

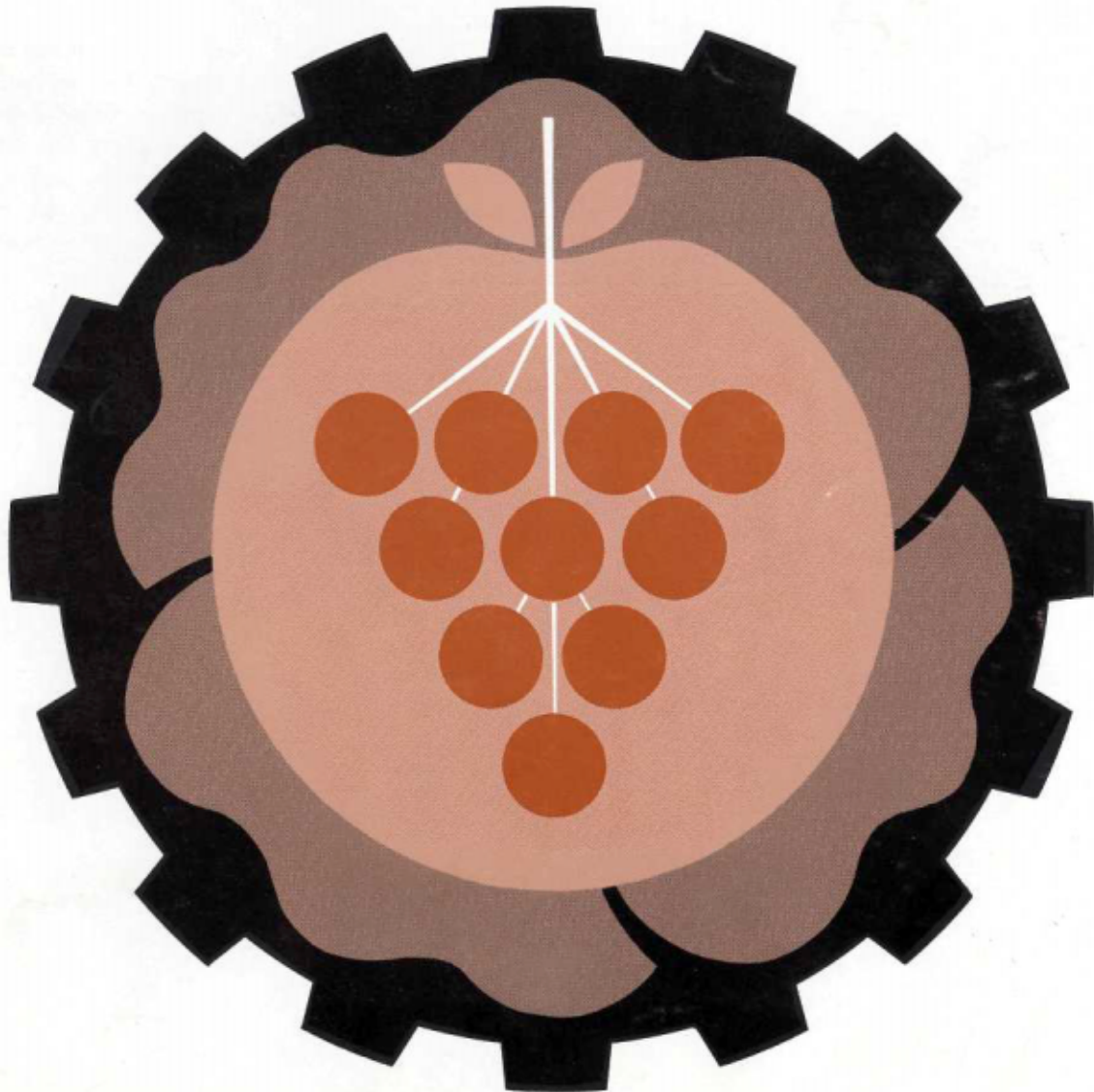
## PHYSICAL SCIENCES

AGRICULTURAL ENGINEERING NUMBER 1

CORNELL UNIVERSITY AGRICULTURAL EXPERIMENT STATION, NEW YORK STATE COLLEGE OF AGRICULTURE, A STATUTORY COLLEGE OF THE STATE UNIVERSITY, AT CORNELL UNIVERSITY, ITHACA, NEW YORK

## MECHANICAL HARVESTING of FRUITS and VEGETABLES

E. S. Shepardson, E. D. Markwardt, W. F. Millier, and G. E. Rehkugler



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From the mid to the late 1950's, it became increasingly apparent that the New York State fruit and vegetable industry would have to mechanize more, if not all, operations to remain competitive with other producing areas. While other farm operations in general had reduced their labor requirement to 33 percent of that used in 1940, fruit and vegetable farms had reduced labor to only 57 percent of the 1940 requirement.

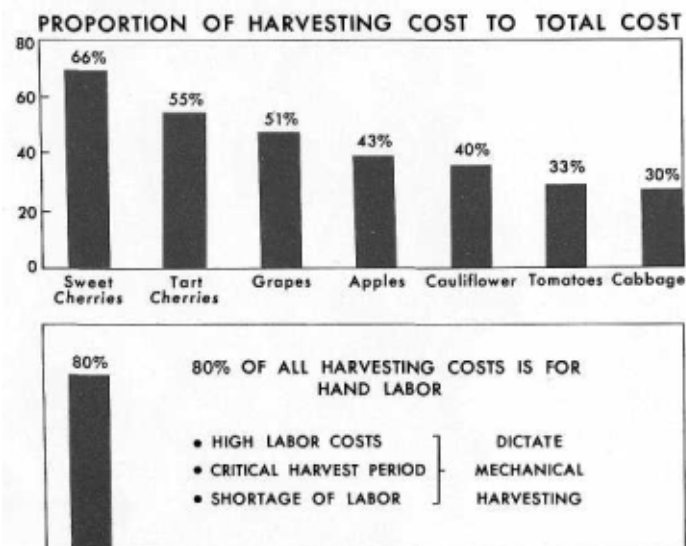
Most of the hand labor is in harvesting (30 to 55 percent), since traditionally fruits and vegetables have been hand-picked for fresh use. But fresh-market use has dropped markedly and processed-product use has greatly increased — particularly frozen fruits and vegetables.

The large amount of labor required for harvesting is no longer available; that remaining is becoming more costly and poses more and more management and social problems. Predictions for the near future are that only crops that can be mechanically harvested and processed will be grown. In any event, producers are increasingly demanding mechanical harvesters.

Mechanical-harvesting research on development of a grape harvester was begun in 1957 in a joint project by the New York State College of Agriculture at Ithaca and the New York State Agricultural Experiment Station at Geneva. Next in the series were a cherry harvester, a dry-bean direct-combine attachment, and a processing-apple (and other tree fruits) harvester. Others have been developed and still more are in some stage of development. One of the most difficult tasks under way is that of producing a successful harvesting machine for the tender varieties of apples, widely grown in the Northeast for fresh-market sale.

Mechanical-harvesting research is still a sizable program in agricultural engineering, pomology, vegetable crops, food science, and other related areas at the College of Agriculture and the Geneva Experiment Station. This bulletin summarizes primarily the machine-development phase of the research.

The cost of hand labor grows increasingly prohibitive, and comprises 80 percent of all harvesting cost. Competition for what labor is available makes the reliability of the supply a limiting factor for many farmers. Further, the production areas of the United States that compete with New York growers for their markets are moving rapidly into every conceivable kind of mechanization.



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# GRAPES

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New York State grows more than 30,000 acres of grapes, and harvesting costs account for more than half the total production costs. Hand labor comprises 80 percent of harvesting costs, or more than \$3,000,000 yearly.

The joint search for a mechanical-harvesting method that was started in 1957 received some financial assistance from the New York State Concord Grape Production Research Fund, **Inc.**

The first successful, commercially available grape harvester is pictured in figure 2. Built by the **Chisholm-Ryder Company (CRCO)**, it was first used in 1967. This machine is identical in principle to the one developed at Cornell (fig. 1). Shown also in figure 2 is the Geneva Double Curtain (GDC) vine-training system developed by N. J. Shaulis. Resulting yield increases ranged from 40 to 90 percent.

The system is naturally adaptable to the freely rotating, spike-wheel, vertical-stroke harvester, which harvests both curtains of the row at once. Modifying costs for the vineyard are from \$200 to \$400 per acre.

Grapes shaken from the vines by the variable-speed, spike-wheel shaker(s) fall on a flexible-leaf collector (fig. 3) and are conveyed to covered bulk containers holding about 2000 pounds. Vine debris is removed by an air stream.

A popular new machine is the horizontal-action harvester designed only for conventionally trained and trellised grapes. Horizontal-stroke beaters are forced against the trellis to knock off the grapes. The collection device and the travel speed are the same for both machines. It can harvest from 3 to 6 tons per hour and replace about 17 men. This machine also is made by the Chisholm Ryder Company. By slight modification of the conventional trellis, the vertical-stroke machine can harvest grapes trained in this manner.

From the first commercial harvesting in 1967, it is estimated that 75 to 80 percent of New York State grapes were mechanically harvested in 1970.



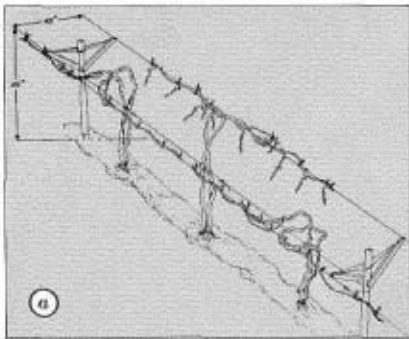


Figure 2(a).  
Diagrammatic sketch  
of Concord vines  
trained to GDC  
system. Spurs and  
canes are shown  
only on the middle  
vine of the  
post length.  
(b). 1967 CRCO  
spiked-wheel,  
vertical-stroke grape  
harvester, shown  
harvesting  
GDC-trained vines.  
Plastic-lined wood  
pallet boxes of  
1-ton capacity  
in next row.

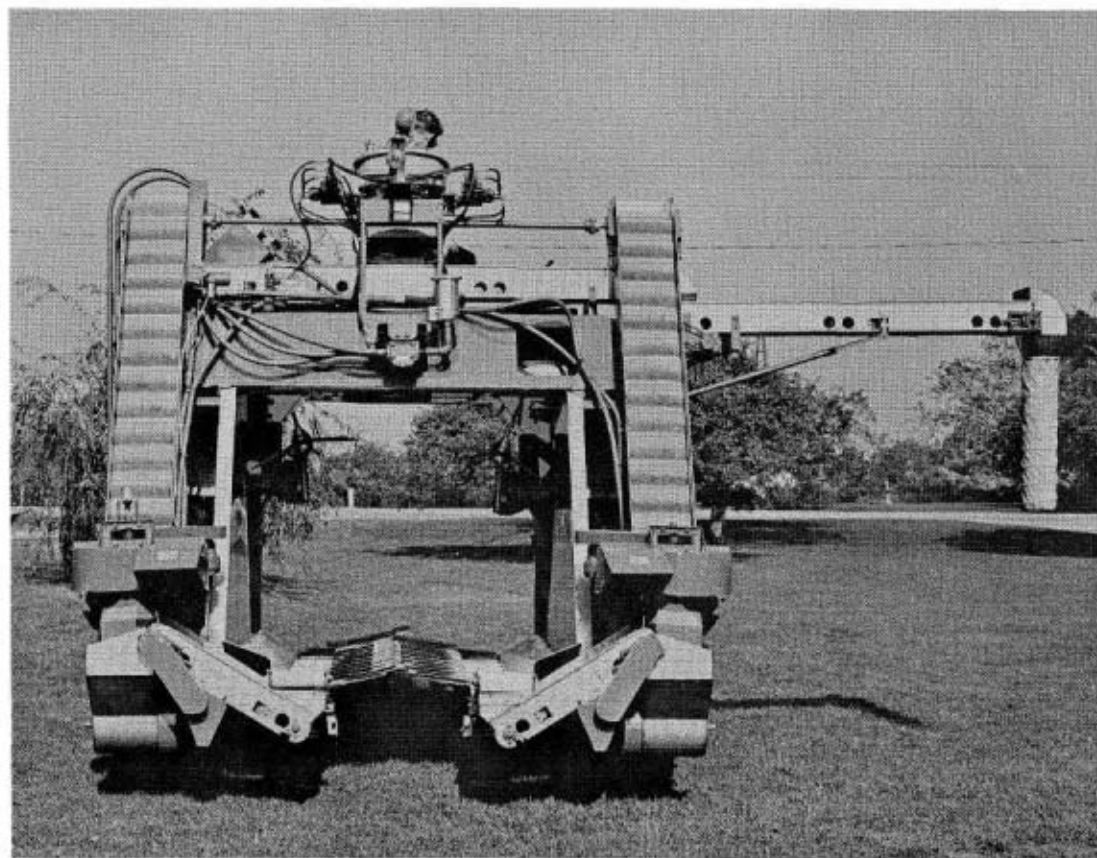
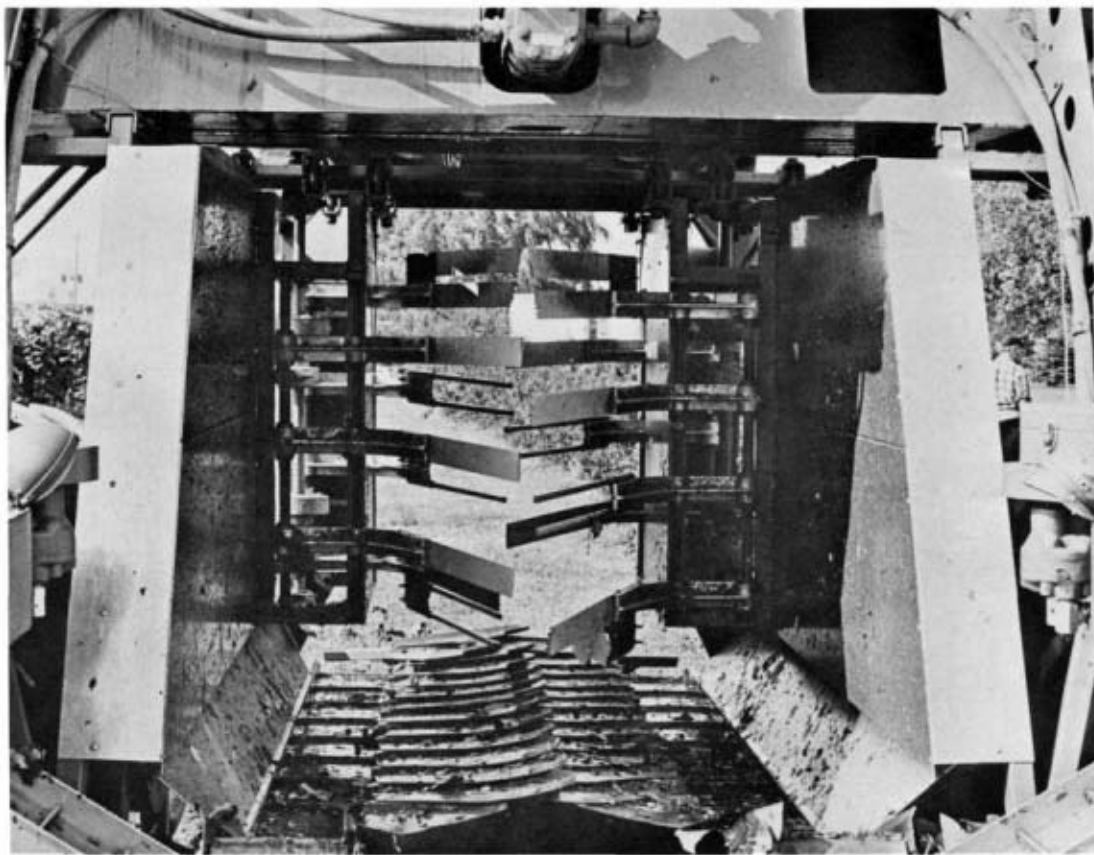


Figure 3.  
CRCO 1968  
production model  
of grape harvester,  
showing spiked-wheel  
shakers, flexible-leaf  
collector, cleaning  
fans, elevators, and  
conveyors. The  
harvester travels  
about 1.4 miles per  
hour, harvests about  
1 acre per hour  
(up to 12 to 15 tons),  
and replaces as  
many as 30 men.



*Figure 4.  
Close-up of CRCO  
horizontal-action  
grape harvester.*



*Figure 5.  
The basic concept  
for collecting  
cherries was  
developed from  
this experimental  
machine.*

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## CHERRIES

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The annual production of red tart cherries in New York from 1963 to 1967 averaged about 20,000 tons. In the early 1960's the harvesting cost was about 3 cents a pound; now it's over 5 cents. The major cost is for hand-picking the fruit.

In 1959 joint studies were initiated by this college and the Pomology and Food Science Departments of the Geneva Experiment Station, with some financial assistance from the New York State Canners and Freezers Association and the New York Cherry Growers Association .

Results of the research demonstrated the feasibility of mechanically harvesting cherries without causing excessive damage to the fruit and trees, and the basic concept for a catching frame was developed. This was adopted by commercial manufacturers, and by 1965 about 25 percent of the crop was harvested by machine. Today, 75 percent of the crop is machine harvested.

With only 3 men, a typical mechanized harvester can harvest 30 trees per hour, replacing 90 or more hand-pickers. The fruit is conveyed directly into bulk tanks containing ice-chilled water and holding about 1000 pounds of cherries each. Or the tanks may be taken immediately to a cooling station, where water chilled by mechanical refrigeration or by ice is pumped through the cherries to promote rapid and complete cooling.

Sweet cherries are harvested with the same type of machine. A high percentage of removal is more difficult to achieve with these cherries, but chemical looseners show promise in solving this problem.

Hand-held shakers and hand-moved catching frames are also being used. They are relatively inexpensive and are finding a place on small-acreage plantings. Also they are most adaptable to small trees. Harvest rates may be around 3000 to 4000 pounds per day.

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## APPLES

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About 23 million bushels of apples are produced annually in New York State. More than half are processed into slices, sauce, or juice. The labor cost for harvesting is about three-fourths of the total harvest cost.

In 1960, research was begun (again jointly by this college and the Geneva Experiment Station) on a project designed to adapt the cherry harvester for harvesting processing apples. It was found that fruit of several varieties could be removed by shaking the trees. Fruit quality was acceptable, but various inadequacies were apparent in the collecting equipment.

A new design for a catching frame was developed "in 1964-65. The machine had a low profile and was intended for conventional-sized trees (fig. 7). The entire collecting area was covered with deceleration strips to slow the fall of the fruit. Padded conveyors beneath carried the fruit to a tiltable bulk box filler. The machine was highly maneuver-able and could move readily in the orchard.

It was quickly accepted by growers and processors, and G. J. Perry and Sons started commercial development of the design immediately. Many of the machines are being

used throughout the eastern United States to harvest processing apples, as well as in California for peach harvesting.

The Cornell experimental and commercial machines have been used to harvest other fruits such as cling peaches, prunes, pears, and both sweet and tart cherries.

Some orchard modification is necessary with conventional-sized trees for the machine to operate successfully. Clearance must be provided under the tree so that collecting equipment can be positioned quickly. Scaffold limbs should be at least 20 inches above the ground. The branches and foliage around the periphery of the tree should be 1½ to 2 feet above the ground. Some pruning of small branches on major scaffold limbs or trunk is also necessary to provide a place for attaching the shaker.

The rate of harvest varies with different conditions, but 10 to 20 trees per hour can be expected with large trees and 40-50 trees per hour with small, dense, well shaped trees. Probably less than 5 percent of the processing apples are machine-harvested today but there is no doubt that the proportion will increase.



*Figure 6.  
In early attempts  
to harvest apples  
mechanically,  
the Cornell cherry  
harvester was  
modified to handle  
processing varieties  
of apples.*



*Figure 7.  
Field-testing the  
Cornell low-profile  
experimental  
multifruit harvester.  
Previous "apple  
version" of the  
cherry harvester  
at right.*



*Figure 8.  
Close-up of the  
"output end"  
of the Perry  
apple harvester.*

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## TENDER-VARIETY AND FRESH-MARKET APPLES

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More than half of the dollar value of New York apple production comes from apples marketed as fresh fruit. The currently available apple harvesters using the shake-catch method are not satisfactory for harvesting the tender fresh-market varieties such as McIntosh and Golden Delicious. Devices and techniques are now being developed and evaluated in cooperation with the Geneva Experiment Station to harvest this fruit. Figure 9 illustrates one experimental approach to reducing bruise damage of fruit falling through the tree. Padded tines inserted into the path of the falling apple control to some extent the motion and velocity. This technique has shown some reduction in large bruises and a slight increase in number of small bruises.

Padded oscillating tines have been incorporated into a continuous harvesting device (fig. 10). This experimental unit was designed to move continuously down a row to detach the fruit by shaking the branches from the outside and to collect the fruit on a catching frame that delivers it to a water-filled holding tank. Closely spaced trees formed into a

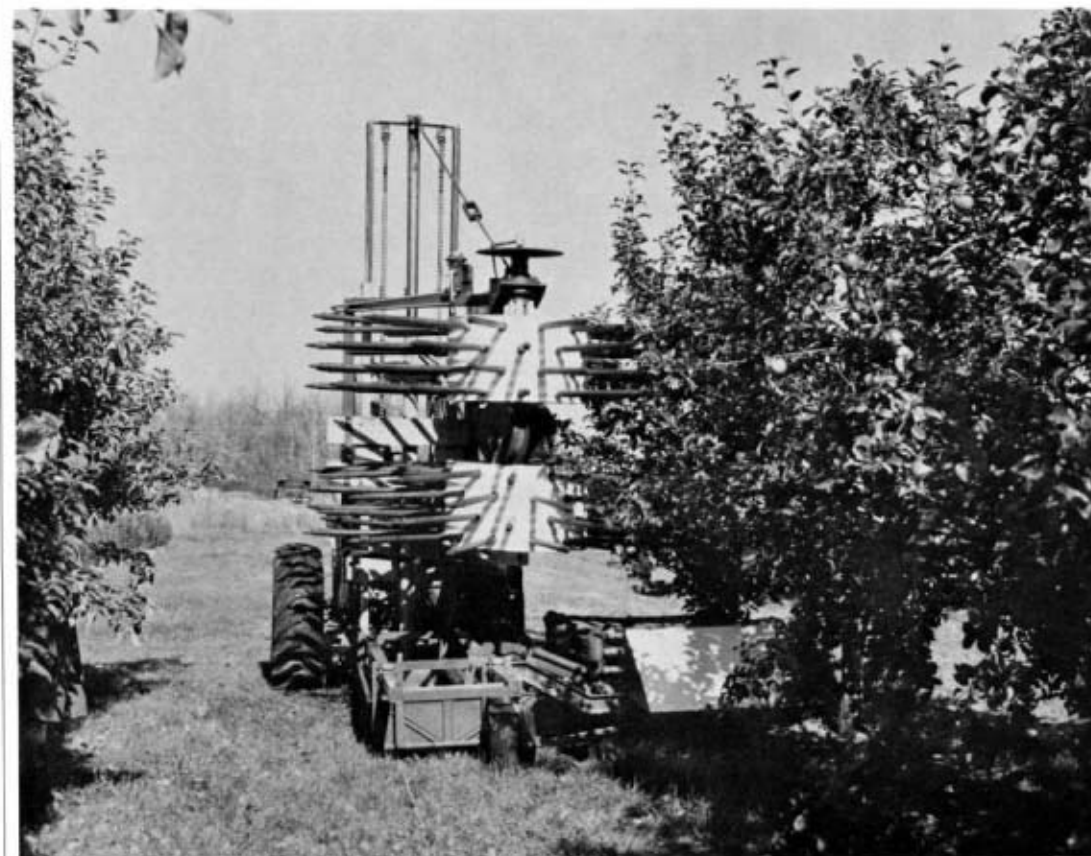
hedgerow shape have been satisfactorily harvested with this device. Damage to the tender fruit, although no greater than with the more conventional shake and catch method, is still too great for satisfactory harvest of fresh-market apples. Less damaging mass-harvesting methods are currently being investigated. Figure 11 shows an experimental fruit-collecting system evaluated during the fall of 1970. It is an insert-able, multiple-level device to intercept and roll fruit from the tree before serious damage occurs. The intercepting surfaces are made up of tines to which inflatable bags are attached. After insertion, the bags are inflated to form resilient troughs to conduct the fruit from the tree. Fruit is detached by a limb or trunk shaker.

Automatic bruise detection is now being developed for machine-harvested apples. If the economic loss of damaged fruit could be satisfactorily offset by cost reductions in handling, grading, sorting, and packaging, it would permit higher levels of fruit damage than with hand-harvesting methods.

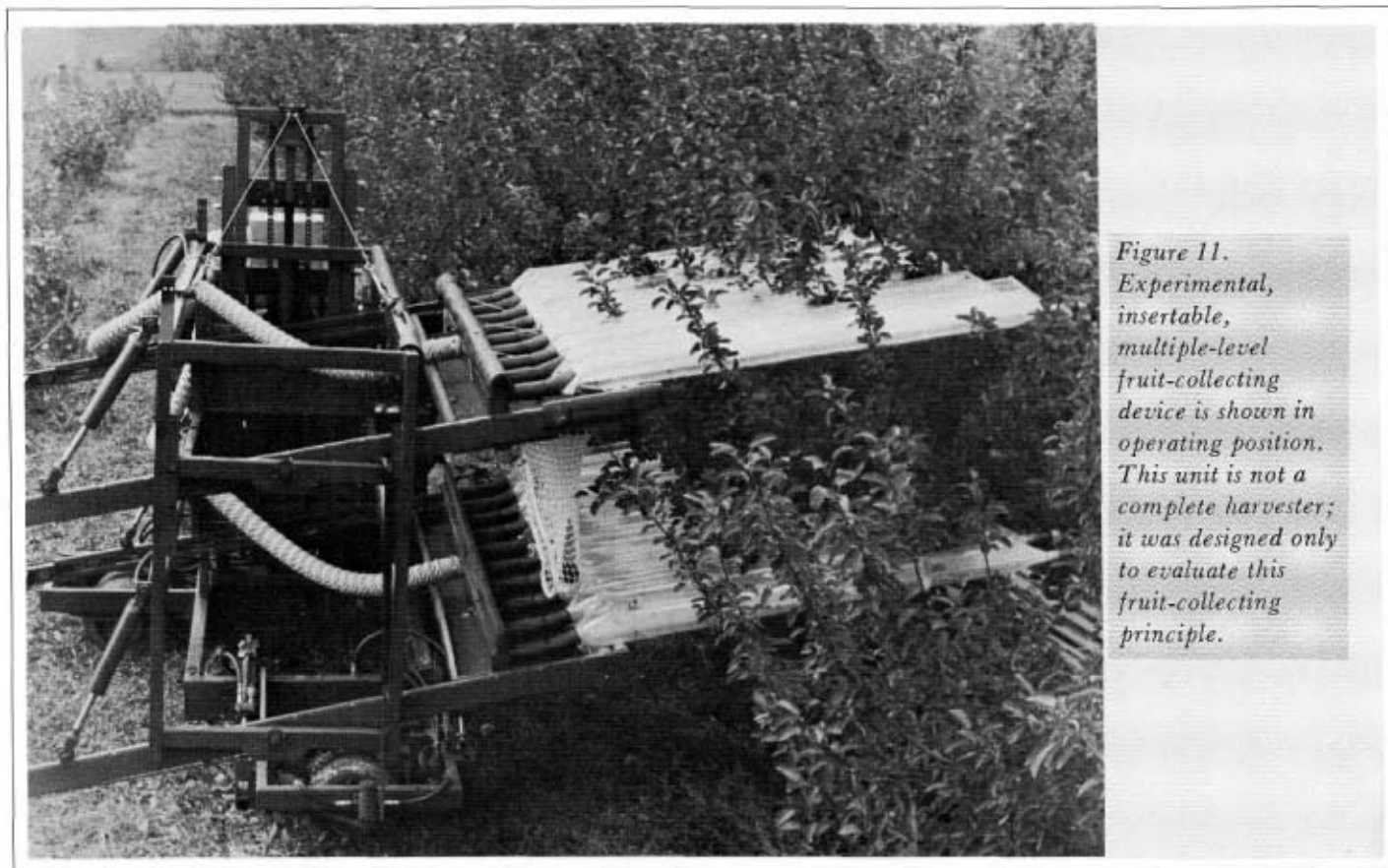




*Figure 9.  
Padded tines are  
inserted into the  
tree near the fruit.  
These control fall  
of fruit from  
branches to  
catching frame.  
Fruit is detached  
by shaking either  
limbs or trunk.*



*Figure 10.  
Experimental  
continuous harvester  
moving down a  
tree wall. Vertical  
motion of tines  
shakes fruit from  
trees, and tines  
control fall of fruit.  
Drum and tines are  
free to rotate  
about a vertical  
axis. Apples are  
collected on a  
catching frame  
and conveyed to  
a holding tank.*



*Figure 11. Experimental, insertable, multiple-level fruit-collecting device is shown in operating position. This unit is not a complete harvester; it was designed only to evaluate this fruit-collecting principle.*

## BEANS

In 1939 research was begun on direct harvest of dry beans to reduce labor and to prevent heavy field losses. The machine pulls the plant and traps the beans between two flat belts. It cuts losses to one bushel per acre, as compared to 1.4 bushels or more. Also the beans are cleaner when harvested by this method. The unit is not yet commercially available.

## CABBAGE

Half of the total labor required to produce New York's 10,000-acre annual cabbage crop (75 man-hours per acre) is used for harvesting. In an effort to improve this situation, research was started in 1963 on a mechanical harvester. The resulting machine can cut perfectly as much as 80 percent of the cabbage crop for fresh market, storage, or processing; can be used for any variety and under any

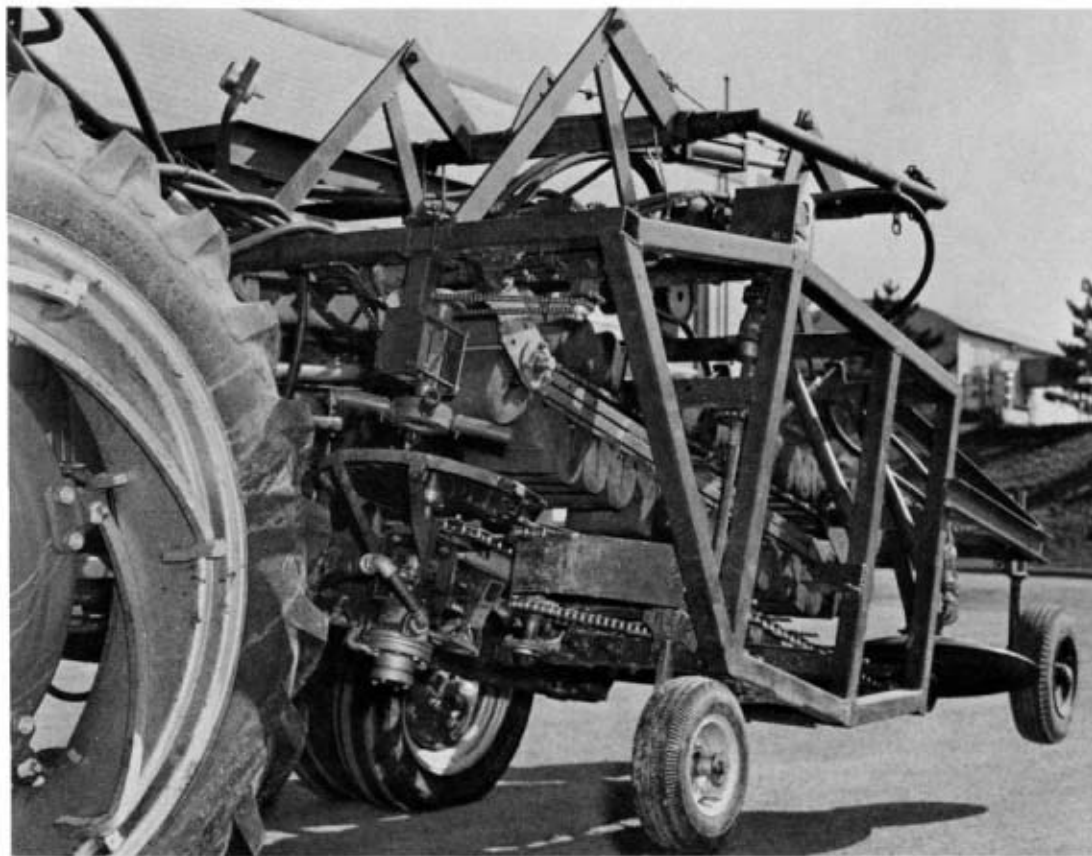
field condition; and cuts man-hours per acre from 75 to 9. The machine has not yet been produced commercially, although various components have been incorporated in some commercial units. Some cabbage was mechanically harvested in 1969, and about half of the 1970 processing crop was harvested by this method.

## LETTUCE

Hand-harvesting of lettuce is a precise and tedious "stoop-labor" task. It requires 42 percent of all labor used in lettuce production. Buyers are exacting about a clean cut and the experimental harvesting machine cannot do a "hand" job. It can, however, do a creditable, high-speed job with no damage whatever to the lettuce head. But some stumps are not cut precisely and some are slightly soiled. We hope to improve these flaws, but they may have to be accepted, for the present at least, to keep New York State competitive with other sections of the country in lettuce production. Meanwhile, research continues toward the development of a successful harvesting machine.



*Figure 12.  
Bean combine with  
Cornell-developed  
direct-harvest  
pulling attachment.*



*Figure 13.  
Cut-off saw,  
hydraulic motor,  
saw mount, and  
elevating hold-down  
conveyor of  
cabbage harvester.*



*Figure 14.  
Entrance or  
"finding" discs,  
elevating-lifting  
conveyor, and  
re-orienting unit  
can be seen in this  
field picture of the  
cabbage harvester.*



*Figure 15.  
Experimental  
lettuce harvester.*

**Editor's Note.** This new series replaces the former Experiment Station Bulletin series published by the New York State College of Agriculture at Cornell University. It results from an intensive study made by a special committee, which recommended that all existing publication series be streamlined and modernized to better answer today's needs of both scientific and general audiences. It was thought important to identify each publication with its appropriate subject matter discipline, such as Animal, Biological, Food, Physical, or Plant Sciences, as well as with a departmental designation.