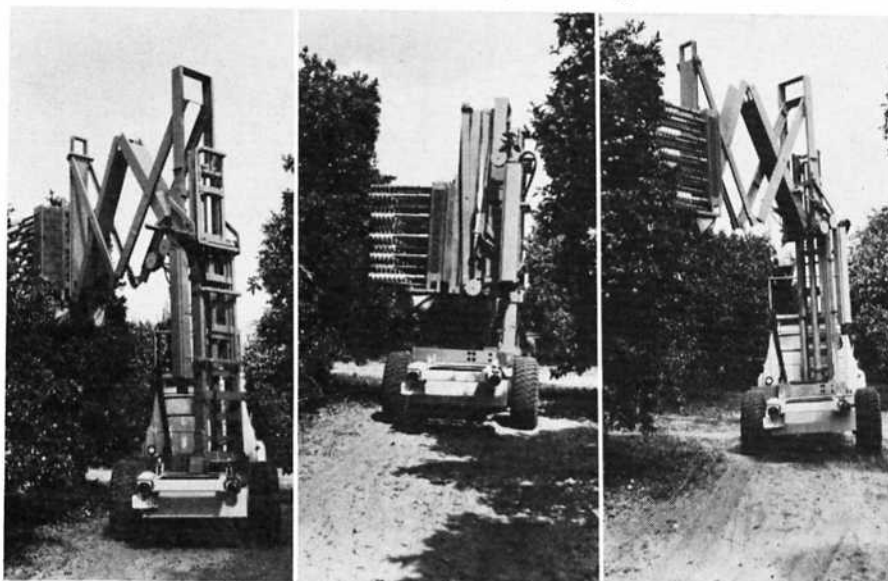


FIG. 7 Positioner with 5-ft square auger bank extended to pick the part of the tree next to the three-row center line and retracted to pick the part of the tree closest to the drive row.

auger or any other fruit contact device since it takes the same amount of time to pick a given size tree regardless of how much or how little fruit is on the tree.

Green Fruit Removed On Test No. 2, 1.54 times more green than ripe fruit was removed. This seems to be an excessive amount; however, most of this green fruit was loose and ready to fall off naturally. The diameter of this green fruit was not measured, but it appeared to be much smaller than for tests 4 and 5.

Tests 4 and 5 are probably much more significant with respect to the green fruit removed than test No. 2. At the time of these tests, there was very little green fruit falling off naturally. It is not known how much the removal of 0.21 to 0.27 times as much green fruit as ripe fruit would affect the next year's yield; however, the inertia shaker, under these same conditions, would be expected to remove about 0.60 as much green fruit as ripe fruit.

Fruit Damage Approximately twice as much mechanically picked fruit as hand-picked fruit had decayed after three weeks in storage (Table 4). This was also true at the end of 1-week and

2-weeks storage. An exception to this trend was the fruit picked in the Indian River section (East coast) of the state on May 28 in which the decay of the mechanically picked fruit and the hand-picked fruit was about the same. Further tests would have to be run on the relatively thin-skinned, tender Indian River fruit to be certain that the augers actually do less damage to this fruit than the interior fruit.

The decay of mechanically harvested fruit is probably low enough for utilization as fresh fruit; however, more tests need to be run on different varieties of fruit in various areas of the state.

Letting the fruit drop onto the ground increased the decay in all of the tests except the first one. This was probably because the ground was softer in this test and was not covered with a canvas as it was in all of the succeeding tests.

Discussion

A maximum of 65 percent of the fruit was removed with the prototype auger bank under any of the test conditions. The value of this much fruit remaining on the tree, under present economic conditions, is more than the total cost of hand picking. Fruit removal with

the augers would have to be improved or else a very cheap method developed for recovering the fruit left on the tree for the auger to be economically practical.

A substantial improvement in fruit removal can probably be made by modifying the existing auger bank to pick down into the top of the tree. It appears that much of the fruit left on the tree could be reached in this way; however, more drastic changes will probably be required to make the system economically practical. Very possibly trees will have to be trained specifically for the augers. A fan-shaped tree, with the large scaffold branches trained into the center of the tree, would decrease equipment cost and could increase fruit removal. I believe there will have to be a substantial change in the shape of the tree before a harvester of this type can be practical under present economic conditions.

References

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