**Mechanical Harvesting of Cane Fruits**

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**Harvesting** is the most time-consuming and costly operation performed in cane fruit production. It may exceed 50 percent of the total production cost when performed by hand, according to a survey conducted by Cleveenger (3)*. The time and cost factors have stimulated interest in mechanizing the harvesting operations.

Blackberries, dewberries, and raspberries are included in the general classification of cane fruits. The terms “cane fruits” and “bramble fruits” are often used interchangeably. They refer to a group of perennial shrubs belonging to the Rosaceae family, genus Rubus. The aboveground parts of many brambles are biennial and the fruit is borne on the two-year old growth. The one-year old growth consists mainly of succulent shoots. As these shoots mature, they acquire a more woody nature and are called canes (8, 1). This paper deals with selected varieties of blackberries and raspberries which have commercial importance in the western United States.

Cane fruits may be classified as erect or as trailing types according to their natural growth characteristics. Raspberries and some of the blackberries are of the erect type and have canes that are substantially self-supporting, while many blackberries are trailing or prostrate and do not have self-supporting canes. In commercial production, the fruit-bearing canes of the trailing varieties must be supported on trellises which may be made of wood and wire (4, 5, 9). The placing of canes on a trellis or their orientation in the row is called training.

**Training/Trailing Berries for Mechanical Harvesting**

Training systems and accompanying pruning practices influence the total production cost because of the amount of hand labor required. They may affect the yield and location of the fruit through fruit-bud orientations and spacing. This, in turn, influences the operation of mechanical-harvesting equipment. Training of the succulent shoots which will bear fruit the following year is also important because damage to these new canes will have an adverse effect on the next year’s crop.

In the Pacific Northwest, most trailing berries are trained on a single horizontal wire approximately five feet above the ground. The canes of each plant are gathered into a compact bundle which is wrapped around the trellis wire. The canes are usually trained in both directions from the plant and extend approximately three-fourths of the way to the adjacent plant. Variations of this system involve using an extended length of cane which may be looped down and returned toward the mother plant on a second wire placed approximately 18 to 24 inches below the top wire. These systems are not well adapted to the use of mechanical-harvesting practices.

The new canes are usually gathered together along the ground beneath the trellis wire in order to get them out of the traffic area between the rows. Canes on one side of the row are trained in the one direction while those on the other side are trained in the opposite direction.

With interest developing in mechanical harvesting of trailing berries, a concurrent interest has developed in training systems which are better adapted to the use of mechanized equipment. Training investigations involving several trailing berry varieties have been under way at the North Willamette Experiment Station for the past four years and are being continued.

The best all-round system of training for Marion blackberries tried at this station has been to use two wires spaced 18 inches apart vertically with the top wire approximately five feet above the ground. At harvest time, the lowest hanging berries are approximately 22 inches above the ground. This provides adequate space for training the new canes along the ground beneath the trellis. The fruiting canes are trained individually in a spiral wrap around the two wires with the longer canes being put up first. The object is to keep the canes spread out as uniformly as possible along the trellis wires and avoid concentrations of canes piled on one another. Shorter canes that are not long enough to wrap around the wires may be woven through the other cane spirals. Care must be exercised in wrapping the canes around the wires. Canes that are not held securely in place may come unwrapped and interfere with the...
operation of the mechanical harvesting equipment.

The two-wire system of training used on plants spaced 2.5, 5 and 10 feet apart has shown increases in yields as compared with similar plantings trained on a single wire. This is believed to be the result of spreading the canes so that more of the fruit buds have an opportunity to develop normally.

With the two-wire system of training, the fruit is located in a more accessible position for mechanical harvesting than with the single-wire system. In a typical single-wire system, 40 percent of the berries may be located within 22 inches of the ground. With the two-wire system, approximately 15 percent will be below this 22-inch level. Fruit below the 22-inch level is unavailable to the present mechanical harvesters and is frequently left by many hand pickers. Since considerable space under the trellis is required for training the new shoots, it is doubtful that there would be much advantage in lowering the catching platform of mechanical harvesters.

Increases in yield and a more desirable position of the fruit production area, as indicated for Marion blackberries, are equally important with the Thornless Evergreen variety. Yields two to three times greater have been obtained on plants trained on a single wire. This is believed to be the result of spreading the canes so that more of the fruit buds have an opportunity to develop normally.

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The fact that the berries do not all mature at the same time complicates harvesting. For most cane berry varieties, the force required to detach the fruit the parent plant varies with maturity. Fortunately mature or ripe berries may be detached more easily than immature berries. It is this natural growth characteristic that is utilized by mechanical-harvesting devices to selectively harvest only the ripe berries.

An example of the detachment-force variation for Marion blackberries is shown in Fig. 1. The soluble solids content of mature berries is an index of the sugar content and is also frequently used to describe the degree of ripeness of fruit. A Scherr-Tumolo precision dynamometer having a 0-250-gram range was used to measure the detachment force. A plastic ring fitted to the torque arm of the dynamometer was used to engage the berry at a point about one-half the berry length below the abscission. The operator held the stem of the berry in one hand while operating the dynamometer with the other. The stem was held perpendicular to the ground in order to reduce the effect the weight of the berry might have on the detachment force. Detachment resulted from a horizontal force exerted on the berry by the dynamometer torque arm. Each individual berry was weighed and placed in a separate compartment of a covered plastic box. The soluble solids content of each berry was determined in the laboratory using an American Optical Company temperature-compensated hand refractometer. The "picking" action described above is not too unlike that used by field workers when picking blackberries by hand. They generally grasp the berry between the thumb and forefinger. A slight rolling motion is imparted by the thumb and wrist causing the detachment of the berry.

Cane fruits can be harvested by mechanically shaking the fruit-bearing canes. Investigations of possible devices for this purpose have been going on for many years. Bell (2) reported on three such units in 1951. Numerous other harvesting devices have been tested with varying degrees of success. All have utilized some kind of shaking action to detach the ripe fruit from the plant.

Detachment of the fruit by shaking has one distinct advantage over regular hand harvest. Field workers depend primarily upon color to determine whether or not an individual berry is ripe. Color alone is not an adequate index of maturity for all berry varieties. For example, a Thornless Evergreen blackberry may have a shiny black color yet be quite immature because of a low soluble solids content. Such a berry will turn red when it is frozen and thereby reduce the quality of the frozen pack. Thornless Evergreen blackberries harvested by shaking have been found to have a higher soluble solids content and a more uniform maturity on the average than the hand-picked berries. Katten et al reported similar findings for other blackberry varieties (6).

The physical makeup of the various cane fruits affects the mechanical harvesting potential. The structure of the fruit of blackberries and dewberries is somewhat different from that of raspberries. Botanically speaking, none of these are true berries but are aggregate fruits. They are made up of many small parts called drupelets. The drupelets are formed around a central core called a receptacle (10). According to Bailey, the distinguishing feature between raspberries and blackberries is whether or not the receptacle remains on the plant when the fruit is picked (1). The raspberry drupelets adhere to one another but separate from the receptacle when the mature fruit is harvested. The receptacle is generally dome shaped. The shape varies with the variety and thus some are harder to pick than others. Blackberries and dewberries have fleshy, elongated receptacles that form a part of the fruit which is detached from the plant (10). Detachment normally occurs at the calyx end of the receptacle where an abscission layer has formed (Figs. 2 and 3). Unfortunately detachment does not always occur at the abscission layer. Detachment may occur behind the calyx or at other points along the stem as a result of mechanical action. Some varieties have weaker stems than others. Having the calyx or part of the stem attached to the berry is undesirable because of the increased processing cost involved.

Field Tests of Rotating-Cylinder Picking Units

A series of tests was conducted in 1960 and 1961 involving the use of rotating cylinders to detach the fruit. Shaking of the fruit-bearing canes was accomplished by attaching various fixtures to two six-inch-diameter steel cylinders seven feet long. These cylinders were mounted parallel to each other with their longitudinal axes inclined about 40 degrees with the ground. The lower ends of the cylinders were toward the front of the harvester frame. Two rubber bumper bars, 1 1/2 inches high, extending the full length of the cylinder and spaced 189 degrees apart,
FIG. 4 Overlapping-plate type of platform used for collecting harvested fruit. Each plate is hinged and spring-loaded to permit lateral movement when an obstruction is encountered.

were attached to each cylinder. A row of three-inch long neoprene fingers were placed adjacent to each bumper bar. The fingers were 1/8 inch in diameter and were spaced 3 inches apart. The canes were subjected to a combination shaking and combing action by the counter-rotating cylinders. Cylinder spacing and position with respect to the row were adjustable. A variable-speed drive was provided to permit adjustment of the cylinder rotation speed.

The experimental harvester was a one-row, straddle-type machine. It had an overlapping-plate-type platform for collecting the harvested fruit (Fig. 4). A belt conveyor on each side of the machine moved the harvested fruit from the collecting platform to stations at the rear of the machine where the fruit was placed in cannery crates. An IHC Cub tractor was mounted on top of the frame and supplied the power necessary to operate the harvester components.

The picking action of the fingers was far too severe and resulted in considerable mechanical damage to the fruit and to the fruit-bearing canes. Numerous modifications of the picking unit were made to improve its operation. Best results were obtained using only one cylinder and replacing the fingers with rubber beater flaps (Fig. 5). Tests were conducted using cylinder speeds ranging from 75 to 158 rpm. With speeds lower than 75 rpm, insufficient shaking action was obtained. A cylinder speed of 90 rpm appeared to be optimum under the operating conditions encountered.

Typical harvest trial results are shown in Table 2. "Green" fruit included only those berries which were obviously immature. Berries which were mechanically damaged or which had the calyx or the stem attached, or for any other reason were not suitable for processing, were termed "call" fruit. Leaf material, broken fruit spurs not physically attached to the berries, or any other foreign material present in the harvested fruit were classified as "debris." As indicated previously, berries that are harvested by shaking have a higher average soluble solids than hand-picked fruit. This same trend was present in the fruit harvested by the rotating-cylinder unit. At the time the tests were made, there were no provisions on the harvester for removing any of the debris in the harvested fruit which accounts for the high values shown in the table. A suction-cleaning system was later installed on the harvester, and its use greatly reduced the debris in the harvested fruit.

Several problems were encountered in the use of the rotating-cylinder picking units. Fruit located near the center of the row beneath the trellis wires was essentially inaccessible to these units. Failure to remove all of the ripe berries each time resulted in a substantial increase in the amount of cull fruit in successive pickings. Beater flaps of different shapes were tested, but those that were most effective in reaching the berries beneath the trellis wires also caused increased mechanical damage to the fruit and to the canes. Many berries, both ripe and immature, showed the effects of abrasion damage. This is undesirable where the quality of the processed fruit is partially determined by the appearance of individual berries. Even if this were not a factor, excessive abrasion damage to immature berries is serious because these berries do not attain their maximum potential size and weight upon reaching maturity. The consequence is a reduction in yield and an accompanying reduction in crop value to the grower.

Field Tests of Hand-Held Vibrating Units

A hand-held, pneumatically operated vibrator unit was tested in 1960. The picking head consisted of a four-tined rake attached to the oscillating member of a pneumatic saber saw. The longitudinal axis of the tines or fingers was perpendicular to the direction of oscillatory motion. Detachment of the fruit was the result of direct contact of the canes with the vibrating fingers. Picking-head variations tested included the use of rubber fingers and semirigid plastic fingers, fingers of different lengths and diameters, and different finger arrangements on the picking head.

It was found that fruit could be detached with all of the picking heads tested. None of them, however, was ideal in its operation. The air hose restricted the movement of the unit and increased operator fatigue. There was substantial mechanical damage to both the ripe and immature fruit. The amount of damage was a function of operator skill. With some training systems, it was quite difficult to harvest all of the ripe fruit each time the row was picked. Typical test results are shown below the Table 3. In general, it was concluded that the use of the pneumatically operated vibrator did not offer any substantial advantages over the hand-held pneumatic vibrator.

![FIG. 5 Beater flap on rotating-cylinder picking unit imparts a shaking motion to the canes.](image)

![FIG. 6 Swinging-panel picking unit of the type used on the Weygandt blackcap harvester.](image)
over regular hand harvesting and no further tests were conducted.

In 1963 an electrically driven handheld vibrator unit was tested in Marion blackberries and Thornless Evergreen blackberries. This was a commercially available blueberry harvesting device built by Blueberry Equipment, Inc., South Haven, Mich. The unit had a four-tined picking head operated by a direct-current electric motor. The longitudinal axis of the aluminum fingers was parallel to the motor shaft. The harvesting characteristics and the problems encountered were similar to those described above. The unit was much easier to maneuver and was, by far, the better of the two handheld vibrator units tested. However, its use for blackberry harvesting did not appear to be feasible.

Utilization of Personnel to Shake the Canes

Shaking the fruit-bearing canes to detach the ripe berries may be accomplished in many ways. How the shaking action is achieved apparently is not too important as long as the amplitudes and frequencies used do not result in excessive mechanical damage to the fruit or to the plant. Field trials were conducted in which the canes of selected varieties were shaken by hand. Marion, Boysen, and Thornless Evergreen blackberries were included in the tests.

The harvester frame used previously for testing the rotating-cylinder picking units was modified and made into a personnel carrier for transporting the "shakers" along the row. Two shaker stations were installed on each side of the machine. The stations were placed at different elevations to give the shakers more convenient access to all parts of the row above the catching platform.

Results of the field trials showed that there were both advantages and disadvantages connected with the hand-shaking method of harvest. It was demonstrated that on the varieties tested, much greater harvest rates are possible than were obtained by regular hand picking. For example, in 1962 harvest rates ranged from 20 pounds per hour per man to 170 pounds per hour per man in a Thornless Evergreen blackberry planting that yielded 5 tons per acre. The season average was 78 pounds per hour per man on rows 600 feet long. This was approximately three times greater than the average of Thornless Evergreen blackberries picked by hand as reported in Clever's survey (8). The harvest rates are dependent, of course, on the total crop production as well as the training system.

This method of harvest has considerably more appeal for the thornless berry varieties, both from the standpoint of personnel and of reduced mechanical damage to the harvested fruit. Considerable drupelet damage can result when the berries come in contact with thorny canes. The hand-shaking method of harvest has been used on Thornless Evergreen blackberries for four years. The fruit harvested in this manner has consistently been more uniform in its maturity and had a higher soluble solids content than hand-picked fruit from the same field. Shaking the canes by hand is physically more difficult than regular hand picking.

Field trials were conducted in 1963 in which the berries were picked in the normal manner, but in which the hand pickers were moved along the row on the personnel carrier. The results were quite similar to those obtained using the hand-shaking method of harvest. Hand picking from the personnel carrier proved to be somewhat slower than hand shaking, but the percentage of good fruit was higher than for hand shaking.

Commercial Cane Fruit Harvesters in Oregon

Weygandt Blackcap Harvester R. M. Weygandt and son, Canby, Ore., berry growers, have developed a machine which will harvest blackcaps or black raspberries. The harvester is built on the stripped-down frame of a wide-tread lumber carrier. Two plywood panels, one on each side of the row, form the basic elements of the harvester's picking unit. The panels are approximately three feet wide by four feet long and are hinged on their leading edges. Pitman drives cause the panels to oscillate back and forth in a vertical plane achieving a motion much like that of a swinging door. The oscillation of the panels is timed so that both panels move in the same direction at the same time. This results in a vigorous shaking action being transmitted to the berry canes. No trellising system is used with blackcaps because of their erect growth habits. A panel oscillation rate of 250 cycles per minute is satisfactory for harvesting blackcaps. A schematic diagram of an oscillating panel unit is shown in Fig. 6.

The fruit shaken off the canes falls onto an overlapping-plate-type catching device similar to that shown in Fig. 4. An internally belted belt conveyor system moves the fruit to a pneumatic

![FIG. 7 Simple sketch of vertical-cylinder picking unit of the Industrial Sciences harvester.](image-url)

TABLE 4. INFLUENCE OF PLANT SPACING ON THE FRUIT GRADE OF MARION BLACKBERRIES HARVESTED BY HAND SHAKING THE FRUITING CANES

<table>
<thead>
<tr>
<th>Spacing of plants in row, ft</th>
<th>Percent good fruit*</th>
<th>Percent no-value fruit</th>
<th>Percent reduction in yield compared with regular hand picking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Cull</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>82.4</td>
<td>14.3</td>
<td>3.3</td>
</tr>
<tr>
<td>5.0</td>
<td>82.5</td>
<td>14.4</td>
<td>3.3</td>
</tr>
<tr>
<td>10.0</td>
<td>83.0</td>
<td>15.6</td>
<td>4.4</td>
</tr>
</tbody>
</table>

* All percentages are on a weight basis.

TABLE 5. FRUIT GRADE OF BOYSENBERIES HARVESTED BY HAND SHAKING THE FRUITING CANES AND BY HAND PICKERS TRANSPORTED ON A PERSONNEL CARRIER

<table>
<thead>
<tr>
<th>Method of harvest</th>
<th>Percent good fruit*</th>
<th>Percent no-value fruit</th>
<th>Percent reduction in yield compared with regular hand picking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Cull</td>
<td></td>
</tr>
<tr>
<td>Hand shaking canes from personnel carrier</td>
<td>86.5</td>
<td>6.3</td>
<td>7.2</td>
</tr>
<tr>
<td>Hand picking from personnel carrier</td>
<td>85.7</td>
<td>4.7</td>
<td>9.6</td>
</tr>
</tbody>
</table>

* All percentages are on a weight basis.

TABLE 6. FRUIT GRADE OF THORNLESS EVERGREEN BLACKBERRIES HARVESTED BY HAND SHAKING THE FRUITING CANES AND BY TRANSPORTING HAND PICKERS ON A PERSONNEL CARRIER

<table>
<thead>
<tr>
<th>Method of harvest</th>
<th>Percent good fruit*</th>
<th>Percent no-value fruit</th>
<th>Harvest rate, acres per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Cull</td>
<td></td>
</tr>
<tr>
<td>Hand shaking canes from personnel carrier</td>
<td>84.8</td>
<td>2.8</td>
<td>12.6</td>
</tr>
<tr>
<td>Hand picking from personnel carrier</td>
<td>92.1</td>
<td>2.9</td>
<td>7.9</td>
</tr>
</tbody>
</table>

* All percentages are on a weight basis.
cleaner installed on top of the machine. From the cleaner, the berries pass into an inspection belt and then into containers for transportation to the processing plant. A deck over the top of the harvester frame provides space for personnel and storage of the harvested fruit.

Eight of these units were in use in 1964. One machine will harvest about 50 acres of blackcaps. Harvest rates may approach one acre per hour. The cost of harvesting blackcaps mechanically is about one-half that of regular hand picking. Clevenger's study (3) indicates that the mechanical harvester dropped more berries on the ground than did the hand pickers. However, at the end of the harvest season, the machine left only 4.7 percent of the total yield on the canes whereas the hand pickers left 17.4 percent of the fruit unharvested. Taking this into consideration, the grower could expect to recover more fruit by machine harvesting than by hand picking if the machine losses do not exceed approximately 15 percent of the total production.

Industrial Sciences Harvester Industrial Sciences of Portland, Ore., has developed a mechanical harvester with a picking unit consisting of two vertically-mounted cylinders. Each cylinder has nearly 800 radial, aluminum fingers. The fingers have a 0.375-inch diameter and are approximately 12 inches long. Shaking of the fruit-bearing canes is accomplished by causing the cylinders to oscillate in a horizontal plane. A diagramatic representation of the picking unit is shown in Fig. 7. Contact with the canes causes the cylinders to rotate about their vertical axes as the machine moves along the row. Monroe and Levin (6) reported on the use of a somewhat similar picking device for harvesting blueberries in Michigan.

The Industrial Sciences harvester has been field-tested on Santiam, Marion, Boysen, and Thornless Evergreen blackberries, and red raspberries. Good results have been obtained for most of the trailing varieties harvested. Operating speed is approximately 0.8 mph. Different berries, of course, require different operating conditions. For the blackberry varieties harvested with this machine, cylinder oscillation rates of 750 to 1000 cycles per minute and amplitudes ranging from 0.125 to 0.5 inch have produced satisfactory results.

This front-wheel-drive harvester is quite maneuverable and has hydraulic drives throughout. It is approximately 16 ft long but can make a 180-degree turn on a 20-foot wide headland without stopping. The harvested fruit is conveyed to a pneumatic cleaner and then to inspection and crating stations on each side of the machine. Two Industrial Sciences harvesters were in use in Oregon in 1964.

Summary
Mechanized equipment does not automatically guarantee a solution to all cane fruit harvesting problems. Successful mechanical harvesting requires that good cultural practices be followed in growing the crop. Some examples will serve as illustrations. The systems of trellising trailing berries must insure that the fruit will be accessible to the mechanical picking device. The best in weed control must be used because it is virtually impossible to remove certain weed seeds from the harvested fruit. Disease control, tillage, irrigation, and selection of planting site are also important. The success or failure of a mechanical harvester is largely dependent upon these and other cultural practices.

Harvesting is one phase of cane fruit production that has been slow to change over the years. A major part of the total production is still harvested by hand, one fruit at a time. It is doubtful that mechanical harvesting will ever completely replace hand picking. However, if the current economic trends and attitudes continue, there can also be little doubt that mechanical harvesting of these crops will have increased importance in the future.

References