STATE OF THE ART AND FUTURE OUTLOOK FOR MECHANICAL STRAWBERRY HARVESTING

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For Presentation at the
TECHNICAL SEMINAR ON IMPLICATIONS OF MECHANIZATION
FOR FRUIT AND VEGETABLE HARVESTING

Held under the auspices of the
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Sponsored by
The Rural Manpower Center, Michigan State University
in cooperation with
U. S. Department of Labor, Washington, D. C.

Chicago, Illinois
December 8, 9, 10, 1968

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Strawberry production involves several interrelated phases which have generally evolved to fit local situations with respect to strawberry varieties, cultural practices, harvest procedures, and market conditions. Harvesting has a high hand labor requirement and is the most expensive phase of production. Removing the fruit from the plant, sorting, capping and stemming, and placing the berries in containers are some of the specific tasks now executed by hand pickers during the harvesting operation. Mechanization of the harvest system can be expected to force changes in other production and processing procedures.

Scope and Diversity of the Strawberry Industry A Challenge to Mechanical Harvesting

In ancient times, the strawberry was known as a wild herb having medicinal value. Records show that it was cultivated in Europe as early as 1324 (27)*. In North America, the early settlers were treated to an abundance of wild strawberries. Commercial production began in the New England area in the early 1800's (15). Since then, the strawberry industry has spread to nearly every state.

The strawberry is now the most widely grown small fruit in the United States (10). Some 67,000 acres were harvested in 1967. The five states leading in strawberry acreage were Oregon - 14,000; California - 8,000; Michigan - 6,800; Washington - 5,600; and Louisiana - 3,800. There has been a downward trend in strawberry acreage over the last few years. The harvested acreage for the period 1961-65 averaged just over 80,000 acres per year. Slightly more than 478 million pounds were marketed in 1967 as compared with a 510 million pound average for 1961-65. Even though the acreage and production figures are down, the value of the 1967 crop, $97,021,000, was about one-half of one per cent greater than the 1961-65 average. Figures for the five states leading in strawberry production are shown in Table 1. Twenty-six states had productions

Table 1. Top Ranking States in Strawberry Production for 1967

	Total Production lb	Average Yield lb/acre	Value to Growers
California	208,800,000	26,100	$ 43,282,000
Oregon	91,200,000	6,800	12,915,000
Washington	35,840,000	6,400	5,765,000
Michigan	29,240,000	4,300	5,505,000
Florida	17,600,000	8,800	5,790,000

* Numbers in parentheses refer to the appended references.

that exceeded a million pounds. The three Pacific Coast states accounted for 70 per cent of the total procution (51). Yields varied greatly across the country with a high of 30 tons per acre being reported in California (1).

Fifty-eight per cent of the 1967 production, or 278.4 million pounds, were sold on the fresh market. The average price paid to the grower was 24.7 cents per pound. The states leading in fresh market procution are shown in Table 2. Fifty-three per cent of all the strawberries sold on the fresh market were grown in California (51).

Table 2. Top Ranking States in the Production of Strawberries for the Fresh Market in 1967

	Production, lb.	Value to Growers
California	148,100,000	$ 34,359,000
Michigan	18,100,000	3,773,000
Florida	17,600,000	5,790,000
Louisiana	11,600,000	3,246,000
New Jersey	9,100,000	2,435,000

The remainder of the U. S. Production, 199.7 million pounds, went for processing. Processing, in this instance, includes such things as canning, freezing, and the preserve and ice cream trades. Strawberries sold for processing received an average price of 14.5 cents per pound in 1967. Production figures for the five states leading in processed strawberries are shown in Table 3. Ninety per cent of the U. S. grown

Table 3. Top Ranking States in the Production of Strawberries for Processing in 1967.

	Production, lb.	Value to Growers
Oregon	88,100,000	$ 12,422,000
California	60,700,000	8,923,000
Washington	32,300,000	4,851,000
Michigan	11,100,000	1,732,000
Oklahoma	1,300,000	234,000

processed berries came from the three Pacific Coast states (51). It should be noted that the dollar values indicated in the preceding tabulations represent only the amounts paid to the growers. The total value to our economy would be increased several fold as a result of such things as processing, marketing, and distribution that take place after the fruit leaves the field.

As might be expected, there are many strawberry varieties in existence. Each major strawberry producing area has its own particular varieties. In 1966, 27 varieties made up 97 per cent of the commercial acreage. The Northwest variety, which is grown primarily in Oregon and Washington, accounted for 18 per cent of the total acreage. The Blakemore variety ranks second in the country with about 14 per cent of the total acreage. The next most predominant variety, Midway, accounted for 8 per cent of the acreage and is grown in Michigan and several of the Norhteastern states (10). Each of these varieties, as well as the many not specifically mentioned, have varietal characteristics which must be taken into account when considering mechanical harvesting. There are a number of extensive plant breeding programs underway in various parts of the country. However, developing a strawberry variety that is commercially acceptable and also possesses the ideal characteristics for mechanical harvesting is a long-range project. Consequently, the mechanical harvesting research is necessarily restricted to the strawberry varieties currently in production.

Diversity of cultural practices used in the various strawberry producing areas further complicates the mechanical harvesting picture. Some examples will serve to illustrate the differences that may be encountered. The soil may be tilled so that the planting area is essentially flat, or it may be formed into raised beds. One or two rows may be planted on the raised beds. A single-plant row or hill system is used in some areas while in others matted rows of various widths are predominant (13, 39, 31, 25). Climatic conditions may dictate that the strawberry plants be mulched. Mulches are also used for weed control and to reduce moisture evaporation. Mulch materials range from grain straw and pine straw to polyethylene film (13, 17, 18, 31). The use of black plastic mulch has resulted in increased yields in some instances (1, 31). The useful life of a planting generally ranges from 1 to 3 harvest seasons depending upon the area (17, 24, 42). It is evident that all of these factors have some influence on mechanical harvesting and that one machine will probably not function effectively under all growing conditions.

Interest in mechanizing the strawberry harvesting operation has not been generated overnight. It has been building up as a result of both local and foreign conditions. On the local scene, production costs continue to rise and there are the continued uncertainties regarding harvest labor supplies. The foreign picture is dominated by the competition from the Mexican strawberry industry. Thus far in 1968, Mexico has shipped 60.2 million pounds of frozen strawberries and 18.9 million pounds of fresh berries to this country (49). A comparison of these import figures with individual state production figures indicates that Mexico ranks third in the production of strawberries for both the U.S. fresh and processing markets.

Many strawberry producers are looking anxiously to mechanical harvesting as a means of reducing their production costs or at least as a means of slowing down the production cost increase rate. Harvesting is, by far, the most expensive phase of production. Dennis and Sammet (12) report harvesting costs from 14 strawberry producing areas in 10 different states. Harvesting costs ranged from 47 to 76 per cent of the total production cost. This was based on 1958 data. More recent reports do not indicate any appreciable change in the situation. Approximately 50 per cent of the total expenditure required for the crop production goes for harvesting (1, 17, 18, 20, 42). Harvesting costs are also influenced by the market for which the fruit is intended. Generally speaking, harvest costs for fresh market fruit are higher than those for fruit that is to be processed.

Availability of an adequate supply of pickers at harvest time is an ever-present problem to the grower. Some areas utilize a labor force of local origin. Others depend upon the influx of migrant labor to harvest the crop. Strawberries are picked by both the young and the old. In Oregon, for example, it is estimated that about 90 per cent of the crop is harvested by young people ranging in age from 12 to 16 years. Many pickers are required to harvest strawberries. A rule of thumb used in Oregon is that 1.25 pickers are required per acre per ton of yield. In other words, it requires 5 pickers per acre to harvest a 4 ton per acre crop. Studies have shown that worker productivity rates are lower for children and teenagers than for adults (21). This being the case, much of Oregon's present source of strawberry pickers could be banned from the fields by such things as minimum wage laws. The possibility of eventual unionization of agricultural workers does not help to brighten the picture. Undoubtedly, comparable situations exist in other strawberry producing areas.

Auxiliary Devices to Assist in Hand Harvesting Strawberries

Traditionally, strawberries have been picked by hand. From a practical standpoint, the harvest of this crop is still completely dependent upon hand labor. Proper training (33) and adequate field supervision are helpful in making the best use of the available labor force. However, it is felt by many that the strawberry industry cannot continue to flourish unless the harvesting operation can be mechanized. It has long been recognized that the development of a successful strawberry harvesting machine would be a difficult, time-consuming task. The pressure to develop such a machine has never been greater.

Much thought and effort have been directed toward increasing the productivity of the hand picker and protecting the quality of the harvested fruit. Picking procedures vary greatly from one location to another. Depending upon the market, the berries may be picked with or without caps and stems. Cap, in this case, refers to the calyx. In many areas, the picker places the harvested fruit directly into the shipping container. In still others, the fruit is picked in one container and later transferred to a shipping container. Oftentimes a grading operation takes place along with the transfer.

Containers influence picker productivity and play an important part in maintaining fruit quality. Many different picking and shipping containers are currently in use. Terms like crate, tray, lug, flat, carrier, and handy are used to describe a container. Smaller receptacles may be placed in these containers which are referred to as hallocks, cups, and baskets (13, 16, 34, 38). A crate in California refers to a container holding 12 one-pint baskets (34). In Tennessee, a 24-quart crate is commonly used (32) while a 16-quart crate is used almost exclusively in Michigan, Illinois, and Indiana (38). A carrier of the type used in the Pacific Northwest holds six hallocks, each of which weighs approximately one pound when filled with fruit. Most of the containers have developed through local usage. However, the diversity in terminology and the lack of standardization in sizes creates confusion when attempting to compare productivity and harvesting results from different areas.

An intermediate step between traditional hand picking and machine harvest is the use of picker aids. Picker aids are found in many forms. One of the simplest is the picking stand used in California and other areas (34). Since handling results in bruising of the fruit and a subsequent reduction of fruit quality, berries destined for the fresh market are oftentimes placed directly into the shipping containers by the hand picker. The picking stand is used to support the shipping container at a convenient height for the picker. Since the market container does not come in contact with the ground, it is kept clean and attractive for marketing purposes. Moving of the fruit-filled container is facilitated through the use of the picking stand. Picking stands are also utilized in the harvest of berries for processing, but to a lesser degree.

A somewhat similar device in function is the picking cart. Literally thousands of these units are used by the strawberry pickers in Oregon, Washington, and California for both fresh market and processing fruit (1, 3, 33, 24). The picking cart is essentially a lightweight, wheelbarrow-like device which is used to transport the field containers. See Figure 1. It has an advantage over the picking stand, however, in that the picker does not have to lift the entire weight of the container when moving the unit along the row.

Numerous devices have been developed which will transport both the picker and the harvested fruit along the row. These labor-saving machines are intended to increase the picker's effectiveness by relieving him of these tasks. More of his time can be spent picking strawberries, and less of his energy is expended in moving his body and the harvested fruit. Personnel carrying devices range in size from one-man units to those capable of carrying 14 to 16 persons. Generally, the personnel carriers are self-propelled. Most of them have been constructed by the grower in his own farm shop. Consequently, each one is somewhat of an original.

An example of a one-man unit is the Ride-A-Row Crop Harvester built by J. H. Olson of Salem, Oregon. This four-wheeled, battery-powered machine straddles one row. The operator works from a semi-kneeling position. Steering and forward motion of the machine are controlled by the manner in which the operator applies body pressure to the chest support. Racks are provided on each side of the machine to carry containers for the harvested berries. While the Ride-A-Row Crop Harvester was originally developed for use in picking strawberries, it has also been used for transplanting, weeding, and harvesting other low-growing row crops. Six units were built in 1962. But, unfortunately, the initial cost precludes its use by the strawberry grower.

Multi-row personnel carriers are essentially traveling platforms with picker stations and facilities for the handling and temporary storage of harvested fruit. See Figure 2. Picker stations are generally located directly above the rows. The pickers work lying face down on padded platforms (2, 5, 19, 46, 47) or from a sitting position (13, 31). When the strawberries are grown in beds or wide matted rows, there may be two pickers per row. There are some machines reported, however, which carry the pickers between the rows. The pickers work from the sides of the row on these machines rather than from directly over the plants (13). Nearly all of the machines are self-propelled and some of them even incorporate simple guidance systems.

The harvested fruit may be placed in the shipping container by the picker or, on some machines, it is moved from the several picking stations to a central location on the machine by means of a belt conveyor system. The latter arrangement permits additional grading of the fruit by someone other than the picker. Nearly all of the personnel carriers used in Oregon were equipped with lights. The original intent was to provide illumination for picking at night. A typical installation provided two 150-watt bulbs at each picker station (2, 19). It was found that the lights also provided some benefits for daytime operations. The lights served as heat sources to keep the pickers' hands warm during low-temperature periods or when the plant foliage was wet from dew or rain (3, 5). Some machines were outfitted with cloth-covered canopies which protected the pickers from the sun or from rain showers.

Both fresh market and processing strawberries have been harvested by pickers riding on personnel carriers. Relationships between carrier ground speed, crop yield, worker productivity, and harvesting efficiency have been established (46). The personnel carriers have a number of desirable operating characteristics. By carrying the picker along the row, losses resulting from pickers walking or sitting on plants is practically eliminated. On machines equipped with conveyor systems and central crating stations, it is possible to upgrade the quality of the pick by utilizing additional sorting facilities on the machine. The personnel carrier can operate more than one shift per day, particularly if it is equipped with lights. The picker platform protects the pickers' clothing from wet plant foliage making it possible to resume harvesting sooner after a rain than would otherwise be possible. Personnel carriers may be used to havest low-growing crops other than strawberries, thereby distributing the equipment costs (5).

The personnel carriers also have some deficiencies. The major shortcoming is that the increase in picker productivity is not very great. Under certain conditions, a picker on a personnel carrier may double his picking rate. The average in Oregon and Washington, however, is about 25 per cent (2, 19). A person having a mediocre hand-picking record will generally demonstrate a far greater increase in productivity when working on a personnel carrier than will a person who is normally a fast picker. The larger multi-row units require relatively straight rows, a uniform stand of fruit, and essentially level ground for best operation. Large headlands are required for turning and the machines are cumbersome to move from one field to another (5). Although some distinct advantages may acrue to users of personnel carriers, these machines are not used consistently or to any great extent in the major strawberry producing areas.

The intent of most picker aids is to protect the quality of the harvested fruit and to ease the burden associated with the support and movement of the fruit container or with moving the picker's body along the row. In each instance, however, the picker's fingers are utilized in detaching the fruit from the plant. Stem-grade fresh market berries are picked by pinching off the stems one to two inches from the calyx. A device patented by R. S. Jacobson of Langley, British Columbia, is designed to assist the picker in severing the strawberry stems. It consists essentially of two thimbles which the picker wears on his thumb and forefinger. A cutting blade is attached to each thimble. As the picker's fingers close around the berry, the stem is simultaneously cut off. According to the inventor, use of the strawberry picking thimbles is advantageous in reducing picker discomfort resulting from broken fingernails and from foreign material becoming lodged under the fingernails (28).

Strawberry Harvesting Machines

In general terms, mechanical harvesting means the utilization of power equipment to harvest a crop. By some means or other, the mechanical device locates and removes the desired crop part or parts from the plant, places the detached material into a suitable container for further handling or processing, and rejects the unwanted portion of the plant (14). The abovementioned operations must, of course, be performed in a manner such that an acceptable level of product quality is maintained.

The strawberry picker performs several specific tasks. He searches out the fruit and decides which berries shall be picked and which shall not. He detaches the desired fruit from the plant and places it in a container. In some cases, the picker also caps and stems the berries. In addition, the hand picker grades the harvested fruit and usually transports the filled field containers to a central location such as a field check station or packing shed. Of the several known mechanical strawberry harvesting machines currently under investigation, none has the potential capability of doing all of the jobs now expected of the hand picker.

Achieving a successful solution to a mechanical harvesting problem usually involves research and development work in several related areas. Oftentimes, new varieties must be developed which possess the desirable characteristics for mechanical harvesting as well as the fruit quality traits which make them commercially acceptable. New cultural practices may have to be developed in order to take advantage of the plant growth characteristics and accommodate the harvesting equipment. New fruit handling and processing procedures and equipment may also be required. The machine which will harvest a particular crop, strawberries in this case, is the end product of that coordinated effort.

One of the early seekers of strawberry varieties suitable for mechanical harvesting was Dr. E. L. Denisen who is now head of the Iowa State University Department of Horticulture. In 1959, he initiated a program of screening strawberry varieties for mechanical harvesting according to the following criteria: (a) the plants must produce a concentrated set of fruit with uniform ripening characteristics to permit a once-over harvest, (b) the berries must be firm and have a broad shoulder, and (c) the berries must have either a brittle peduncle (stem) or easy capping characteristics to facilitate detachment of the fruit from the plant. One of the tools used in evaluating the mechanical harvesting potential of a strawberry variety was the stone fork. The berries were removed from the plant by the stripping action of the tines passing through the plant foliage (6, 11). The operation of strawberry harvesting machines known to be under investigation at several universities in the United States and Canada are dependent upon variations of the stripping method of fruit removal.

Strawberry harvester research is currently under way at Iowa State University, the University of Illinois, the University of Arkansas, Oregon State University, Louisiana State University, and the University of Guelph in Ontario, Canada. The following summaries of work done and progress made are based on published information or personal communications with the respective researchers. There may also be other experimental harvesters in existance that for one reason or another have not been revealed to the public.

IOWA STATE UNIVERSITY

The first Iowa State University strawberry harvester was a three-point hitch PTO operated unit. Its design and construction was begun in 1964. The picking mechanism consisted of 16 picking forks, each having 1/4-inch diameter fingers spaced 5/8-inch apart for a total width of 25 inches. The steel fingers, or tines, were slightly curved to facilitate entry into the plant foliage and to keep the detached fruit from rolling off. The picking forks were directed toward the rear of the harvester. The object of moving the pickers in the reverse direction was to reduce the relative horizontal motion between the fingers and the plant. This permitted the fruit to be detached from the plant during an interval when the path of finger travel was essentially in the vertical direction. An arrangement of cams and followers controlled the orientation of the fingers with respect to the ground. The picking forks were also used to convey the harvested fruit to a platform at the rear of the machine (6, 11).

The machine was field tested in 1965. During the testing, it was noted that the harvester operation was improved when the leaves of the strawberry plants were removed prior to harvesting. This was accomplished by using a rotary mower ahead of the harvester. Beds that were level and free from ridges were required to reduce the tendency of the picking forks to dig into the ground. The presence of long-stemmed mulches interferred with the operation of the harvester. But fine mulches such as ground corn cobs were beneficial (11).

Data from five field tests with the Sparkle variety indicate that the machine detached and recovered 40 per cent of the available fruit. An additional 23 per cent was detached from the plants but was dropped on the ground, while 37 per cent was not picked and remained on the plants. Approximately 50 per cent of the harvested berries exhibited signs of mechanical damage (11).

In 1966, the harvester was converted into a self-propelled machine. During the harvest season, the direction of travel of the picking forks was changed to correspond to the direction of the machine travel. It was noted that the picking action was improved and fewer berries were dropped on the ground. However, the published results do not indicate the direction of picking fork travel used during the tests, and therefore, are not sited in this summary. Work on this particular harvesting device is currently in an inactive state.

A new harvesting device was tested in 1968. The picking mechanism consists of a 20-inch wide row of steel fingers spaced 0.4 inch apart. The 8-inch long fingers are 5/16-inch in diameter and are mounted on a frame which in turn is suspended from four inclined arms. See Figure 3. When in operation, the frame and attached fingers are caused to oscillate with a motion parallel to the ground. The general path followed by the leading ends of the fingers is upward and rearward from the extreme forward position and returning to the original position during the second half of the cycle. A 5/8-inch stroke at 1,000 cycles per minute has been effective in harvesting fruit. The oscillating picking frame also functions as a conveying mechanism to move the detached berries to the rear of the machine. An air elevator and cleaning system are to be incorporated into the harvester at a later date (43, 44). See Figure 4.

According to test data taken on Everbear variety plots, the machine picking effectiveness ranged from 51 to 90 per cent when travelling at 0.85 miles per hour. On the average, the harvester picked about 66 per cent of the available fruit. No data is available regarding the physical condition of the harvested fruit. Removal of plant top growth and the presence of ground corn cob mulch was noted as being desirable for the operation of the harvester. Application has been made for a patent on this harvesting device (43, 44).

UNIVERSITY OF ILLINOIS

Laboratory studies were conducted in 1963 and 1964 to determine some of the bioengineering properties of strawberries that might be useful in developing a harvesting machine. Six varieties, Steelmaster, Vermilion, Redglow, Sparkle, Surecrop, and Midway were included in the studies. Measurements were made of the tensile, or picking forces, for single berries, single leaves, groups of three leaves, and to break the plant at the crown. It was found that the picking force of a single berry was significantly less than the forces required to detach leaf stems or to break the plant at the crown. Measurements were also made to determine shear characteristics of the fruit (22).

Other laboratory studies were conducted to determine the effects of finger size, cross-sectional shape, and spacing on fruit detachment, recovery, and damage. Two finger shapes, square and round, were investigated. For each shape, three sizes and three spacings were studied. Evaluation of the laboratory data indicated that stripping fingers spaced 0.4 inch apart should produce the best harvest results. With this spacing, fewer green strawberries were picked with round fingers, but less damage to the fruit occurred when square fingers were used on the laboratory stripping apparatus. About 25 per cent of the strawberries showed some signs of mechanical damage. Approximately 38 per cent of the immature berries were left on the plant while only about 4 per cent of the mature remained unpicked (22, 23).

A field machine was constructed and tested in 1964. It was a self-propelled unit powered by a one-cylinder air-cooled engine and was designed for harvesting strawberries grown in matted beds. Its picking mechanism consisted of a series of straight fingers attached to horizontal picking bars which were supported between two power-driven roller chains.

The fingers were 3/4 inch in diameter, 2 1/2 inches long, and were spaced 3/8 inch apart. Orientation of the fingers about the picker-bar axis was cam controlled so that the fingers penetrated the foliage with near horizontal motion. The horizontal motion of the fingers was in the same direction as the machine travel. Harvested berries were carried on the fingers until a picker bar reached its maximum vertical travel. As the picker bar was carried around the top chain sprockets, the berries would be dumped by gravity and allowed to fall into a container on the machine (22, 23). See Figure 5.

Field test results and laboratory test results were not always in agreement. Damage to the mature fruit was less in the field than in the laboratory. However, the field machine picked more immature berries and missed a greater percentage of mature fruit than did the laboratory apparatus. With the field machine, more leaves were stripped off the plants and more plants were broken at the crown than occurred in the laboratory (22, 23). The University of Illinois strawberry harvester work is in an essentially dormant state at the present time.

UNIVERSITY OF ARKANSAS

The University of Arkansas harvester utilizes a pneumatically-assisted stripping device. A series of short fingers attached in rows to a continuous belt are used to detach the fruit from the plants. Synthetic bristle brushes are attached to the belt between each row of fingers. The bristles are slightly longer than the fingers and serve to gently dislodge berries that were lying on the ground. High velocity air, approximately 6,000 feet per minute, lifts the berries off the ground thus permitting the stripping fingers to function more effectively. The detached fruit is carried on the stripping fingers to an air lock and then discharged into a suitable container. The air that lifts the berries also removes the leaves and lighweight debris from the harvested fruit (29, 40). A schematic diagram of the harvester is shown in Figure 6.

Tennessee Beauty and Surecrop varieties were used in testing the one-row, tractor-drawn harvester. Prior to harvest, the leaves were removed from the plants. The recommended height of the lower edge of the picking head above the ground is 1.25 inches. More berries are picked up if the edge is closer to the ground, but the mechanical damage and contamination of the fruit with soil particles is increased. The picking efficiency of the harvester is enhanced if the plants are on level beds shaped to fit the configuration of the picking head. Field test data is shown in Table 4.

Table 4. Effect of Plant-Bed Preparation on Strawberry Yields and Harvester Efficiency (Seasonal and Varietal Means)(29)

Measure	Total Crop		Acceptable Crop[1]	
	Natural Bed	Shaped Bed	Natural Bed	Shaped Bed
Total yield (T/A)	4.67	4.84NS	2.53	2.31NS
Machine yield (T/A)	2.71	3.62**	1.32	1.57**
Machine efficiency (%)	58	75**	52	68**

**Significant at 1% level.
[1]Average yield for Arkansas is 1.25 tons per acre.

The relationship of maturity to berry size has been studied extensively. Samples of mechanically harvested fruit were divided into five maturity levels, namely, decayed, acceptable, color inception, mature green, and immature. Acceptable is defined as fruit having red, ripe color while color inception means those berries that have a slight pink color. Results of these studies are shown in Table 5.

Table 5. Maturity Distribution of Harvested Strawberries (Varietal Means from "Shaped-Bed" Plots)(29)

Stage of maturity	Total yield of			Seasonal average		
	1st harvest	2nd harvest	3rd harvest	Total yield	Machine yield	Fruit weight
		Percent		Percent		Grams
Decayed	9	10	15	11	10	6.6
Acceptable	44	50	46	47	43	8.0
Color inception	16	15	17	16	16	5.4
Mature green	14	15	12	13	16	4.0
Immature	17	10	10	12	15	1.8
Tons per acre, yield	4.37	5.33	4.83	4.84	3.62	---
Grams per fruit, wt.	5.7	4.8	5.0	4.2	5.3	---

The possibilities of grading for maturity on the basis of size rather than color sorting is being studied (29). The basic principles of a mass sorting system have been worked out and are to be further tested in 1969 (8). Color is only one means of measuring fruit quality. Some of the other important factors that may be considered are shown in Table 6.

Investigations have been conducted in the post-harvest changes in color and mold count on the harvested fruit. Harvested berries in the mature green and color inception categories have been ripened to an acceptable color when stored in controlled environmental conditions for 2 to 4 days (29).

Table 6. Objective Quality Attributes of Mechanically Picked Berries of Acceptable Color and of Fruit Left in Plots and Picked by Hand(29)

	1st harvest		2nd harvest		3rd harvest	
Quality attribute[1]	Machine	Hand	Machine	Hand	Machine	Hand
Mold count**	9	18	14	17	15	26
C.D.M.a/b**	1.9	2.0	2.1	2.2	2.1	2.3
Titratable acidity[2]**	6.6	6.4	7.0	6.2	6.2	6.0
Soluble solids %*	6.5	6.4	6.3	6.0	5.9	5.8
pH*	3.35	3.36	3.34	3.40	3.35	3.39

1* and ** indicate differences between machine-picked and hand-picked berries were significant at 5% and 1% levels, respectively.
2Ml of N/10 NaOH per 5 ml of filtrate.

Blueberry Equipment Incorporated of South Haven, Michigan has undertaken the construction and development of a production prototype model of the University of Arkansas harvester. See Figure 7. The prototype is self-propelled and is reported capable of harvesting at ground speed of 12 to 3/4 mile per hour. This machine was tested in Arkansas and Michigan in 1968 (8, 9, 39).

LOUISIANA STATE UNIVERSITY

An experimental harvester is under investigation at Louisiana State University. The harvesters picking mechanism is a pneumatically-assisted stripping device. Construction details and harvest results are not available at this time.

UNIVERSITY OF GUELPH

A tractor-mounted strawberry harvesting unit was tested in 1967. This device was in the form of a hollow picking reel 38 inches long and 12 inches in diameter. Curved steel fingers were attached to three picker bars located on the periphery of the reel. The curved fingers were made of 3/8-inch square bar and were spaced 3/8 inch apart. The picking reel was mounted with its axis perpendicular to the row. Harvested fruit was removed from the picking reel by means of a belt conveyor (25, 26).

The harvesting device was capable of delivering good quality fruit. Several problems arose during the testing, however, which eventually led to the abandonment of the unit. Difficulties were encountered in removing the harvested fruit from the stripping fingers causing berries to be carried over and dropped onto the ground. Picking up fruit which was lying on the ground was a major difficulty. When the picking fingers were operated close enough to the ground to reach the low-growing berries, the fingers oftentimes became entangled in the plants. The result was that plants were uprooted and the soil surface disturbed. It was concluded that the picking action of the fingers could be enhanced if some means were available to lift the berries off the ground (25, 26).

Laboratory studies showed that compressed air could be used effectively to lift the berries off the ground. A new stripping device was constructed and tested in 1968. See Figure 8. The stripping mechanism of this machine consisted of nine sheet-metal boxes mounted between two roller chains. The stripping fingers were attached to the leading edge of each box. A set of probes was designed that were individually pivoted and spring loaded. When in operation, the probes would "skate" along the soil surface. The probes were made of thick wall, 1/4-inch O.D. tubing and had three number 70 holes drilled in one side. The probes were spaced 3/4 inch apart. Compressed air at 40 to 50 psi was fed into the probes and exhausted through the orifices. Under proper pressure and air flow conditions, the strawberries would be lifted off the ground and suspended by the air streams, enabling the stripping fingers to function more effectively (25, 26).

The proper relationship between the air probes and the stipping fingers remains to be worked out. Inadequate clearance between the path of the stripping fingers and the air probes oftentimes caused the machine to become plugged with vegetative material (25, 26).

OREGON STATE UNIVERSITY

A half-row tractor-drawn harvester was constructed and underwent limited field testing in 1967. The picking mechanism consisted of a hollow reel 12 inches in diameter and 22 inches long. Curved steel fingers 1/4 inch in diameter and having a radial length of 8 inches were attached to 6 bars located around the outer edge of the picking reel. There was a 5/8-inch space between the fingers. The axis of the reel was parallel to the strawberry row. As the reel rotated, the fingers moved through the plant foliage in a direction perpendicular to the fingers (4).

A conveyor belt, located inside the hollow picking reel, moved the harvested fruit through the open end of the picking reel and into a suitable container at the rear of the machine. Picking reel speeds ranged from 2 to 10 rpm. At rotational speeds above 10 rpm, fruit recovery rates were reduced. Several strawberry varieties were included in the testing program, but most of the work involved the Northwest and Hood varieties (4).

Field results using the half-row harvester are shown in Table 7. The harvested fruit was sorted into several maturity levels. The categories have been modified slightly for convenience in comparing results with other areas. The maturity levels are defined as overripe--dark and dull in color, soft but having commercial value; ripe--more than 80 per cent of surface with full red, ripe color; color inception--20 to 80 per cent of surface with pink color; and green--berries that were green or white in color. Mechanical damage to the harvested fruit was reported in two categories, severe damage was interpreted to mean fruit that was broken, torn, severely abraded, internally contaminated with foreign material, or mashed; surface damage means surface cuts or macerations. The yield data and efficiency figures were based on berries actually picked by typical hand pickers in the same field and not on the total available fruit (52).

Table 7. Mechanical Harvester Test Results

	Mechanically Harvested		Hand Picked Control	
	Northwest	Hood	Northwest	Hood
Maturity level	Per cent		Per cent	
Decayed or diseased	7	17	6	5
Overripe	18	25	14	29
Ripe	53	47	60	58
Color inception	16	6	21	13
Green	6	4	0	0
Mechanical Damage				
Severe*	6	7	--	--
Surface*	15	21	--	--
Yield				
Total yield (T/A)	8.05	5.34	--	--
Machine efficiency (%)	23	35	--	--

* Per cent by count. All other percentages are by weight.

Studies have been conducted to determine certain plant growth characteristics that might have an influence on the operation of a mechanical harvesting device. Data on one and two-year old plants has been reported pertaining to the number of berries and flowers on the plant and the number and lengths of peduncles and scapes. Once-over yields have been as high as 75 per cent of the total possible production for the Northwest variety and 80 per cent for the Hood variety. These figures lend support to the acceptance of once-over harvesting for strawberries (7).

A full-row self-propelled harvester was built and tested in 1968. See Figure 9. This machine had two picking reels with fingers 3/8 inch in diameter and spaced 3/4 inch apart. A rotary mower was mounted on the front of the harvester to remove the plant top growth. The machine had its own conveying and cleaning systems. Harvest results are shown in Table 8. All percentages are on a weight basis.

Best results were obtained with uniform-size single-plant rows, which were slightly ridged. When the ridge was properly shaped, the harvester picked more than 90 per cent of the available fruit. When the ridge profile did not have the proper shape, excessive numbers of berries in the center of the row above the plant crown were not picked. The finger size and spacing used on the 1968 machine were not as effective as those used in 1967. The larger diameter fingers did not penetrate the plant foliage as well and with the wider spacing, the amount of fruit picked by the harvester was reduced from what it might have been had the fingers been closer together.

Table 8. Mechanical Harvester Test Results, North Willamette Experiment Station, June 27, 1968.

Harvester Ground Speed rpm	Hand Pickings on Plots Before Harvester Test	Ripe Fruit on Plot at Time of Harvester Test in Tons/Acre	Picking Reel Speed rpm	Ripe Fruit Not Picked by Harvester* % of yield	Ripe Fruit Picked By Harvester but Dropped on Ground % of yield	Ripe Fruit Picked and Recovered by Harvester % of yield
0.2	1	3.95	21	47.3	18.9	33.8
	2	1.93	21	66.2	17.7	16.1
	2	1.77	21	61.7	28.1	10.5
0.4	1	2.14	21	49.3	14.5	36.2
	1	3.26	21	51.4	10.5	38.1
	2	2.02	14	57.0	23.1	20.0
1.0	1	0.995	21	34.4	18.8	47.0
	1	3.02	21	69.0	12.4	18.6
	2	1.37	21	79.0	6.8	13.6

* Includes all ripe fruit remaining on plants regardless of berry size.

Condition of Fruit As Received from Mechanical Harvester		Maturity Level Distribution				Quality Distribution of Ripe Fruit		
Form	% of total	Green %	Immature, Lacking Red Color %	Ripe %	Overripe %	Good %	Mechanical Damage %	Mold and Disease (Cull) %
Clusters	12.4	--	--	--	--	--	--	--
with Caps and Stems	32.7	28	16	48	7	44	33	22
with Caps only	52.5	18	16	51	15	46	35	18
Capped and Stemmed	2.4	--	--	--	78	--	--	--

Table 9. Quality assessment of mechanically harvested strawberries from the James Heater Farm, July 3, 1968. Hand-picked fruit from the same field was also evaluated for mechanical damage. It was found that 51 per cent of the hand-picked berries had experienced some mechanical damage during the picking operation. Evaluations were made by the Oregon State University Department of Food Science and Technology. All percentages are on a weight basis.

NEW STRAWBERRY HARVESTER PATENTED

A California resident was recently granted a U. S. Patent on a strawberry harvester. According to the claims of the inventor, the machine ". . . will harvest those strawberries of an appropriate ripe color and will not harvest strawberries of an unripe green color." As invisioned by the inventor, a series of photoelectric cells scan the strawberry plant. When a ripe berry is located, the picking mechanism is activated. The picking mechanism consists of a series of vertically-mounted telescoping tubes, each of which has a serrated knife around the periphery of its lower end. The tube moves downward and circles the ripe berry causing the stem of the berry to be severed. Air moving under negative pressure lifts the detached fruit from the ground and deposits it in a reservoir filled with water. Water jets move the floating strawberry to the rear of the reservoir and onto an inclined flighted belt conveyor. Since the entire reservoir chamber is under vacuum, the berries must be discharged from the machine by means of a rotary air lock (45).

There are 14 claims associated with the patent. The inventor has not made any information available on the present status of the machine or plans for its future.

Strawberry Capping and Stemming

Strawberries moving into fresh market channels currently must have the cap (calyx) attached to qualify for U. S. No. 1 Grade (50). Caps are not specified for U. S. No. 2 Grade. Fresh strawberries moving into a process pack must have all stems, bracts or sepals entirely removed. Berries shall be considered defective if they have whole or partial caps, stems, or sepals attached (41).

If the same varieties are to be picked mechanically for both the fresh market and the process market, the berry must have a rather firmly attached cap to withstand the stripping action of the picking operation. If the market flexibility is sacrificed and process berries are raised for the process market only, the industry might look to the plant breeder for help in supplying a "self-capping" berry. No presently known commercial varieties of strawberries have a natural abscission layer which permits both the stem and the calyx to remain on the plant consistently when the berry is picked by a straight pull. Some strains are considered "easy cappers" but do not have the color, firmness, texture, productivity, disease resistance, and climatic adaptation necessary for widespread economic production. A berry plant with all these desired attributes is not on the immediate horizon for commercial production (30).

In 1967, the harvested crop of strawberries in the United States was 478 million pounds. Fifty-eight per cent went to fresh market and 42 per cent, or 200 million pounds, went into a canned or frozen pack (49). This 200 million pounds was mostly hand-stemmed and hand-capped as part of the field hand-picking operation. For any mechanical picking system for process berries to be practical in the United States, it must incorporate a mechanical stemming and capping operation. While berries are hand-capped in processing plants in Mexico, the in-plant labor requirement for such an operation in the United States would appear to be intolerable.

Mechanical cappers appear to have been developed prior to World War II. Professor Arthur H. Morgan at the University of Tennessee was working on capping machines at this time and was awarded U. S. Patent No. 2,323,668 in 1943 (35). He subsequently received U. S. Patent No. 2,383,268 in 1945 (37) and No. 3,122,187 in 1964 (36).

Professor Morgan constructed a machine utilizing 120 stainless steel 3/8-inch diameter rolls matched with an equal number of 3/8 inch diameter rubber-covered rolls as shown in Figure 10. These rolls are mounted vertically to form a solid cylindrical rotating basket. Small spur gears at the ends of the metal rollers engage a stationary ring gear to provide rotation when the entire basket is in motion. Six equally-spaced circumferential troughs hold the berries against the rollers for nearly one full revolution about the outside of the basket. The stems and caps are discharged through the center of the basket assisted by jets of water located about the periphery.

Tests conducted by the University of Tennessee in 1955 and 1956 indicated the Morgan Capper was 93 to 94 per cent as effective as hand-capping in the complete removal of caps. An average of about 45 per cent of the strawberries in this study retained a portion of stem after the capping operation was complete (32). The capacity of the machine was 1,000 to 2,000 pounds per hour. Their economic studies indicated the berries could be capped more cheaply by machine when 700 to 960 24-quart crates were handled per season depending upon local prevailing cost differentials in hand picking. In spite of this, no more than nine of these machines were ever built and used.

Canners Machinery Limited at Simcoe, Ontario, Canada manufactures the CML strawberry "huller" which also matches equal diameter steel and rubber-covered rolls. The 7/16-inch diameter rolls are mounted in a flat bed which can be tilted slightly to promote the flow of fruit across the bed. The path of travel of the berries is at right angles to the longitudinal axis of the rollers. Positive travel of the fruit is provided by metal scrapers mounted on a pair of continuous chains over the roller bed. According to one major processor in the Simcoe area who had used these CML machines for over 15 years, they did get 80 to 90 per cent hull removal on reasonably firm Premier and Pocahontas berries. The Sparkle variety grown in that area did not hull satisfactorily. Tests were conducted at Oregon State University on one of these machines using Northwest variety berries hand-picked with stems and caps on. The berries were taken three times weekly from two different farms throughout the harvest season. Capping and stemming effectiveness varied from 22 to 38 per cent over the season. Tests on Northwest berries picked by the Oregon State University strawberry harvester showed 22 to 51 per cent were capped and stemmed by the CML machine.

T. C. Fenton, Limited, also at Simcoe, Ontario, manufactures a machine similar to the CML except that it has a double bed with one unit above the other to give double capacity.

Magnusson Engineers, Incorporated at San Jose, California manufacture a stemming machine which employs a bed of counter-rotating rubber rolls similar to those shown in Figure 11 that are at right angles to the direction of product flow. A quick-return reciprocating motion to the bed progresses and gently agitates the fruit permitting the stems to be gripped between the rolls and removed. The same reciprocating motion also drives the rolls, with alternate rolls being gear-driven in opposite directions by stationary gear racks on each side of the machine. The manufacturers indicate varying degrees of success with the machine when used on strawberries and do not recommend it as a general purpose strawberry capper.

Mr. Fred L. Rahal at Northeast, Pennsylvania manufactures a machine similar to the CML unit. One variation, according to Mr. Rahal, is the employment of unequal-size rubber and metal rolls. His machine matches a larger rubber roll to a smaller rubber roll as shown in Figure 12, to promote better tumbling action as the berries progress across the bed.

Models of the Brueser Stemming Machine have been imported from Germany for use originally as cherry stemmers. The Stayton Canning Company at Stayton, Oregon tested two of these machines in 1967 as strawberry cappers with some success. The Brueser machine utilizes counter-rotating 3/8-inch diameter smooth rubber-covered rolls as shown in Figure 11. The longitudinal axis of the rollers is parallel to the path of travel of the berries. The berries are agitated and forced to progress along the rollers by a reciprocating scraper bar which slides under the fruit.

Literature has been obtained on the Zero Total Meccanofrutta Italiana machine manufactured in Verona, Italy and the Henri Biageaud Machine manufactured near Paris, France. Both machines apparently use a sloping bed of transverse steel and rubber rolls similar to the CML unit. Correspondence and personal visits with European processors indicate that these machines work successfully with some of their European varieties but would have difficulty with any variety having a tight-clasping calyx or firmly attached stem.

The counter-rotating roller system currently used by all known makes of stemming and capping machines has two serious limitations. First, the rolls have difficulty in catching hold of all parts of a tight-clasping calyx. If the exposure of the berry to the rolls is sufficiently severe and repeated to clean off the calyx, the damage to the berry flesh is excessive. Secondly, the rolls cannot consistently reach the "short stem" or a stem 1/8 inch or less on typical oblate, globose, globose conic, and short wedge shape berries (10). Necked berries present the stem and cap for easy grasping by the rollers if they can be made to tip up on end.

If a satisfactory method could be devised for orienting individual berries into troughs or individual sockets for height positioning, the caps and stems could be cut off with a high-speed curved knife passing below them. Some berry flesh would be lost in the cutting, but the severe scraping and abrasion damage inflicted by the present roller machines could be avoided.

Another approach to capping and stemming is to quick-freeze (IQF) the fruit direct from the field before any water has been applied to it. At -20 to -30F the stems and calyx are quite brittle and can be broken off by brushing, tumbling, or buffing. Success of this approach will be partially dependent upon how much of the stem base can be removed and how much might be tolerated in the processed pack. A side advantage of this system would be the possibility of holding a large portion of the harvested crop in the freezer during peak production periods when the picking rates exceed the plant processing capacity. These frozen berries might be washed, graded, and sliced later without being completely thawed.

Summary and Future Prospects

To be successful, a mechanical harvesting system for strawberries must include suitable field equipment to pick the fruit, strawberry varieties and cultural practices compatible with machine operating characteristics, and equipment and procedures to insure that the mechanically-picked fruit is in marketable condition. None of these requirements have, as yet, been completely fulfilled. There are several experimental harvesters but they are still in the early stages of development. Nevertheless, the state of the art has been developed sufficiently to demonstrate that strawberries can be harvested by mechanical means.

With continued progress in the development of field equipment, a substantial part of the fruit for processing could be picked mechanically within 10 years or less. Some changes will be required in the processing plant to accommodate the mechanically-harvested fruit. For example, there will be increased sorting and grading requirements resulting from the presence of both green and overripe fruit. It will be necessary to provide facilities for capping and stemming the berries. However, unless equipment can be developed to cap, stem, sort, and grade the fruit, the advantages offered by mechanical picking will be lost. Some fresh market fruit may be mechanically harvested within the next 10 years but probably not in any great amounts. Since the margin of profit is greater for fresh market strawberries, there is not the same urgency for mechanization that there is for processing berries. It is not anticipated that the entire U. S. strawberry production will ever be completely machine harvested. There will always be some hand-picked fruit for home use, the fresh market, and for specialty or luxury products which can command a premium price.

Development of equipment and procedures for mechanical harvesting must proceed using commerically acceptable varieties. It is well understood that the present strawberry varieties do not possess the growth habits and fruiting characteristics readily adaptable to a mechanized harvest system. Consequently, the equipment designer is severely handicapped. The efforts of the plant breeder to bring into being new and improved strawberry varieties for mechanical harvesting must not be reduced. Even if the ideal variety were available today, it would take a minimum of five years to build enough planting stock to supply a production area such as the state of Oregon. The strawberry industry cannot afford to wait for the appearance of the ideal variety.

At the present time, strawberries are picked several times during the harvest season. Depending upon the particular area, the length of the harvest season may span a period of two to three weeks to several months. Mechanical harvesting may also be on a multiple-pick basis or it may be on a once-over basis. For the immediate future and also from the equipment standpoint, the once-over harvest approach appears to have the greatest potential. A once-over harvest may be either destructive or nondestructive as far as the plants are concerned. A destructive-type harvest would not be acceptable in areas where the useful life of a planting is two or more years. In some instances, as much as 80 per cent of the total production has been recovered with one picking (7), but this is the exception rather than the rule. A reduction in the amount of fruit recovered will be a consequence of the once-over harvest approach.

There are several ways in which the reduced yield problem may be alleviated. One possibility would be to increase the plant population in the field, thereby increasing the amount of fruit available for harvest. Such an approach would require the availability of increased amounts of planting stock and the development of transplanting equipment to facilitate closer plant spacings. Bed sizes may be increased, and in areas where the single-plant row system is utilized, the row spacing may be reduced. With machine harvesting, it would no longer be necessary to reserve space between rows for human traffic. Any changes in cultural practices adopted to facilitate mechanical harvesting must be in keeping with demonstrated procedures for controlling such things as gray mold (Botrytis cinerea) and red stele (Phytophthora fragariae). The use of chemicals may also have a place in regulating the fruiting habits of the plants. Work directed toward this goal is in progress at Oregon State University and at other universities. Ultimately, the long-range solution would be the development of a high-yielding strawberry variety having a concentrated fruit set with uniform ripening characteristics.

The role of the plant breeder in developing a successful mechanical harvesting system for strawberries cannot be overemphasized. There are, at the present, no commercially significant varieties that are universally grown in all strawberry producing areas. Consequently, it can be assumed that no single variety developed specifically for mechanical harvesting will be suited for all parts of the country. Unless a high degree of control of fruit maturing characteristics can be achieved through the use of chemicals or by other artificial means, several varieties will be required in order to spread the harvest season over a longer period of time within a particular production area. It is also quite likely that varieties suitable for processing may not be acceptable for the fresh market.

There are several plant growth characteristics that would greatly facilitate the use of mechanical harvesting equipment. Concentrated fruits set for a once-over harvest has already been mentioned. The fruiting inflorescence should have sufficient strength to support the berries up off the ground. All of the presently known experimental picking devices would function more effectively if the berries were two or more inches above ground level.

Mechanical damage to the harvested fruit is always a problem. It is a well known but oftentimes overlooked fact that hand-picked berries are not free of mechanical damage. Bruising of a berry may occur when it is detached from the plant or when it is dropped into the field container, or in subsequent handling operations. The technique used by the picker in removing the cap and stem for a processing berry can cause considerable damage to the fruit. Limited amounts of this type of damage can and are being tolerated. Contamination of the fruit from foreign material, such as imbedded soil particles, cannot be tolerated because the contaminant is extremely difficult or impossible to remove. Damage resulting from the mechanical harvesting operation must be held to a minimum in order to maintain fruit quality. Hopefully, the damage level of the mechanically-harvested berries will not exceed that of the average hand-picked fruit.

Firmness and seed characteristics are important factors related to damage resistance. A berry that is firm and has a resilient skin with reasonable toughness to resist abrasion is required. The seeds should be flush or nearly flush with the surface of the berry. Protruding seeds cause skin abrasion when the berries come in contact with one another during handling. Breaks in the skin detract from the general appearance of the fruit as well as its storage life.

New containers must be developed for handling the harvested fruit. Currently, containers of various sizes and shapes are used in transporting the berries to the processing plant. While they may be satisfactory for hand-picking operations, their size and construction features are not well suited for use on mechanical harvesting equipment. Integral dividers and smaller receptacles are used in many of the fruit containers. Berries falling on the dividers or edges of the smaller boxes would be subject to unnecessary mechanical damage during a filling operation. Such sources of mechanical damage must be eliminated wherever possible to maintain fruit quality.

Although not yet a reality, enough progress has been made to demonstrate that mechanical harvesting of strawberries is possible. Considerable interest in mechanical harvesting is now being exhibited by growers and processors alike. At the university level, assignment of personnel and funds to mechanical harvesting research is increasing. People from many disciplines are involved. Agricultural engineers, horticulturists, food scientists, economists, growers, and processors will all contribute to the development of a successful mechanical harvesting system for one of our most popular small fruits, the strawberry.

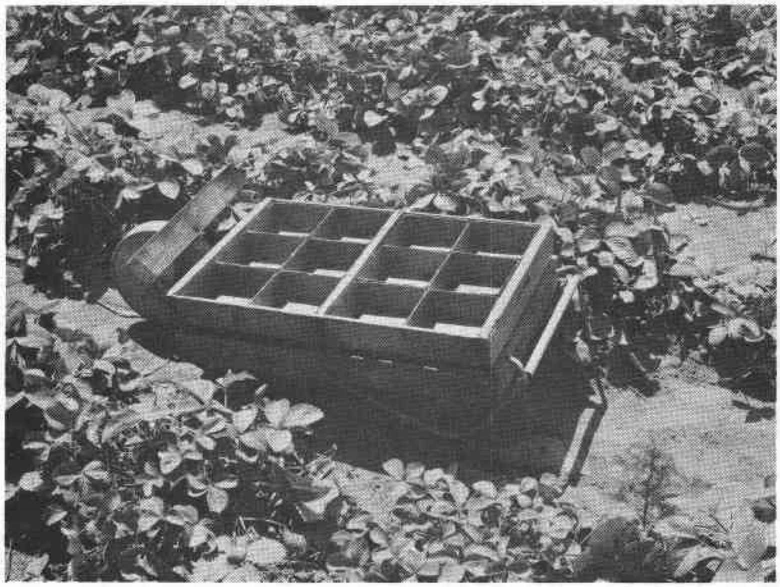

Figure 1. The picking cart shown is typical of the units used in harvesting strawberries in the western United States.

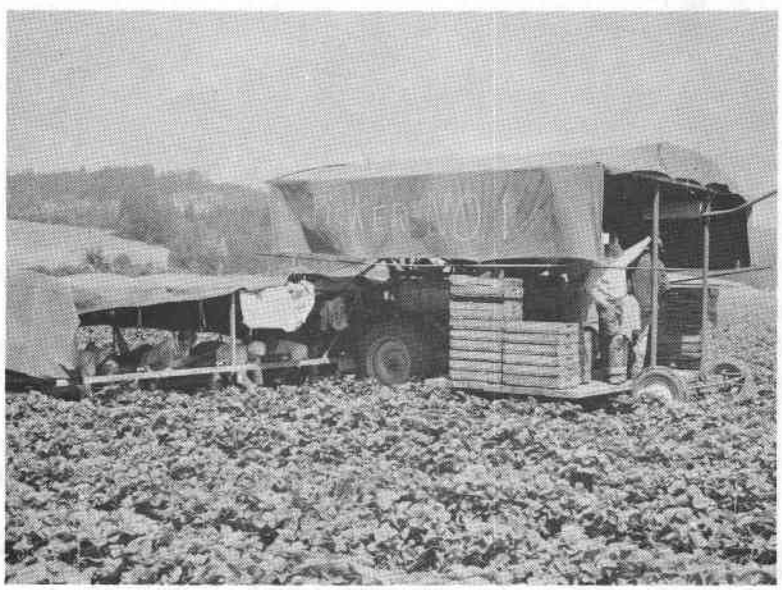

Figure 2. This ten-row personnel carrier was built on a used, self-propelled grain combine frame.

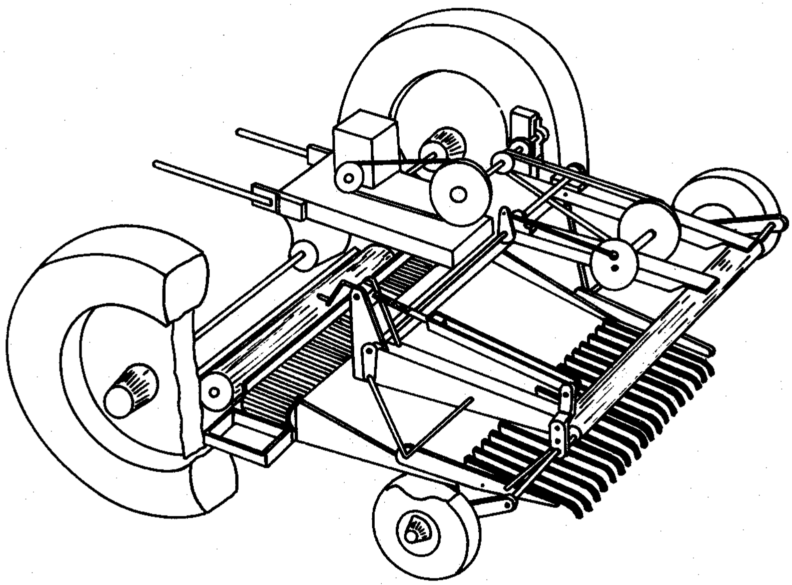

Figure 3. The strawberry harvesting device under development at Iowa State University features a row of oscillating fingers. [Drawing courtesy of Graeme R. Quick, (42)].

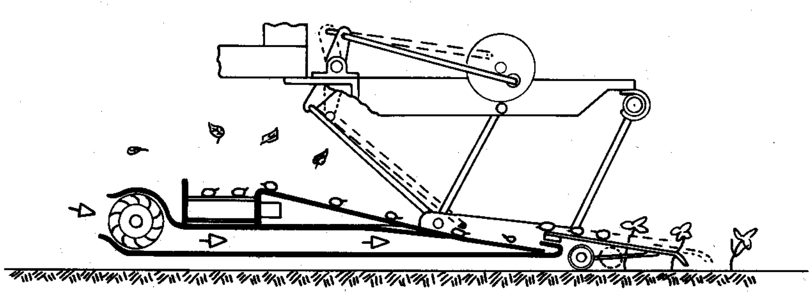

Figure 4. A side view of the Iowa State University harvester shows how air is used to aid in conveying the harvested fruit and in removing leaves. [Drawing courtesy of Graeme R. Quick (42)].

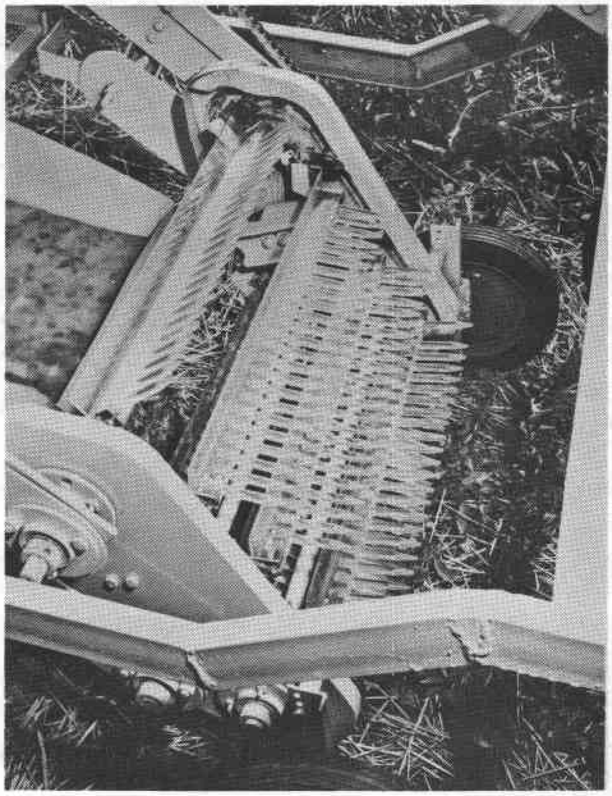

Figure 5. The stripping mechanism of the University of Illinois harvester originally had plastic fingers. [Photograph courtesy of Dean L. Hoag (23)] .

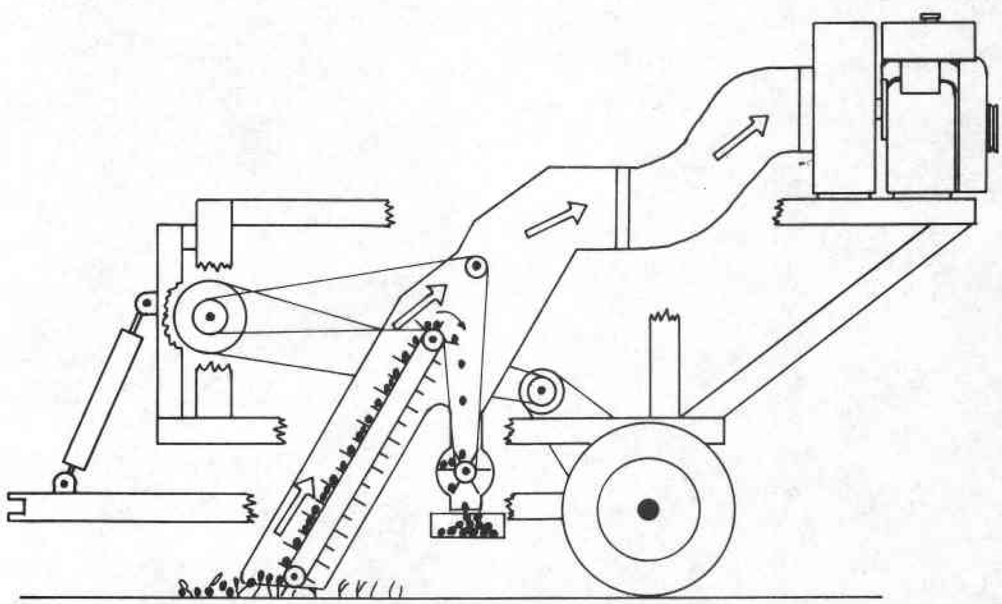

Figure 6. The operation of the University of Arkansas harvester is shown schematically (23).

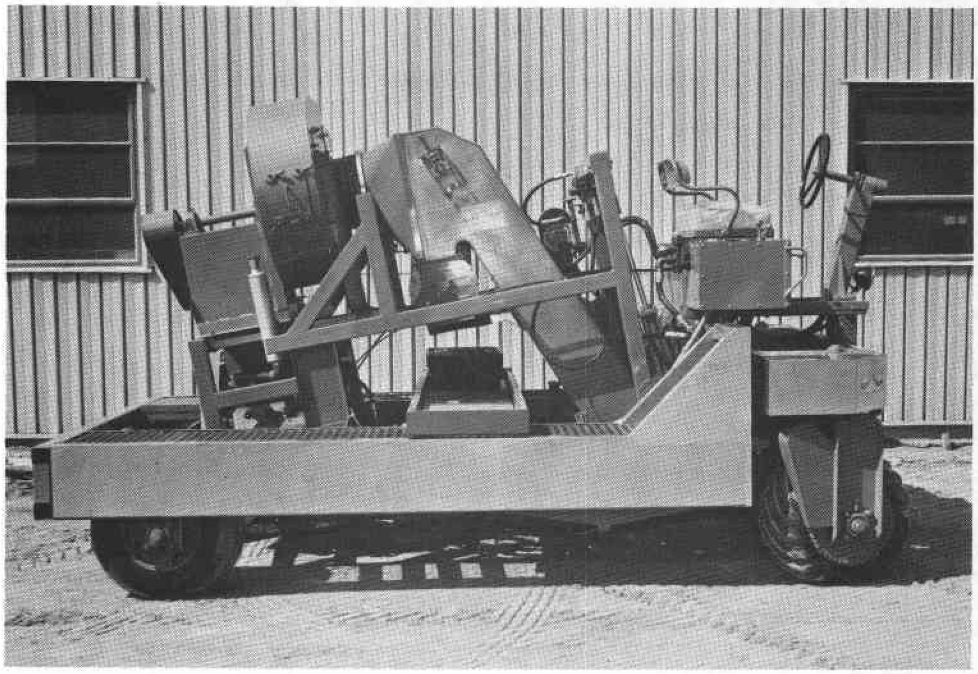

Figure 7. A production prototype of the University of Arkansas strawberry harvester has been built and tested by Blueberry Equipment, Inc. of South Haven, Michigan. [Photograph courtesy of Donald B. Cunningham (8)] .

Figure 8. Compressed air is used to lift the strawberries off the ground in the operation of the harvester developed at the University of Guelph, Guelph, Ontario, Canada. [Ontario Department of Agriculture and Food photograph courtesy of Harold A. Hughes (25)] .

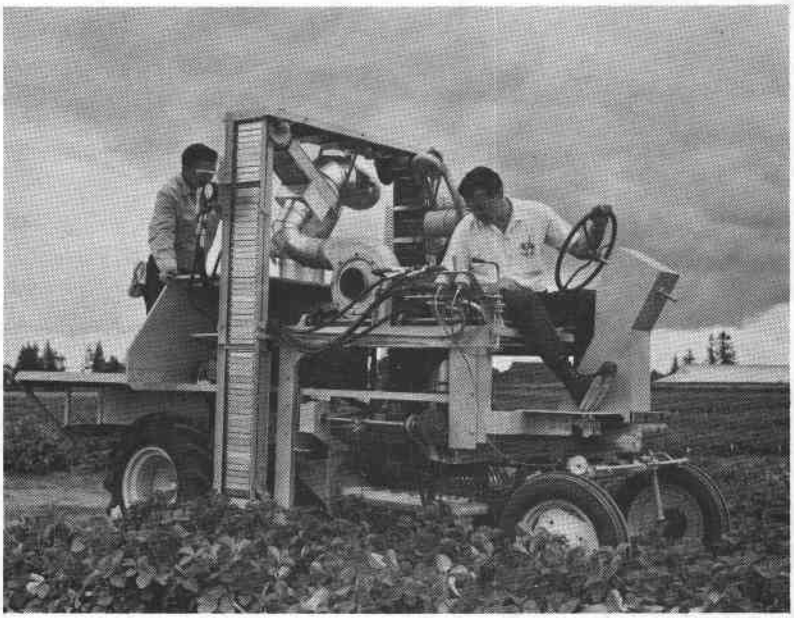

Figure 9. A full-row, self-propelled strawberry harvester was field tested by Oregon State University in 1968.

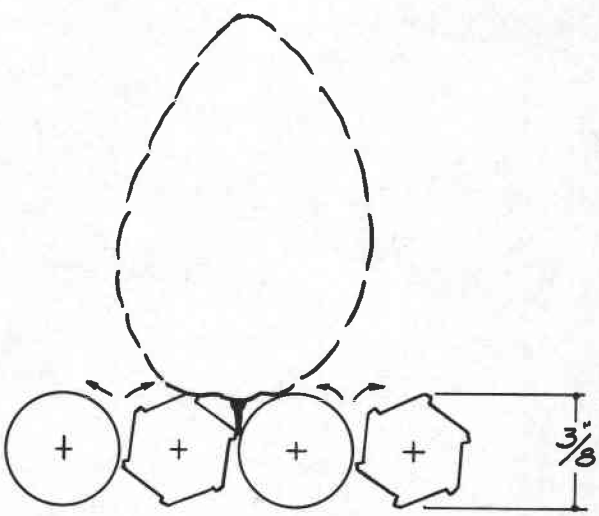

Figure 10. Serrated metal rolls matched against counter-rotating rubber-covered rolls.

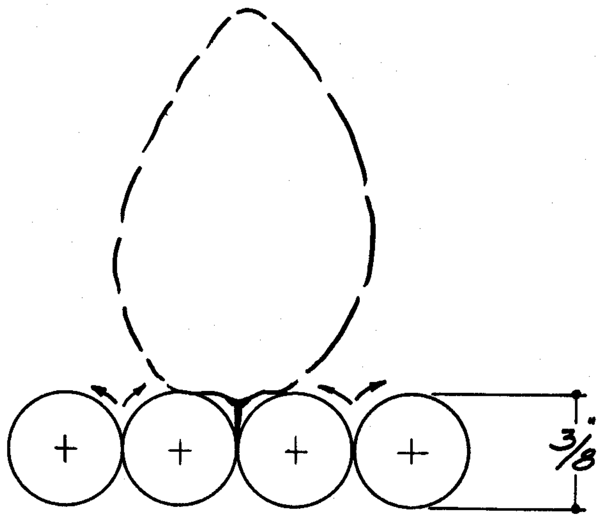

Figure 11. Counter-rotating rubber-covered rolls.

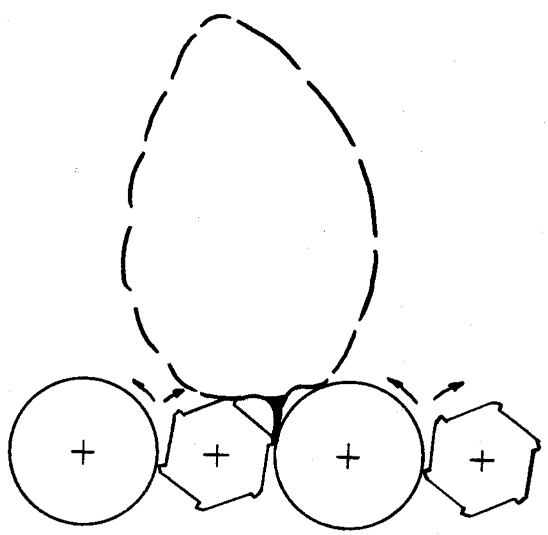

Figure 12. Serrated metal rolls matched with larger diameter rubber-covered rolls to give better tumbling action.

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