TREE FRUIT AND GRAPE HARVEST MECHANIZATION PROGRESS AND PROBLEMS

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The past decade has seen a marked increase in the mechanical harvest of some tree fruits grown on the Pacific Coast. Prunes and cherries are extensively harvested by a shake-catch method, walnuts and almonds by pickup machines or catching frames and tree shakers, and figs by pickup machines after natural drop. The trend indicates that machine harvest of clingstone peaches, apricots, and grapes will soon be commonplace.

Mechanization of fruit harvest involves the development of mechanical principles, modification of the biological system, and adaptation of handling and processing operations. Failure in any one of these can prevent successful mechanical harvesting.

Machine development, primarily the responsibility of the engineer, includes conception of an idea and its reduction to practice. The problems encountered by plant scientists and engineers are largely determined by the type of mechanization: either an aid to workers who pick the fruit, or a machine that actually harvests the fruit itself.

Man-Positioners.

Harvesting aids such as man-positioners have particular potential with crops expecially subject to damage, for example, fruits intended for the fresh market. Since the productivity associated with such aids is relatively small, however, this approach is practical only as long as sufficient labor is available. Under most conditions at present, the average increase in picking rate with most man-positioners is about 20 to 25% being greatest with average or slow pickers. It is particularly difficult to improve the productivity of good pickers given an incentive wage. Economic justification of such machines is difficult since investment per man is very high for a machine that carries only one picker, and the rate of picking is largely dictated by the slowest worker when the one machine carries several workers.

Recent efforts to develop more effective man-positioners for deciduous fruits have been directed toward machines for close-planted or hedgerow orchards. The USDA has reported on such a machine for harvesting apples for the fresh market. The machine carries four workers, one seated and one standing along each side of the aisle picking fruit as the machine passes between the hedgerows. Each picker, working at a fixed elevation, places individual fruits in separate pockets on a special conveyor designed to eliminate contact between fruits and thus reduce fruit injury.

Another machine is under development at the University of California (Fig. 1), called a multi-level platform, the machine has a series of 2-foot-wide steps with a 1-foot rise between steps. A guard rail along each side of the machine supports a narrow conveyor that receives the picked fruit. The width of the machine is adjustable to accommodate a variety of hedgerow spacings. The machine is intended for use only on hedgerow plantings, which present a relatively continous wall of fruit without movement of the pickers into and out of the tree row. It is designed to provide flexibility for the workers so they can move to the location of the fruit and help each other as needed. The machine moves continuously at a slow rate. With the trees planted close and trained into a relatively solid row, little time is lost between trees. During recent limited tests on pears, a crew of ten pickers (four on each side of the machine and two ground pickers) plus one operator picked fruit at the rate of four to six bins per hour (slightly over 0.4 bin per man-hour). With ladder picking in the same orchard at an hourly pay rate, the same pickers averaged about 0.2 to 0.25 bin per man hour.

Such man-positioners require a well-shaped, uniform hedge. Since a man can reach about three feet, it has been thought that a hedge no more than six feet thick would be satisfactory. Experience indicates, however, that pruning to four feet would be much more desirable, for two reasons: a picker can harvest about 33% faster when he does not have to reach far; and fruit weight tends to spread trees wider than the pruning width. If the machine crowds the tree row to reduce the reach required, limbs interfere with the pickers, slowing them considerable. Ideal for harvest platforms would be hedgerows like the palmeta system of growing pears and apples in Italy.

Before this approach to harvesting comes into extensive use, questions must be answered about yield, harvest costs, tree training, and other factors determining total profit. What tree spacing, row spacing, and hedgerow thickness are optimum? How can trees best be trained, and how can limbs best be kept from leaning out into the aisle? What fruits require the relatively gentle handling of the hedgerow system and are adaptable to it? Next to the shake-catch harvest, I consider this method to have the greatest potential of any known method for easing the arduous task of harvesting deciduous tree fruits.

Shake-Catch Method.

Current technology limits shake-catch harvest to fruits for processing and to fruits which can withstand some impact. Tree shakers and catching frames became practical for the harvest of soft fruits with the developments of the inertia principle of tree shaking and decelerator strips that minimize impact injury by breaking the fall of fruits. Since 1960, when the inertia tree-shaker principle was reduced to practice, a number of different commercial trunk and limb shakers have been developed. Almost without exception shakers used on soft fruits are of the inertia type. The primary advantage of inertia shakers independent of the specific mechanism used, is that the shaking forces are isolated from the carrying vehicle and therefore they can be mounted directly on catching frames. The well-coordinated system that results makes possible harvest rates that justify the equipment investment.

With shake-catch harvesting, some type of deceleration device is essential to minimize injury caused by fruit falling onto other fruits, particularly in or around conveyors. Extensive tests on cling peaches in 1966 and 1967 (Fig. 2) demonstrated that the total system must be well-designed and properly managed for economic soundness. Several points of particular importance are: (a) the shaker must remove at least 95% of the fruits; (b) the frame must be of size and design to catch essentially all fruits; (c) catching-surface must have all hard portions effectively padded, and all portions over and near conveyors where density of fruit is high must have decelerators; (d) the conveying and bin filling system must cause essentially no bruising; (e) the trees must be pruned to minimize interference with equipment; (f) fruit-bearing hangers must be kept short so that the vibration imparted by the shaker will be transmitted efficiently to the fruits; (g) the major limbs should be pruned to form a vase with no major limbs located one beneath another, minimizing impact injury from fruits hitting large branches; and (h) maturity must be relatively uniform. Under such conditions, machine-harvested fruit was not significantly different in quality from hand-harvested fruit 24 hours after harvest. When some of the above essentials were absent, however, fruit loss approached or exceeded 10% (determined to be about the maximum loss which can be justified economically). Thus, not only must the machine be of good design but, of equal importance, the trees must be adapted to machine harvest. Further, losses during storage must be minimized by processing the fruit within 24 hours. Minor bruises and cuts which do not down-grade the fruit during the first 24 hours lead to rot and fruit breakdown if processing is delayed.

Tests have shown that minor or moderate bruises and cuts on apricots tend to cook out during canning, so that apricot injury is not as serious as that with cling peaches. Thus, protective equipment on catching frames and tree shape, though important with apricots, is not as critical as with cling peaches. A primary cause of fruit loss is variable maturity both within an orchard and within a tree. Two seasons of tests have shown that, at best, shakers are only slightly selective in regard to removing mature apricots from a tree while leaving immature fruit on the tree. As a result, the best method is to harvest an orchard selectively, going over it more than once, shaking each tree only once. This procedure allows for tree-to-tree variability but not for within-tree spread in maturity. Best results thus call for cultural practices which will induce uniform maturity on each tree. Pruning, fertilization, crop load, hormone applications, or other factors may require adjustment.

Fig. 1. Rear view of multi-level platform.

In addition, equipment is advantageous which is relatively fast, covering the orchard quickly, and either a slow rate of maturing or a gradient in maturity across an orchard would further add to the acreage which could be handled by one machine.

Tests on freestone peaches for processing are limited, but they seem to present a combination of the problems of both cling peaches and apricots. In addition, the requirements for postharvest ripening makes a fungicidal treatment mandatory. Thus, the pruning and equipment design described for cling peaches will be required to minimize field loss and fruit injury; and superimposed on that will be the fruit-maturity considerations discussed for apricots.

Grape Harvesting.

Several approaches to the mechanical harvesting of grapes have been followed in the United States in recent years. Engineering principles have included cutter bars, various types of vibrators, and a vacuum device. An impact device (Fig. 3) has shown considerable potential for wine and raisin grapes in California. Grapes are removed from the vines by an impacter rod which strikes the under side of the trellis wire. The impact separates most fruit from the cane, immediately ahead of the impacter rod. With varieties having large, compact clusters and weak stems, such as Thompson Seedless, removal largely consists of whole clusters. Varieties with small, loose clusters on fibrous stems are subject to a high percentage of cluster breakup. Cluster breakup also increases with maturity. Training and trellising are important for all types of grape-harvesting equipment, including the impacter harvester. The recommended trellis for the impacter is the general shape of a T with a single wire supported at each end of the crossbar. The wire is supported in a vertical slot so that the motion induced by the impacter will not damage the trellis. The training system, known as the duplex system, places canes so that essentially all fruit is produced along the wire.

Research is currently underway to further improve the system for the harvest of raisin grapes. Since fruit damage is a serious problem, a cultural practice is being investigated for harvesting Thompson Seedless grapes as undamaged individual berries. Four to six days before harvest, fruiting canes are severed near the vine head and allowed to dry in place on the trellis. With this practice, the fruit is removed by the impacter harvester largely as individual berries, partially dried and less subject to mechanical damage.

Conclusions.

The current trends are certain to continue. New mechanical principles will solve many harvest problems for plants that are properly prepared for mechanization. Research on new varieties should, of course, consider the requirement of mechanization, but short-term potential gains from new varieties of tree fruits and grapes will be limited by the long productive life of orchards and vineyards, and by the long time involved in breeding. Thus, immediate assistance to mechanization will come through pruning, training, fertilization, and other modified or new cultural practices.

Fig. 2. Shake-catch harvester for cling peaches.

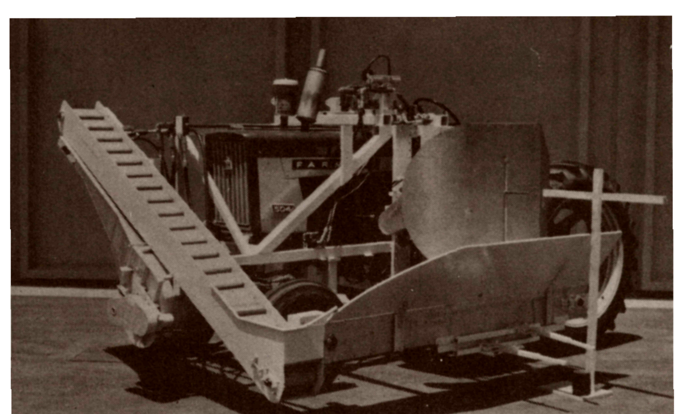

Fig. 3. Impacter harvester for grapes.

Literature Cited

1. Adrian, P. A., R. B. Fridley, and L. L. Claypool. 1968. Adapting shake-catch method of harvesting to cling peaches. *Trans. of Amer. Soc. of Ag. Eng.* 11(2):159-163 and 166.
2. Berlage, Arnold G., and Gilbert E. Yost. 1968. Tree walls for the tree fruit industry. *Agricultural Engineering* 49: (4) 198-201.
3. Claypool, L. L., R. B. Fridley, and P. F. Lasker. 1968. How to proceed, what to expect in mechanical harvest of 'cots. *Western Fruit Grower* 22(6):9-10.
4. Ross, Jack. 1968. Multiman picking machines and systems in California. Paper presented before the *International Citrus Symposium*, Riverside, California, March 19.
5. Studer, Henry E., and Harold P. Olmo. 1968. A mechanical harvesting system for wine and raisin grapes. Paper presented before the *Society of Automotive Engineers*, San Francisco, California, August 12-15.
6. ———, Training and trellising grapevines for mechanical harvest. 1968. *University of California, Agricultural Extension Service* AXT-274.

MECHANIZED GROWING AND HARVESTING OF VEGETABLE CROPS IN THE EASTERN UNITED STATES

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Although there are several ways to discuss mechanization of crop production, I have chosen the evolutionary approach. Mechanization goes through evolutionary stages. As new crops are mechanized, the intermediate steps could be by-passed if the evolutionary pattern is understood. Let us examine some of the steps taken in mechanization with various vegetable crops.

Hand thinning of vegetables was once a tedious and high-labor requiring job. Later, machine thinning was developed for many crops and now precision seeders may eliminate the thinning operation entirely. It would seem then, that instead of devoting out efforts to mechanical thinning equipment, we should go directly to the most advanced step–precision seeding.

Weed control has been one of the highest labor consuming operations in vegetable production. Hand weeding has been supplemented with or partly replaced by mechanical weeding. More recently, herbicides have taken over more and more of the operation. Since chemical weed control is presently the most advanced method, shouldn't we devote more attention to improving this method and to looking for new methods rather than trying to improve cultivators?

Harvest mechanization has brought about drastic changes in crop growing systems. Where late maturing, large-vined varieties were planted in wide-spaced rows and hand harvested several times, early maturing, dwarf varieties in close-spaced rows are grown for a single destructive harvest. Processing peas were the first important vegetable crop to complete this transition. The change took place so long ago that most of us cannot remember seeing tall-vined peas grown in wide rows to be hand harvested for canning. But this evolutionary change seems to be inevitable as we mechanized more and more crops. It is coming rapidly for pickling cucumbers and appears to be the direction we must go for tomatoes in the Eastern U.S. Many years of research and development effort in mechanizing production and harvesting of a crop can be saved if this inevitable evolutionary change is recognized.

Unfortunately our harvesters have sometimes been made to fit only the existing row spacing. In snap beans, experimental results have consistently shown that yields increase when rows are spaced approximately 9 to 12 inches apart when compared with 36-inch rows. In spite of this information, present harvesters can only be used on rows about 36 inches apart. The wide rows are vestiges of the necessity to fit the rows to the width of a horse for cultivation.

Closely related to the changes in row spacing and plant size is the evolution of harvesting methods. The usual stages proceed from hand harvesting, to mechanical aids for hand harvest (as conveyors), to destructive machine harvest following hand harvest, to a single destructive harvest. The most advanced stage is the single destructive machine harvest.

An evolutionary sequence is also involved in handling the harvested crop. In the early stages of machine harvesting, the crop is usually collected in some small container already in use. Sometimes the packing and sorting operations are an integral part of the harvester. In more advanced operations the crop is handled in bulk and transported to a central location for washing, grading, and packing or processing.

There is a need for an integrated approach to mechanization. If we understand the evolutionary steps, then search for presently available ideas, we can frequently mechanize a crop by putting the ideas together in sequence or in one machine. Varieties, fertilization, precision seeding, weed, insect, and disease control, plant spacing, scheduled plantings, irrigation, mechanical harvesting and mechanized postharvest handling must all be considered simultaneously if we are to be most efficient.