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PICKING CITRUS FRUIT BY MECHANICAL MEANS

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Picking citrus fruit is an operation which involves separation of the fruit from a tree and placement of it into a suitable container on the ground. Hand picking is a strenuous and time consuming task which requires the major portion of the hand labor needed in producing and harvesting a citrus crop. It is becoming increasingly dificult to find suitable labor willing to do this type of work as long as they can find work elsewhere.

Previous attempts to pick citrus by mechanial means have not been very successful. These attempts included tree shaking and separation of one fruit at a time by snapping the supporting twig or by pulling the fruit with a suction force. Patents on such devices date back before the turn of the century.

Problems associated with the design of fruit picking equipment differ greatly from those associated with the design of equipment for harvesting annual row-crops. A citrus tree represents a major investment which must produce a profitable return to the grower for many years. Therefore, any picking device or method must not damage the trees in any way which would reduce their annual production or their productive life. Also, the fragility of the fruit requires that it be handled with care. However, this is more important for fruit produced for the fresh fruit market than for fruit produced for processing. Not only do these requirements have to be met, but the machine and the method which is to be used must be justified economically. That is, the machine must save enough on labor requirements over hand picking to offset the investment and operating costs. These and other design problems associated with fruit picking equipment seem insurmountable when measured by past knowledge. However, research has revealed basic information which may make their solution less difficult.

Methods of Fruit Separation.—Oranges, grapefruit and tangerines are attached to their supporting twig through a small button (calyx). It is at this button that separation occurs when the fruit is picked. The conventional hand method of separating this fruit is illustrated in Figure 1.

In Florida most oranges and grapefruit are separated by grasping the fruit in hand and rotating it and at the same time giving it a sharp jerk at an angle to its major axis. As shown in Figure 1, separation forces A and B are acting on the button. Force A is the reaction of the twig to force B which is applied by the hand. These forces are applied progressively around the button as the fruit is rotated, thus reducing the danger of plugging, that is removing part of the peel with the twig. If force B were applied as a straight pull or quick jerk parallel to the axis of the fruit, it would be transmitted equally to the entire button. This would increase the total force requirement as well as increase the danger of plugging. Tangerines, which are highly susceptible to plugging when picked in the same manner as oranges and grapefruit, are usually clipped close to the button using small hand clippers.

The motions employed in the conventional method of separation are varied and complex. They are extremely difficult to duplicate by mechanical means. These motions as nearly as possible are broken down into categories in Figure 1 and listed as spinning, tree shaker No. 1 and tree shaker No. 2 concepts. The motions in these categories are more easily duplicated by mechanical means.

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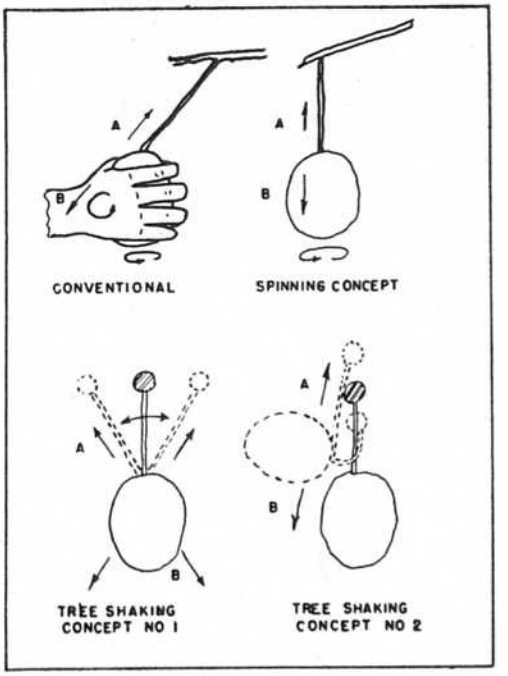

Figure 1. Force analysis of separating citrus fruit by the conventional method and by the spinning and tree shaking concepts.

The spinning concept consists of rotating fruit, in a plane normal to its major axis and the axis of the twig, while applying a force parallel to its axis. This rotation sets up a torsional force in the twig tending to make it curl while the force parallel to the axis of the twig prevents this from occurring. Tests have shown that oranges, grapefruit and tangerines can be separated in this manner without plugging. The number of revolutions required seem to be influenced by fruit maturity as well as by size and length of the twigs and magnitude of the parallel force.

Tree shaking concept No. 1 consists of shaking limbs in a plane normal to the axis of the fruit and depends on the resultant forces of inertia and gravity to effect separation. Force A in this case is the applied force and force B is the resultant of the reaction forces caused by inertia and gravity. The magnitude of force A and its direction relative to the axis of the fruit depends on the stroke of the limb, the weight of the fruit, length of twig and the speed of shaking.

Tree shaking concept No. 2 differs from concept No. 1 in that the limb is shaken in a plane parallel to the axis of the fruit. In this case gravity and inertia forces act in the same plane, thus increasing the reaction to shaking force A. By maintaining shaking velocities of the limb above the free fall velocity of the fruit, a rotational effect of the fruit about the button end is obtained as shown in Figure 1. As the limb moves in the upper half of the stroke, the force A is applied to the fruit at an angle to the fruit axis; thus separation is attained.

Spindle Picker.—Several mechanical devices employing the spinning concept for separating fruit from its supporting twig have been studied. These included: rotating rubber rollers and rotating cones to comb the tree, and rotating, auger-shaped spindles made of neoprene which move in and out of the tree canopy. The latter device offers a means for separating the fruit as well as for collecting it after separation.

The picking unit shown in Figure 2 employs the rotating auger principle. It contains 16 spindles spaced $4\frac{1}{2}$ inches on centers in a square pattern. The auger flights are made of $\frac{1}{4}$-inch 35-45 durometer neoprene. The soft flexible auger enables the unit to separate fruit ranging from 2 to $3\frac{1}{4}$ inches in diameter. Manipulation of the unit in the tree is accomplished by a positioning mechanism which can move in three planes. In operation the unit is pushed into the tree canopy with the spindles rotating in the same direction. Any fruit in the path of the unit is engaged between sets of four spindles and rotated until it is detached from the twig. The fruit is then conveyed by the auger flights to the rear of the spindle where it is collected.

When tested in oranges, the device picked almost all fruit entering the spindles. It picked several fruit at a time without causing visible damage to the fruit or excessive damage to the trees. However, it was necessary to selectively position the unit in the tree canopy such that large limbs were avoided. Obviously this requires too much time for such a unit to be practical. Basically, the concept of spinning fruit by means of auger-shaped spindles was sound. However, the greatest factor hindering the incorporation of this concept into a practical machine is the lack of a means for positioning the picking unit such that it will remove all the fruit from the canopy of the tree in a continuous and non-selective operation.

Continuous operation of the spindles could be obtained by using a rotating drum arrangement as shown in Figures 3 and 4. By synchronizing the forward speed of the machine with the peripheral speed of the drum, the spindles will move in and out of the canopy without raking the foliage. It is more difficult to make the operation non-selective because of the location of the large limbs. Possibly the solution will come through tree shaping. A fan-shaped tree with its large limbs in the center of the fan certainly would aid in solving this problem.

Shake and Catch Harvest.—For many years the concept of shaking trees to remove fruit has been practiced in harvesting nut crops such as walnuts, pecans, etc. Recently the concept has been adapted for harvesting prunes and peaches which are produced for processing (1). Usually a catching frame is used to collect the fruit. Three general types of tree shakers commercially available are: fixed stroke, inertia and impact.

The fixed stroke and the inertia type shakers have been tried in harvesting citrus. The fixed stroke shaker employs a positive eccentric drive

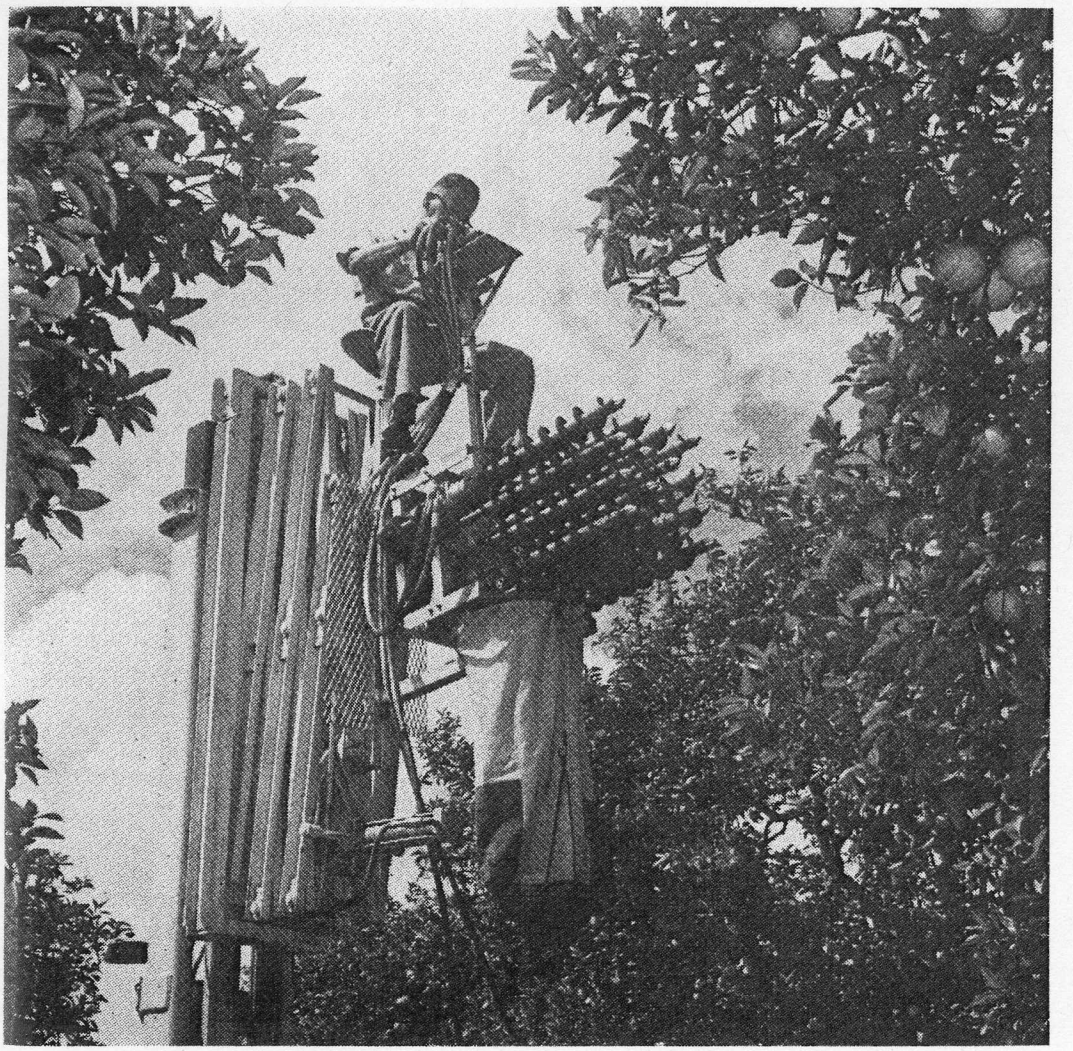

Figure 2. Spindle type fruit picker, incorporating auger-shaped spindles, being tested. In oranges. In operation, the flexible auger flights engage the fruit as the unit is pushed into the canopy of the tree.

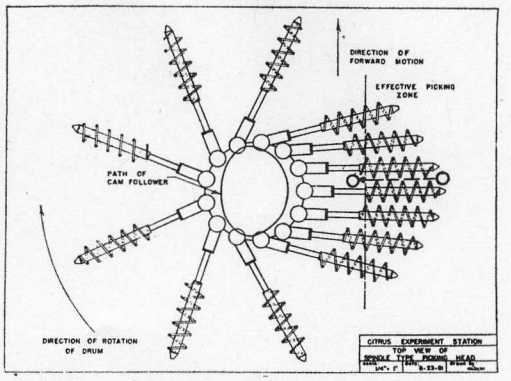

Figure 3. Schematic diagram of a proposed drum type, spindle arrangement showing path of spindles. By synchronizing the forward speed of the unit with the peripheral speed of the drum, a continuous picking operation can be obtained.

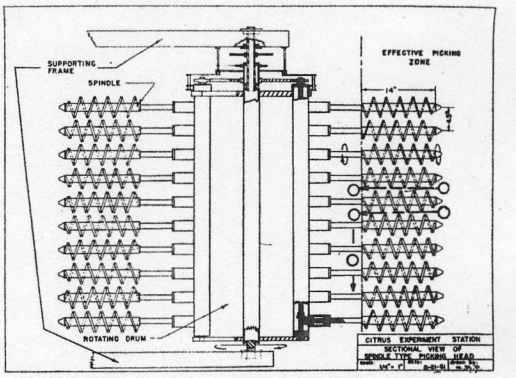

Figure 4. Schematic diagram of a proposed drum type, spindle arrangement showing the path of the fruit.

to produce the shaking action; therefore, it must be rigidly mounted to the transport unit for stabilization. This made mobility difficult in a closely planted citrus grove. The inertia shaker uses a rotating eccentric weight suspended independent of the transport unit to produce the shaking action. The variable stroke characteristic of the inertia principle seems to be desirable from the standpoint of fruit removal. The independent suspension feature also permits mounting so that a high degree of mobility can be obtained.

The experimental inertia shaker in Figure 5 is similar to the ones used for harvesting prunes. It consists of an eccentric drive with an unbalanced weight of 85 pounds attached to a claw through a 12-foot steel tube. The unbalanced weight, made up of the hydraulic drive mechanism, oscillates through a fixed stroke of four inches at frequencies from 0 to 1,000 cpm. The shaking parts are suspended on a turret mechanism. In operation the shaker is manipulated into the tree and attached to a primary limb.

In a test, Valencia orange trees with mature fruits, as determined by the Brix/acid ratio,

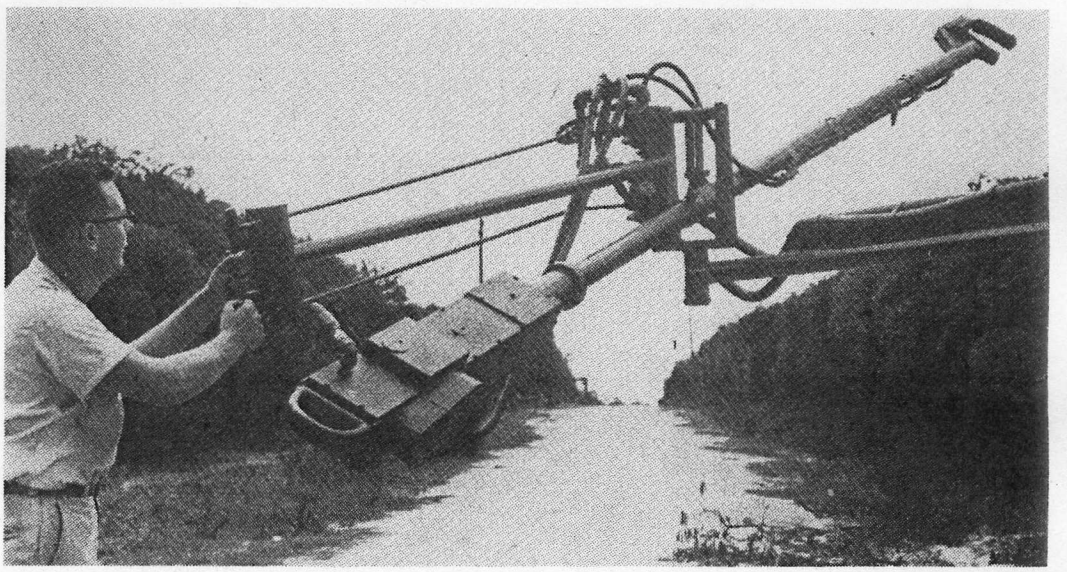

Figure 5. Inertia tree shaker used in the harvest of citrus. It was designed after one developed by the University of California-U.S.D.A. for harvesting prunes. A rotating eccentric weight of 85 pounds produces the shaking action.

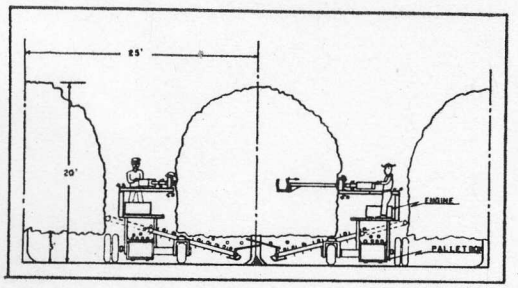

Figure 6. Schematic diagram of a shake and catch method of harvesting which may have possibilities in citrus. It consists of two tree shakers and two self-propelled catching frames working in unison on opposite sides of the tree.

were shaken at two-week intervals beginning on April 26 and continuing through June 5. Fruit removal increased from 44 to 68 per cent over this period while the Brix/acid ratio increased from 13.88 to 16.54. This indicates that a relationship exists between these variables. Brix/acid ratio of the fruit remaining on the trees was not materially different from that shaken off.

Weather conditions and the angle of shaking relative to the fruit axis are important factors other than friut maturity which affect fruit removal. Fruit removal seemed to be easier following a rain or early in the mornings when the fruit was in a turgid condition. In contrast to popular belief, a greater amount of fruit was removed by shaking the limbs parallel to the axis of the fruit. A serious disadvantage to harvesting Valencias in this manner is the fact that a new crop of fruit has already formed when the mature fruit is being harvested. Early and mid-season oranges do not have this problem.

Preliminary shaking tests conducted on early and mid-season oranges indicate that a fruit removal of not over 50 per cent can be expected at the beginning of the harvest season. This low fruit removal is the greatest deterrent to the development of the shake and catch method for harvesting these fruits. The possible use of a pre-harvest spray to loosen the fruit so that its removal would be enhanced has been considered. However, besides the problem of developing such a chemical, there is a greater problem of controlling its use. No doubt, the fruit removal can be increased some by finding the proper clamp angle, stroke and type of shaking action.

When the fruit removal problem has been solved, a harvester consisting of two tree shakers and two self-propelled catch frames working in unison on opposite sides of the tree could be developed. A schematic diagram of such a harvester is shown in Figure 6. The fruit will be caught on revolving drapers extending out from the transport unit, conveyed out from under the tree canopy and discharged into pallet boxes.

Conclusions.—In general, citrus fruit can be picked mechanically by spinning it about its major axis and by shaking the tree.

The auger-shaped spindle type picking device will pick fruit without excessive damage to the fruit or the trees if the large limbs are avoided. The greatest problem hindering the incorporation of this principle into a practical machine is the lack of a means of positioning the unit so that it will remove all the fruit from the tree canopy in a continuous and nonselective operation. Tree shaping may be a solution; however, this may require considerable time and may be uneconomical.

Shake and catch method of harvesting offers a possible method for harvesting citrus which would require only a limited amount of tree shaping. A low per cent fruit removal is the greatest factor hindering the development of this method for harvesting early and mid-season oranges. A preharvest spray to loosen the fruit, if such a spray were developed, would involve problems of control. This method would be more difficult to develop for Valencia oranges because young fruit is usually on the tree when the mature fruit is harvested.

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