ARS SPECIAL REPORT

MECHANIZING the HARVESTING and ORCHARD HANDLING of FRUITS

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ABOUT THIS REPORT . . .

This report discusses the progress that research is making to mechanize the harvesting and handling of fruits. It emphasizes the necessity for this research and how mechanization may save growers time and money and insure for the consumer that which he has always demanded—an abundant supply of quality fruit and berries at a reasonable price.

Some examples illustrate further the advantages of mechanization: One man can mechanically harvest as many blueberries as six handpickers and six men can harvest as many cherries as 33 handpickers. Also, 1 man and an equipped tractor can carry 1,500 bushels of apples out of an orchard in an 8-hour day—a job that formerly required 6 men, 3 tractors, and 3 trailers.

This report has been prepared for county agents and other agricultural leaders.

Information in this report was provided by the Agricultural Engineering Research Division of the Agricultural Research Service.

MECHANIZING THE HARVESTING AND ORCHARD HANDLING OF FRUITS

Changes are taking place in the harvesting and handling of certain fruits. The actual picking of the fruit is being mechanized and the harvest is thereafter handled in bulk lots. Aids are also being developed to increase handpicker efficiency.

The Agricultural Engineering Research Division (AERD) of the Agricultural Research Service, U.S. Department of Agriculture, and the Division's predecessors, pioneered this mechanical handling and harvesting of fruit. In 1949, it initiated research to improve handling. Today, over 80 percent of the deciduous fruit harvested in Washington, Oregon, Michigan, and California are economically and conveniently handled in the orchard by methods worked out and recommended by AERD.

In 1955, AERD began research designed to mechanize fruit and berry harvesting. While this research is still in its infancy, many of its developments have been accepted by many growers in Michigan, California, New Jersey, and elsewhere.

Today, AERD, in cooperation with several States, is studying the mechanical handling and harvesting of the following: Apples in Washington; peaches, apricots, prunes, and dates in California; citrus fruit in Florida and California; and apples, sweet and sour cherries, grapes, and blueberries in Michigan.

SIGNIFICANCE OF THIS RESEARCH

Crops that cannot be harvested cannot be utilized. And many fruit and berry crops in the United States may not be utilized in the future unless research finds ways to harvest them mechanically. The reason: Scarcity of labor to do the harvesting and high costs when labor is available. In 1962, for example, growers received 4.7 cents per pound for their cherries but had to pay 2½ to 3 cents per pound to handpickers. Each year thousands of pounds of berries are not harvested because growers cannot find enough handpickers.

Many fruit and berry growers may be forced out of business before research can solve their harvesting problems. If this prediction comes to pass, the consumer will be the ultimate loser.

Since mechanized harvesting usually means faster harvesting than handpicking, methods to improve and speed up harvest handling are imperative—else advantages accruing to speedier harvesting will be lost. Fruit held too long in boxes or baskets spoil just as rapidly as the unharvested on the bush or tree.

SOME OBJECTIVES AND CONSIDERATIONS

The ultimate objective of this AERD research is to enable one man to do the work formerly done by many. But the quality of mechanical harvests must equal or surpass the quality of handpicked harvests and the harvesting must not injure the tree or bush. In California, Michigan, and elsewhere, where harvests of some fruits are extensively mechanized, these objectives are being realized.

Economic considerations are also important. Mechanization must make money for the grower—enough money so he can afford to invest in the equipment needed. AERD has estimated savings from mechanically harvesting and handling some crops and how much a hypothetical grower must market to make mechanization profitable (*see p. 10–13*). Individual growers, however, who encounter unusual difficulty in getting harvesting help may decide to mechanize even though mechanization will not increase profits.

Before mechanizing, growers should be certain of their markets. AERD advises that not all processors and fresh fruit buyers will accept mechanically harvested fruit. Many of them will, however, and most of them do—after establishing that the quality of mechanically harvested crops equals or surpasses that of handpicked crops.

MECHANICAL HARVESTING—EQUIPMENT AND METHODS

The fact that fruit can be dislodged from trees by shaking the trees led AERD engineers and their collaborators to investigate, test, and develop mechanical shakers and catching frames to mechanize the harvesting of fruit. Today mechanical shakers and catching frames have been used to harvest thousands of tons of prunes in California, millions of pounds of cherries and plums in Michigan, and blueberries in New Jersey and Michigan. Their use will undoubtedly be extended to other crops as research learns more about them.

The shaking force that is applied to trees creates an equal and opposite force (the reaction force) that must be absorbed. This law of physics sometimes limits the effectiveness of shakers. An important segment of AERD research deals with this phenomenon.

Hand-held Mechanical Shakers

Hand-held mechanical shakers may be powered hydraulically, by compressed air, or manually by turning a crank. They are essentially long poles or pipes that transmit the shaking force from the powering mechanism to the tree. They are hooked to or held against individual limbs and then activated. Their use may be exhausting because they often have to be held shoulder high and because the operator must absorb the reaction force.

Hand-held Vibrators for Harvesting Blueberries

Hand-held vibrators for harvesting blueberries are driven by electricity or compressed air. The operator holds the vibrator against the blueberry bush and the driving force vibrates fingers that separate the berries from the bush. The earliest, experimental vibrators were converted from electric hoes.

Boom Shakers

Boom shaker units usually consist of a tractor or truck-mounted boom with a claw (clamp) at the end. They can be maneuvered so the claw can be closed on a main scaffold limb. Once in position the operator can shake the limb by activating the eccentric on the powering mechanism that activates the boom. Under favorable conditions, this is a very effective way of harvesting fruit.

The mass of the truck or tractor, however, has to be greater than the mass of the tree. If it isn't, the truck or tractor will shake more than the tree because of the reaction force.

Inertia Shakers

AERD and State research to increase the effectiveness of shakers has led to the development of inertia shakers. These are designed in such a way that the shaking mechanism itself absorbs the reaction force. This is due to the fact that the shaking mechanism is free to rotate along its main line of motion relative to the claw end, to the ratios between the masses of the shaker and the claw, and the way in which the shaker is supported. The supporting attachment is approximately at the balance point or center of gravity of the shaker and attaches to an extension of the shaker claw.

Catching Frames

Catching frames for fruit are essentially inclined canvas screens fitted under the tree. As the fruit shakes from the tree, it falls on the screen and rolls down into a conveyor that carries it into a box. Some catching frames have manual cranks to move the conveyor. The earliest conveyors were wooden troughs that lifted out so the fruit could be poured into boxes. Most later models have a gasoline engine that moves the frame from tree to tree, runs the conveyor, and powers the shaker.

Figure 1 shows a boom shaker and catching frame being used to harvest peaches.

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Figure 1.—Boom shaker and catching frame are being used to experimentally harvest peaches. Note parallel layers of decelerator strips. These slow the descent of the falling peaches and keep the peaches from bruising when they strike the catching frame.

Collecting frames for blueberries are smaller than those for tree fruit and have no conveyor. They are moved from bush to bush by hand and the harvested berries are poured from them into boxes.

Some Operational Notes

AERD research reveals that shaking periods of 3 to 5 seconds give the best results. Increasing the shaking period does not always increase yields but it does separate more trash and bruise more fruit. The amount of fruit on a tree does not materially affect the time it takes to harvest it.

When heavily laden limbs are harvested, shaking intervals of 1 or 2 seconds should alternate with rest periods of approximately the same duration—to give the fruit a chance to roll off the collecting surface. This procedure reduces strain on the collecting unit and minimizes pocketing and bruising.

Shaker claws should normally be attached to trees in such a way that the angle between them and booms is 90 degrees. To make such an attachment, however, is not always practical. When the angle deviates from 90 degrees, a force is created that may cause the claw to slip. Points at which attachments should be made depend on branch size, distribution of fruit, visibility, and the angle the limb makes with the boom. Best results are usually obtained when attachments are made just below the lowest major lateral branch on a given scaffold branch.

The use of boom or inertia shakers does not appear to damage root systems.

Various amplitudes and frequencies of shaker strokes have been tested. AERD obtained best results in experimental cherry harvesting with a stroke of 1½ inches and a frequency of 900 to 1,200 cycles a minute.

Open trees on level ground with high heads and three or four scaffold branches are the easiest to harvest mechanically. Branches that touch the collecting surface do not shake enough to dislodge the fruit. Rows should be 20 to 24 feet apart and vegetative ground cover no higher than 2 or 3 inches so the movement of equipment will not be impeded. Interplants, especially apple interplants in cherry or plum orchards, often increase mechanical harvesting difficulties by interfering with the proper placement of catching frames.

Other factors that affect harvesting efficiency (for which little research data has been accumulated) include: Spraying, fertilizing, and varietal strains.

Decelerator Strips and Cushioning Material

Two common sources of bruising during the shaking operations are fruit striking other fruit and fruit striking hard surfaces of the catching frame. AERD research approaches these problems through experimental use of decelerator strips and cushioning material.

Decelerator strips are canvas or other woven material, 3 to 6 inches wide, and the same length as the catching frame. They are placed 4 to 5 inches over conveyors or collecting surfaces (*see fig. 1*). If only one layer of strips is used, the strips are usually angled 30 to 40 degrees similar to venetian blinds. When two or more layers are used, the strips may be staggered at different elevations. California experiments showed that deceleration strips prevented serious bruises in mechanically harvested fruit having as much as 24 inch-pounds of energy at impact—a 0.13-pound fruit falling 15½ feet.

In its search for suitable cushioning material, the AERD is looking for a material that, like cotton, absorbs energy rather than one such as sponge rubber that stores energy and then releases it. The latter momentarily holds the harvested fruit but then propels it upward into the fruit that is falling.

In some studies, AERD subjected over 120 different samples of material to impact of a falling ball from heights of 1 to 22 feet and determined the impact force. The data collected are still being analyzed.

AIDS FOR HANDPICKERS

Harvesting fruit for the fresh-fruit market has not been extensively mechanized because equipment now available is not entirely satisfactory. AERD feels, however, that this limitation will eventually yield to research.

Until such equipment is developed, however, AERD is looking for ways to increase picker efficiency so the costs of harvesting for the fresh-fruit market can be reduced. Time studies, for example, show that the average picker spends about one-fourth of his time climbing up and down and repositioning his ladder. And other studies show that a picker can increase his output if he merely picks the fruit and immediately drops it instead of placing it in a picking bag.

Self-propelled, Orchard, and Boom Platforms

Experimental use of these has demonstrated their superiority over ladders and has kept the picker in the tree 100 percent of his time. Most platforms have controls that the picker can use to lower or raise himself as he picks—a distinct advantage over perpetually climbing down, repositioning a ladder, and climbing up up again. Figure 2 shows a self-propelled platform.

Tractors or other vehicles are needed to move orchard platforms. Platforms may also be mounted on the end of booms and the booms raised, lowered, or moved sideways as the picking progresses.

Commercial versions of platforms are available. Currently, however, they are too expensive to justify their exclusive use for picking. Most in use were purchased primarily for pruning and thinning.

Pick-and-drop Equipment

AERD and Washington State University are developing pick–and–drop equipment. It consists of a canvas funnel and a chute mounted on a self-propelled platform (*see fig. 2*). The picker picks the fruit and then drops it immediately into the funnel. The funnel carries it into the chute that in turn carries it into a bulk box also carried on the platform. The chute is padded and baffled so the fruit is not bruised.

Rotating–table Receiver

An experimental table rotates around the picker. The picker, facing any direction, can pick fruit and place it on the table. As the table rotates, it transfers the fruit into a chute that leads to a bulk box.

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Figure 2.—Worker is utilizing a self-propelled platform with pick-and-drop equipment to pick apples.

IMPROVEMENTS IN HANDLING

Before 1949, the fruit and berry harvests were gathered in small "lugs", bushel baskets, or small crates. Each container was then handled separately—lifted and stacked onto trailers, wagons, or trucks to be carried out of the orchard, and then, perhaps, lifted and stacked many additional times before being dispatched to market. To carry 1,500 bushels of apples out of an orchard, for example, required six men, three trailers, and two tractors.

Today, however, one man operating lift equipment and handling the harvest on pallets or bulk boxes can move nearly as many apples in an 8-hour day. AERD is also working on a machine to pick up filled boxes of fruit or produce spotted between rows, and other devices and systems.

Pallets

Pallets are essentially low, portable, double-faced platforms upon which smaller containers can be placed. They are made in such a way that lift equipment can pick them up, and raise, lower, and usually stack them in one continuous operation. Thirty to 60 containers, each containing 40 pounds of grapes or other fruit, can be handled simultaneously as a unit on one pallet.

Bulk Boxes[1]

Bulk boxes are large boxes constructed on pallets. They may hold 15 to 40 bushels and carry between 800 and 1,500 pounds depending on box size and kind of fruit. They can be lifted, carried, and stacked in one continuous operation, the same as pallets, with lift equipment operated by one man. Their initial cost is less than the cost of a pallet and, perhaps, 20 small containers. They seem to be more durable than small containers and are not easily lost. Special equipment may be needed to empty them. Only growers who have lift equipment can utilize bulk boxes advantageously. AERD estimates that an apple grower who produces 8,000 crates of apples would find investing in lift equipment and bulk boxes feasible.

Bulk-box handling methods that AERD developed have become standard practices in all fruit-producing areas of the United States and Canada. During 1962, over 50 million bushels of apples, pears, peaches, and prunes were handled in bulk boxes, thereby reducing production costs about $2 million.

Lift Equipment

ARS 42–20 lists seven types of lift equipment, descriptions of which are summarized below.

Industrial Forklift Trucks

These trucks are the most effective of any for lifting, moving, and stacking unit loads. Growers who pack or store and pack their fruit should provide themselves with this type of lift equipment for use in and around their packing and storage areas. Because these units are heavy, have small tires, and have very little clearance, they cannot be operated on the soft, uneven ground usually found in orchards.

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[1] ARS 42–20, "Equipment Used by Deciduous Fruit Growers in Handling Bulk Boxes," discusses bulk boxes and lift equipment more fully. This publication is available from the Agricultural Engineering Research Division, ARS, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Md. 20705

Field Forklift Trucks

These trucks can be operated in orchards that are sodded and where grades are not excessive. Most, however, are too large and expensive for practical orchard use. They find their maximum, most efficient use around orchard docks and loading areas.

Forklift Tractors

These are effective for orchard use. They are essentially conventional tractors with the lift mast attached to the rear of the vehicle. The gear box, steering mechanism, and driver's seat are reversed so the driver faces the load. Many manufacturers offer new tractors already modified for about $1,200 more than the basic price of the tractor. Others offer units built on secondhand tractors for about $1,500 complete; a tractor of standard make can be modified for about $1,000. Forklift tractors cannot be used like conventional tractors (to pull a plow, for example) unless they are remodified, which is expensive.

Forklift Attachments for Tractors

These attachments are available for both the front and rear ends of practically every tractor of standard make (fig. 3). They are serviceable and operate in practically the same way as those found on industrial lift trucks. They range in price from $450 to $1,000 or more, depending on capacity, the height to which the forks can be raised and other features. AERD recommends rear-mounted attachments because (1) the operator can always see his work, (2) weight of the load is carried by the heavy rear axle and large tires, and (3) steering is usually not affected since the load is off the front wheels.

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Figure 3.—Tractor equipped with forklift attachments being used to carry apples out of an orchard. Other types of lift equipment are available.

Fork Attachments for Three-point Hydraulic Hitches Found on Some Tractors

These attachments, costing about $50, can lift a bulk box about 18 inches. They are quite useful for hauling filled boxes out of an orchard. They cannot be used for stacking. Overloading these attachments may cause leaks in the tractor's hydraulic system.

Fork Attachments for Front-end Loaders

These attachments cost about $50. If used to handle bulk boxes, however, an added hydraulic cylinder costing an additional $50 between the fork and the lifting arms of the buckrake or hayloader is desirable so the operator can keep the forks level. These units have limitations. It is difficult to move the forks smoothly, the forks are on the front of the tractor so it is sometimes difficult for the operator to see the load, and the added weight on the front of the tractor makes steering difficult. When used consistently, AERD recommends (1) that the front axle of the tractor be reinforced, (2) that oversize tires be used, and (3) that the unit be equipped with powersteering.

Homemade Lift Units

Growers with well equipped machine shops can make their own lifts—by shortening a truck chassis, reversing the axle and steering mechanism, and adding a lift mast. Cost of necessary material is about $1,000. Well built units of this type operate effectively.

Trailers and Skids

If it takes 20 minutes or less to make a round trip between the orchard and the packinghouse, storage, or loading area, then bulk boxes can be moved economically by lift equipment. If the round trip takes longer than 20 minutes, trailers or skids may be used economically. ARS 42–20 describes a two-wheeled, bulk-box trailer, and the use of skids.

Straddle Carriers

These vehicles are driven over a load of palletized crates or bulk boxes set on bolsters. Hydraulically operated raising and lowering shoes pick up the load. Loads of 5 to 6 tons can be picked up or set down in 10 to 20 seconds. Loaded straddle carriers can reach speeds of 40 to 50 miles per hour on surfaced roads. Since they have large wheels they can be driven into fields and orchards. They are expensive, however, and AERD estimates that they must be used continuously 10 to 16 hours a day for several weeks before their purchase can be justified. ARS 42–42 illustrates and describes straddle carriers more fully (*see footnote 1, p. 7 and footnote 3, p. 14*).

Handling Fruit in Water

Handling fruit in water, worked out by AERD and Michigan State University, is simple and effective. Cherries, for example, come from the picker's pail onto a sorting board and from there into tank trucks of water. When filled to capacity, the tank and contents are cooled to 60 degrees F. or less by additional running water and the truck then goes to the processing plant. At the plant, the driver attaches a flume, opens the outlet valve and flushes the cherries out with a hose. No other handling between orchard and processor is needed. (Tanks may also be fastened to pallets and handled with lift equipment.)

The sorting table provides a practical means of removing defective fruit. The cooling preserves on-the-tree quality. Distances between orchard and processor are no longer critical—last year cherries in water were transported over 250 miles with no loss in quality. This system eliminates the need for lugs and the troublesome problems of lug storage, maintenance, and distribution. By reducing production costs, it benefits grower, processor, and consumer. Several hundred tons of cherries were handled this way last year.

AERD has also perfected a water-flotation dumping unit for apples that was used to empty over 400,000 bushels of apples last year. At least 12 units patterned after the AERD unit are now in use.

Machine To Pick Up Filled Lugs[2]

In 1961, AERD investigated the feasibility of a machine to pick up lugs and in 1962 the machine was built and tested. It mounts on a tractor. It has a lifting device, powered by a hydraulic motor, that exerts enough pressure against the sides of filled lugs to raise them onto an elevating conveyor as the tractor moves between rows. The conveyor, powered by the tractor's power takeoff, moves the lugs back under the rear axle of the tractor and raises them to a holding platform above a trailing wagon or trailer bed. A worker on the wagon or trailer bed removes the filled lugs without stooping and stacks them.

The pickup device can be adjusted to accommodate almost any size or shape of box so the machine can be used on many crops. The machine also appears to be especially advantageous in small orchards or fields where it might permit a family to harvest its fruit or other crops without employing outside help. It should cost less than forklift equipment. Commercial models are not yet available.

HARVESTING AND HANDLING SPECIFIC CROPS

The fact that shakers and catching frames are practical and commercially acceptable for mechanically harvesting certain tree fruits and berries is encouraging. It has prompted AERD to experiment further with this system and to explore other harvesting methods as well.

Sour Cherries

Domestic production of our sour cherries approaches 130,000 tons yearly, the "farm value" being about $20 million. It formerly required 45,000 workers to harvest Michigan's crop alone—35,000 of which were nonlocal and had to be recruited in other States or from foreign countries. New York, Wisconsin, Oregon, and other States faced similar problems.

Today, under conditions existing in most orchards, 6 men and suitably designed tree shakers and catching frames can harvest as many sour cherries as 33 handpickers. During 1962, about 2 million pounds of sour cherries were harvested mechanically at a cost of approximately ½ cent per pound against 3 cents per pound usually paid handpickers.

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[2] See ARS 42–83, "Machine For Picking Up Filled Grape Boxes," available from the Agricultural Engineering Research Division, ARS, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Md. 20705

Cherry harvesting equipment costs between $5,000 and $7,000. AERD estimates that if a grower has at least 2,250 trees (about 25 acres) and harvests about 100 pounds of cherries from each tree, he could pay for the equipment in about 1½ years. If the equipment were depreciated for 3 years (it would last much longer under normal use), a grower who had only 15 acres of cherry trees could normally afford harvesting equipment.

AERD also found that cherries could be mechanically harvested with no more bruising than normally occurs when cherries are picked by hand. Undergoing mechanical shaking, falling through the tree, striking the collecting unit and rolling over it to the conveyor bruised the cherries very little. Decelerator strips, however, are necessary over conveyors and desirable over catching surfaces.

In three of six orchards mechanically harvested, about 2 percent of the cherries retained their stems. In the other three, however, 7 percent retained their stems. (Stem retention is undesirable in cherries destined for processing.) Causes for this variation are not definitely known. In some tests, however, attachment was found to vary with the maturity of fruit and the nature of shaking—the number of attached stems decreased as cherries became riper; mechanical shaking yielded fewer with stems than manual shaking. AERD is investigating the possibility that a relationship exists between stem attachment and the amount of nitrogen in the soil or tree. A small percentage of stemmed cherries does not seriously hamper processing.

Sweet Cherries

A considerable portion of the sweet cherry crop is harvested for brining before the cherries are mature enough to go to the fresh fruit market or to the canner. Mechanically separating such immature fruit from the tree requires rather violent shaking and causes considerable bruising. None of 20 or more chemicals that AERD tested to loosen the cherries before attempts at mechanical harvesting proved to be satisfactory.

Further AERD investigation, however, reveals that sweet cherries allowed to reach full maturity increase in size and weight by about 31 percent and that such mature cherries can be mechanically harvested. Whether they can be successfully brined remains to be determined.

AERD research also showed that sweet cherries can be handled in bulk boxes at depths of 16 inches without loss in quality and with savings in time, labor, and money.

Plums

Equipment used to harvest sour cherries mechanically can be used to harvest Stanley Prune plums. Many growers in Michigan and elsewhere are profitably exploiting this fact since the two crops mature at different times.

Compared to handpicking, mechanically harvesting Stanley Prune plums saves the grower about 23 cents per bushel. About 80 trees yielding 5.1 bushels per tree would justify spending $90 for the use of mechanical harvesting equipment.

When AERD experimentally harvested 39 Stanley Prune plum trees, 3.1 percent of the plums were severely bruised and an additional 4.2 percent were slightly bruised. Leaves and twigs that shook off with the plums accounted for 2.7 percent of total weight. From 3 to 14 percent came off with stems attached. The quality of the mechanically harvested plums compared favorably with that of the handpicked being received at the same processing plant. The cooperating processor stated that leaves, twigs, and stems could be removed during processing without difficulty and that bruised plums were acceptable if processed promptly.

AERD attempts to harvest Damson plums with the same equipment were abandoned because about 5 percent of the plums came off with spurs attached. AERD feared that losing so many fruit spurs might reduce the amount of plums borne in succeeding years.

Prunes

Prune growers in the Sacramento Valley, Calif., have adopted mechanical harvesting methods. A three-man crew can harvest up to 70 trees per hour using equipment and methods that AERD and the University of California developed. The equipment consists of a conveyor belt 6 feet wide and 22 feet long, suitable catching surfaces, and a shaker. As the fruit shakes from the tree, it falls or rolls onto the conveyor and moves directly into bulk boxes.

Labor costs with this equipment are about \$2 per ton compared with \$12 per ton for hand harvesting. AERD estimates that a grower would have to harvest 3,200 trees (about 30 acres), four boxes to the tree, before he could afford such mechanical harvesting equipment—the cost (including interest, taxes, and insurance) amortized over 3 years.

In the Santa Clara Valley, Calif., most of the prunes fall from the tree as they mature. This phenomenon presents two problems: (1) Shakers and catching frames could not be utilized efficiently every year because in any given year a large percentage of the prunes might already be on the ground, and (2) handpicking the fallen prunes is costly and slow. After studying these problems, AERD concluded that a ground pickup device or a blower-catch operation to harvest many trees quickly or both would be practical.

The ground pickup device became a machine, self-propelled, 20 inches wide, and operated by one man walking behind it. The man and this machine replaces six or seven handpickers and can harvest about 1,000 pounds of prunes an hour. The operation does not damage the fruit or pick up excessive amounts of soil or trash. About 20 of these machines were in use last year.

AERD engineers and their collaborators also produced a device to remove prunes from trees by modifying a commercially available frost protector blower (6-foot propeller; air velocity, over 100 miles per hour). They installed 9-inch louvers that could be either rotated or oscillated in front of the air stream, and harvested 4 plots of 60 trees every 4 or 7 days. Travel speeds of 2½ and 1¼ miles per hour and oscillation and rotation rates of 60 per minute were used. Results showed that this method was selective in removing only ripe fruit, but the total removed was lower than desirable especially on the last harvest. The results were promising, however, and AERD will conduct more research using this device, perhaps with supplemental shaking.

Blueberries

Cultivated blueberries are grown commercially in the Middle Atlantic States, Great Lakes area, and the Pacific Northwest. About 35 percent of Michigan's blueberries and 30 percent of New Jersey's are harvested mechanically by means of equipment and methods already described that AERD developed. These harvesting improvements are currently saving growers about 5 cents per pound. Even at a 4-cent-per-pound savings, AERD estimates that 20,000 pints or 4 acres of blueberries would justify a mechanical harvesting unit. Equipment for a four-man crew costs about $2,000. Amortized over 3 years, the annual cost would be about $800.

AERD and Michigan State University have also done considerable work on a continuous blueberry harvester that could reduce blueberry harvesting costs to ½ cent per pound by enabling 3 men to do the work of 120 handpickers. This experimental unit, under development for about 4 years, has harvested over 90 percent of the ripe berries from experimental plots without damaging the plants and without picking an excessive amount of unripe berries.

The machine is self-propelled and has two large rotating spindles mounted vertically on a steel frame. Each spindle has 160 wooden horizontal "fingers." In operation, the machine straddles a row of blueberry plants with a spindle on either side of the plants. The spindles rotate, and the fingers vibrate against the plants, shaking the berries off into boxes that are at the base of the machine.

Commercial models of this machine are not yet available.

Dates

Date palm trees are 30 to 60 feet high. Growers are finding it increasingly difficult to get handpickers willing to work at such height. AERD, however, is rapidly developing mechanical harvesting methods for dates that should relieve this harvesting crisis. Although experimental, the methods were used last year to harvest commercially more than 1½ million pounds of dates. AERD achieved harvest rates of 0.96 acres per hour (46 palms per hour) where at least one-half the bunches on each palm were mature.

One method utilizes a moving tower from which mature bunches from opposite palms are harvested simultaneously. Workers, using specially designed vibrators, shake mature dates directly into bulk boxes as the tower moves between the rows.

The other method utilizes a smaller tower. One-half a palm is bunch harvested at a time and the bunches are hauled in a trailer to a central point for shaking.

The vibrators deliver a 3¼-inch stroke at 600 to 1,100 cycles per minute and can remove all the dates from a bunch in about 2 seconds. Two men feeding and operating one vibrator can shake 450 bunches per hour.

AERD made time studies of the two harvesting methods and concluded: (1) Bunch harvesting is feasible, and (2) either method reduces total harvesting costs relative to the handpicking method.

Apples

Preliminary studies by AERD and Michigan State engineers showed that it might be feasible to mechanize the harvest of apples destined for processing. The engineers mechanically harvested several hundred bushels of apples and placed them in crates at a cost of approximately 3 cents per crate. Apples apparently shake off the tree very easily. One grower shook off 200 bushels in an hour last year.

But the significant savings made by mechanically harvesting apples instead of handpicking them are now more or less offset by increased processing costs because of bruising and other factors. The aim of present research is to reduce these increased costs—for example, from a possible $7.05 a ton to less than $1.00 per ton.

Apples for the fresh-fruit market are mostly handpicked—again because machine picking causes too much bruising and the consumer won't buy excessively bruised apples.

Peaches, Pears, and Apricots

Engineers at the California Agricultural Experiment Station studied the feasibility of shaking peaches and Bartlett pears onto a catching frame. More than 75 percent of the peaches and an average 68 percent of the pears were free from visible defects. The fall through the trees damaged more fruit than the falling onto and over the catching frame. The taller the tree, the more fruit was injured.

AERD attained a degree of selectivity (harvesting only mature fruit) in harvesting apricots by using an inertia shaker. Frequencies of 250 to 400 cycles per minute and a stroke of 1-3/4 inches at the limbs gave the best results. Similarly harvesting peaches gave only limited selectivity and AERD concluded that such a method of harvesting would not be satisfactory for commercial operations. These studies further showed that the use of decelerator strips and proper padding is mandatory to reduce fruit injury.

Grapes

In 1962, six States in the United States produced 286,250 tons of Concord grapes, which were mostly picked by hand and handled in boxes, lugs, and trays that hold from 32 to 42 pounds each. Thus, about 15 million containers had to be picked up by hand and moved out of vineyards on trailers or wagons. Grapes are harvested late in the season and it is difficult to find workers to do the harvesting.

The efforts of AERD's engineers to relieve this situation began in 1958.[3] They initially found that very little experimental work had been done to improve the harvesting and orchard handling of Concord grapes. They also found that overfilling the lugs, and other accepted harvesting and handling practices, accelerated quality deterioration. Other AERD findings are summarized below:

Mechanical Harvesting

AERD engineers experimentally harvested two 14-vine rows of Concord grapes using the same equipment used to harvest blueberries mechanically. They harvested at the rate of 318 pounds per man-hour—about twice the rate of handpickers. But the vibrators cracked between 45 and 50 percent of the grapes during separation; no damage resulted when the grapes fell on the collecting fame.

Shaker equipment can be designed to harvest muscadine grapes when the acreage warrants.

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[3] See ARS 42–42, "A Progress Report on Harvesting and Handling Concord Grapes," available from the Agricultural Engineering Research Division, ARS, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Md. 20705

Drop Tests

Bunches of grapes should not be dropped more than 6 inches. Single grapes may be dropped as much as 18 inches without causing significant injury.

Pressure and Piling

Bunch grapes may be piled to a depth of 18 inches; shelled grapes (grapes that fall from the bunches) to a somewhat lesser depth.

Settling Tests

Ten inches of freshly picked bunch grapes allowed to stand for 48 hours settled very little. Twenty-four inches of similar lots carried approximately 7 miles in a pickup truck settled about 2½ inches or about 10 percent. Other transporting studies showed that bunches of grapes piled to a depth of 18 inches can be handled without appreciable damage.

Other Properties

Fruit accounts for 97 percent of the weight of bunched grapes; stems for the other 3 percent. Shelled grapes occupy only about 75 percent of the volume taken up by bunch grapes.

Pallet Handling

Handling lugs of grapes on pallets with forklift trucks increased the rate of handling from 40 lugs per hour to 59 in one instance and to 79 in another. These figures indicate that one forklift unit can handle up to 40 tons of grapes in an 8-hour day. AERD estimates that growers with 30 or more acres of grapes can justify the purchase of lift equipment. Less than 30 acres may also merit lift equipment because it makes the work easier—even though profits may not be increased.

Bulk-box Handling

Emptying filled lugs into bulk boxes, accumulating the boxes until 15 were filled, and then carrying the bulk boxes to the plant with a straddle truck increased the handling rate from 40 to 60 lugs per man-hour. These trials were so promising that the cooperating processor asked that the work be continued and expanded.

Citrus

Last year growers paid $50 million to have their citrus fruit picked. Expectations are that this production cost will increase as the supply of handpickers dwindles and until research can develop mechanical harvesting methods.

AERD has already tested shakers and catching frames to harvest grapefruit. In preliminary trials, AERD and the Citrus Experiment Station, Lake Alfred, Fla., achieved from 50 to 70 percent removal using strokes of 1 to 1½ inches. Additional work may reveal that the proper combination of frequency and amplitude of stroke will remove at least 90 percent of the fruit. The experimenters also tested oscillating air blasts at velocities up to 125 miles per hour. They achieved 99 percent removal but felt they also removed too many leaves.

Also tested were a catching frame and a frame-mounted inertia shaker. The frame had a conveyor and elevator to handle fruit in unusually large amounts. A severe freeze halted this work in December 1962. Other work in Florida includes instrumentation of a shaker to measure removal forces and the screening of chemicals to find an efficient fruit loosener.

In California, AERD and State engineers are studying the physical properties of citrus fruit in order to utilize these properties to achieve efficient mechanical harvesting of the fruit. Preliminary tests performed on navel oranges indicate (1) that more than 75 percent of the oranges detached with a pull applied in line with the stem were removed without stem or calyx, and (2) that oranges detached by spinning separated with or without stem or calyx depending on the orientation of the spin axis with the axis of the fruit core. Limited studies of citrus trees and fruit failed to reveal any electrical or thermal properties that could be utilized in mechanical harvesting.

Drop tests in California are being evaluated. Additional work is planned in both Florida and California.

Other Approaches and Applications

AERD, in collaboration with the Michigan and Washington Agricultural Experiment Stations, is also planning research to improve equipment and methods for harvesting apples and pears from trees of different sizes and shapes and at different planting distances—for example, tree walls and tree hedges of standard, semidwarf, and dwarf trees; trees on trellises; and trees topped and in box shapes at different distances apart. Where orchards with the desired tree size, shape, and spacing are not available, trees will be grown for the study by the Michigan and Washington State Experiment Stations.

The University of California, Michigan State, and Cornell Universities are working on machines to harvest and handle grapes. The California machines necessitate training the vines so the grape clusters hang uniformly under holding wires. The machine then clips the clusters with a moving knife and loads them into a trailer. The Michigan State and Cornell machines are applications of the shaker method of mechanical harvesting.

The University of Florida has been working for many years on equipment to pick oranges and grapefruit. One unit tested uses spindles to twist the fruit off the tree. Although experimental, this unit appears to be promising.

Others who have fruit harvesting projects either active or being planned are Pennsylvania State University, Rutgers University, Oregon State University, Ohio State University, and the University of Connecticut. Equipment manufacturers are also conducting research. Any promising technique developed by these and other experimenters will presumably find immediate application in the Nation's vineyards and orchards.