from Kalamazoo, Michigan, via Cape Horn to San Francisco and then overland to Mission San Jose where it successfully harvested 600 acres of wheat. Due to faulty lubrication, this machine caught fire and burned along with the field of grain in 1856. Within the next few years, however, several companies were building combines in California for use on the Pacific coast. It was not until the 1920's that the combine was accepted in the winter wheat belt. The irony of the story is that Michigan, the birthplace of the combine, finally accepted it about 1936 – 100 years after its invention.

The principal reasons for substituting capital for labor (machines for men) are based upon economic factors or the availablility of labor. Oftentimes it is a combination of the two. The introduction of the mechanical cotton picker into California is an excellent example of the place economics played in the acceptance of the machine. By 1949, 16.2 per cent of California's 1,268,000 bale cotton crop was harvested by machine. A study, made by Hedges and Bailey, of 63 machines used by San Joaquin Valley cotton growers showed a relative cost of $45.00 per bale for hand picking vs. $25.76 for machine harvesting. The latter costs took into consideration: labor, overhead and operating cost, field waste and reduced sales value due to reduction in quality of the machine-picked cotton. Needless to say it wasn't long thereafter before the bulk of the California crop was picked by machine.

The rapid adoption of the mechanical cotton picker brought about a serious labor problem for the raisin and wine grape producers. Grapes and cotton are grown in the same general area. We were informed by a delegation of grape growers that the labor that normally picked cotton came in two or three weeks early to pick the grapes. Since there was no more cotton to pick, many of the laborers they had counted on to pick grapes didn't come into the area. As a result, they requested work be started immediately on a mechanical grape harvester. A research program, involving agricultural engineering and viticulture, was initiated. A machine has been developed and licensed for commercial production.

The adoption of a mechanical tomato harvester was a direct result of labor shortage. The labor shortage resulted when the Secretary of Labor banned the importation of foreign labor. The tomato industry of the State faced a serious problem because approximately 85 per cent of the tomatoes for processing were normally picked by nationals from Mexico.

It was fortunate for the industry that the University had launched a long range research program to mechanize the harvesting of tomatoes some 10 years before the ban on importing foreign labor. As a result, a system, somewhat imperfect at the start, became available at about the right time. The research behind it was truly interdisciplinary. It involved plant breeding, food science and technology, agricultural engineering and finally a local manufacturer, and farmers and processors who were willing to risk their future on mechanizing the crop.

If labor in good supply were available today, it is almost certain that we would not have faced the problem and would still be picking tomatoes by hand. The important end result was the saving of an industry for California. Processors were considering the shifting of their operations south of the border where labor was plentiful. This would have resulted in a loss of an annual income to the State of around one-half billion dollars.

Similar situations existed during World War II. The mechanization of sugar beet production is another example. Ten years prior to the war, the University in cooperation with USDA started a program in mechanization. In 1938, the program was accelerated by a sizeable grant from the U.S. Beet Sugar Association. Work was well underway by the time we became involved in the war. In 1942, the sugar beet acreage in California dropped from 170,000 to 70,000 acres. Growers, in anticipation of a shortage of labor, simply did not contract for their full acreage. At this rate of decline, one more year like 1942 would have resulted in no beet sugar being produced in the State. Growers accepted processed seed that approached single germ units and the crude commercial harvester available by 1943 and the processors accepted the poorly topped beets. The result was the harvest was fully mechanized by the end of the war and a multimillion dollar industry was maintained within the State.

During the war, labor shortages showed up in many areas. Mechanical bale and sack loaders were developed. The high cost of sacks and the subsequent handling of sacked grain was an important factor in forcing bulk handling of grain. The introduction of direct combining and artificial drying of rice just prior to the war enabled this industry to triple the acreage during the years of the conflict without a marked increase in labor. By then this industry was producing rice with an input of approximately 7-1/2 man-hours per acre as compared to around 900 in the Orient.

The first attempts to shake prune and walnut trees mechanically took place when so many of our able-bodied men were in the armed forces or engaged in war industries. Out of this experience came rigid-boom, inertia-type tree-shakers and self-propelled catching frames. Three men working with the above-mentioned equipment can harvest 50 to 60 prune trees per hour. Recent modifications in this type of equipment are being used this year in the peach harvest.

Two crops where prototype harvesting machines have been developed but not put into use are asparagus and lettuce. So far, growers have been successful in recruiting sufficient labor. Little interest is generated in mechanization when labor is plentiful and the price of the product is good. Should conditions change, interest in mechanization would be generated overnight. Incidentally, the latest sensing element development for determining the density of lettuce heads is by gamma ray bombardment. This method will also give a measurement of the diameter of the head.

In closing, I would like to remind you that the adoption of mechanization is closely associated with economics, and the availability of labor. The main thing is for the subject matter divisions to have new developments ready for the extension staff to to carry to the field when conditions are right for acceptance.

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MECHANIZATION OF FRUIT HARVEST IN THE EASTERN UNITED STATES

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No one knows when mechanization of fruit harvest began in the United States. It is documented, however, that machine patents were approved for a fruit gatherer in 1899 (9), a mechanical tree shaker in 1927 (1) and a collecting unit similar to today's models in 1931 (24).

Regardless of when serious research and development of mechanical harvesting of fruits commenced, few would question that more progress has been made during the past decade than in all previous history. Innumerable agricultural engineers, horticulturists, food scientists, farmers, equipment manufacturers, and economists have contributed to the wealth of information and know-how which has made mechanical harvesting a practical reality for several fruit crops.

The acceleration of research and development activities has resulted from many factors, but primarily from (1) the increasing costs and (2) the decreasing availability of harvest labor. These factors are well documented, and merit no further discussion here.

Time and space will not permit complete credit to all who have contributed to progress in mechanical harvesting. Any such oversights are unintentional. This presentation will review some of the past and present programs of mechanized fruit harvest in the eastern United States, and will consider some of the present problems and future needs for effective harvest mechanization.

As indicated by Claypool (6), the practical feasibility of mechanical harvesting revolves around (1) plant health and longevity,

(2) yield of salable fruit, (3) fruit condition after harvest, and (4) economic considerations. These inter-related factors should be of primary concern to horticulturists regardless of their specific activity in mechanical harvesting. But, because of individual crop variations in culture, fruit characteristics, and fruit utilization it seems expedient to consider progress in mechanical harvesting crop by crop.

In the eastern United States the deciduous fruits which have received the most attention in regard to mechanical harvest are sour cherry, sweet cherry, apple, grape, blueberry, and strawberry.

Sour (Tart) Cherries

Mechanizing the harvest of sour cherries has been particularly important because of the large number of pickers required (50,000 in Michigan alone) and the high relative cost of harvesting (3 cents per pound) compared to the fruit value (often only 5 cents per pound).

In several respects this crop is ideally suited for harvest mechanization, including: (1) a single variety, Montmorency, (2) almost 100% processed, (3) easy to bulk handle in water, and (4) the fruits can be moved fairly rapidly from orchards to the processing line. Sour cherries, however, are subject to easy bruising, rapid oxidation and scald, which cause color and firmness to deteriorate.

Early mechanical harvesting studies in Michigan (18) and New York (19) demonstrated that sour cherries could be removed effectively by tree shaking, and subsequently handled in various types of collecting units without undue injury.

During the years 1956–1960 considerable progress was made in the development of equipment and procedures for mechanical harvesting and handling of this crop (18, 19). By 1960 a dozen or more growers in Michigan, New York and other states harvested up to 100 tons of fruit using various types of machines. By 1967, between 40 and 50% of the sour cherry crop in the eastern United States was harvested mechanically (10, 20).

Harvesting machinery has evolved from tractor-mounted boom shakers, hand-carried collecting frames and lug-box containers to highly automated self-propelled units with power steering, 4-wheel drive, various tilt adjustments for uneven ground or different-sized trees, and lights for night harvesting. The frames are usually saran covered, and the conveyor systems have been greatly improved to reduce fruit bruising. The inertia-type branch shaker, mounted on frames, is used by most growers.

As equipment improved, it became obvious that considerable improvement was needed in orchards and fruit-handling methods. Most of the established trees were not suited for mechanical harvesting. Too many trees had low branches which slowed the movement of the catching units. Excessive scaffold branches impeded the entry of shakers into the trees and added needlessly to the shaking time. And poorly positioned branches were often injured by improper shaker attachments.

In New York (5) it was found that trees pruned for mechanical harvesting (3 to 4 major scaffolds, open enough for easy shaker attachment and low hanging branches removed) were harvested in 40% of the time required to mechanically harvest unpruned trees. Branch injury from the shaker was about twice as severe on unpruned as on pruned trees. Yields of the pruned trees dropped about 30% the first years after pruning, but were expected to return to normal in about 3 years. Similar results were observed in a 5-year study in Michigan (17).

Bruising has always been a problem in cherry harvesting, whether the cherries were harvested by hand or machine. Unless cooled quickly to 60°F or below, a bruised cherry will scald. This involves movement of the red pigment of the skin from the bruised area, and makes a bright red cherry into a brown, soft cherry. During early experiments with mechanical harvesting, excessive bruising resulted in lower pack-out yields compared to those of hand-picked fruits (2). Also, excessive bruising took place in some commercial orchard operations and at processing plants (34). Rehandling by the grower and processor results in extra bruising with continued loss of fruit color and quality (14, 15).

At present the most suitable method of handling is to convey the cherries directly from the catching unit into a cold water tank (water temp. approx. 50°F). The temperature of the water is not allowed to rise above 60°F. The tank is filled quickly, and then transported to a cooling area near the orchard where cold water is recirculated for approximately 6 hours to firm the fruits. The fruits are then hauled in the same orchard tanks to the processor where they are pitted and processed without further soak time. Many growers and processors are adopting this system.

A number of other programs have promise for further improvements in mechanical harvesting of sour cherries. These include (a) pre-harvest spray cooling (8); (b) volume measurement to eliminate scale weighing and double handling (30); and (c) use of abscission chemicals to reduce attached stems on harvested fruits (3).

Sweet Cherries

Most of the sweet cherries in the eastern United States are picked for brining before the fruits are fully mature. Preliminary mechanical harvesting studies in 1956 were not encouraging due to poor abscission of these immature fruits (10). Recent studies, however, have demonstrated that sweet cherries can be successfully harvested by machine if they are allowed to become more mature on the tree. and then brined immediately to prevent bruise discoloration (10, 31).

In 1967 approximately 1,000 tons of sweet cherries were harvested mechanically in Michigan (10), but grower experience and controlled studies (31) showed that serious problems still existed with (1) poor tree shape, size and structure (2) inadequate fruit abscission and excessive amount of fruits harvested with attached stems, (3) excessive bruising of mature, mechanically-harvested fruits, and (4) logistical problems of brine handling in the orchard.

Studies in 1968 indicated that large, willowy sweet cherry trees could be pruned like sour cherry trees to facilitate mechanical harvesting without seriously reducing yields. Also, an abscission chemical, 2-chloroethanephosphonic acid (Ethrel), used effectively on sour cherries in 1967 showed considerable promise (4).

Apples

Progress has been made in the mechanical harvesting of apples for processing by mass-removal, shake and catch systems (10, 13, 20). In 1960 the mechanized equipment developed at Cornell University for harvesting cherries was satisfactory for harvesting Rome Beauty apples (13). In 1961 improvements were made by increasing the size of the catching frame and conveyor, and including a double layer of baffle strips. A number of apple varieties were harvested with varied results. Trim loss of the harvested fruit due to bruising ranged from 0.7% by weight for the Monroe variety to 3.2% for Northern Spy. Baldwin, Cortland, and R. I. Greening were intermediate. There were harvesting problems due to large dense trees and low hanging branches. Similar results followed in subsequent years (10, 16, 26).

The basic Cornell machine was modified, and is in commercial production (Perry Harvester Co., Gasport, N. Y.). Tree and machine improvements have continued each year, and the volume of processing apples mechanically harvested has continued to increase in several states. In 1967 over 100,000 bushels were harvested mechanically in the 4 states of New York, Pennsylvania, Virginia and Michigan (10, 20). Other types of lower-cost catching equipment and harvesting units have been developed in Michigan (10).

The shake and catch systems have not generally been satisfactory for fresh-market apples. In Virginia, 1967 studies showed that losses in value of mechanically harvested Golden Delicious would range from $1.47 per 100 pounds for small trees to $2.44 per 100 pounds for large trees (26).

Attempts have been made to reduce fruit-bruising through machine innovations for harvesting large trees, such as a Plateau Harvester developed at Pennsylvania State University. Also, Cornell researchers built padded tine panels which were thrust into the tree, hopefully to slow down the fall of the fruits, and thus reduce bruising (20). The results did not indicate any clear-cut reduction in bruising. Mass-removal systems for fresh-market fruits will probably be restricted to small trees, or to trees which have been heavily pruned, so that a fruit will fall only a short distance and not strike any branches or other fruits during its descent.

Mechanical man-positioners and self-propelled platforms to improve harvesting efficiency have been developed and evaluated in Pennsylvania (21) and Massachusetts (33). These and other types of mechanical aids vary in their economic efficiency depending on size and type of tree, uniformity and size of crop, variety, and picker experience. It appears, however, that vertical-type hedgerows that can be "assembly-lined" picked, offer the best possibilities for effective use of mechanical aids. Dwarf or semi-dwarf trees planted close enough in the row to build a complete fruiting wall have great promise. Many changes are needed in tree-training and cultural management. An extensive tree-wall training study is being developed at Pennsylvania State University (32).

Grapes

Research on pruning, training and trellising for mechanical harvesting of grapes has been conducted in New York for over 10 years (27). This work produced the Geneva Double Curtain (GDC) system of training, a bilateral cordon well-suited for increased production of vigorous vines and mechanical shaking (28, 29). The New York Agricultural Experiment Station developed a straddle row harvester which harvests both curtains as it travels the row, harvesting at the rate of about 1 acre per hour. Most of the fruits are shaken off as individual berries or cluster fragments. The N. Y. Double Curtain Harvester is presently being manufactured commercially

(Chrisholm-Ryder Co., Niagara Falls, N. Y.).

Due to the high cost of trellis conversion to the GDC system (12, 29) and to the lack of sufficient vine vigor in many vineyards to warrant conversion, several machines have been developed to harvest single-curtain or verical trellises (12, 23).

Blueberries (High-bush cultivated)

Blueberry harvesting trials initiated in 1957 established the feasibility of the "shake and catch" method for harvesting this crop (10). Hand-held vibrators and single-bush, hand-moved collecter units soon came into widespread use. In 1959 the prototype of a straddle-row, continous harvester was made and tested. Commercial machines with a capacity of 2000 to 3000 pounds per hour became available in 1966 (10).

The harvesting machines have essentially eliminated the labor problems in harvesting cultivated blueberries and have greatly reduced harvest costs. However, considerable cane damage occurs. To eliminate cane damage a change in cultural practices particularly pruning, is necessary. Also, mechanically harvested berries require additional cleaning and hand grading.

Strawberries

Prototype strawberry harvesters have been developed in Iowa (7), Illinois (11), Arkansas (22), and Louisiana (25). All of the machines employ a one-harvest, continous stripping or scooping action which removes both mature and immature fruits.

Results are promising for commercial mechanical harvesting, even though yields are reduced by approximately 40%; one-third to nearly one-half of the machine-harvested fruits must be processed immediately (7, 22). E. L. Denisen of Iowa State University suggests that the major horticultural improvements needed for mechanical harvesting of strawberries are:

1. Close plant spacing (crowded, matted rows), level beds, elimination of weeds and debris, and mowing of top leaves prior to harvest.
2. Improved, productive varieties with concentrated ripening, brittle peduncle, resiliant fruit, resistant to bruising. Surecrop, Sparkle, Blakemore, Redglow and several Iowa State University selections appear best at present.

In conclusion, these are but a few highlights of mechanical harvesting advances in six fruit crops in the eastern United States. Progress has also been made with cling peaches, plums, raspberries, blackberries and wild blueberries. Innumerable problems remain to be solved before fresh-market fruits pass from the tree to the market tray without feeling the touch of human hands.

Immediate improvements are urgently needed in varieities and culture for uniform ripening, heavy and consistent cropping over an entire orchard or plantation, and maintenance or improvement of fruit quality. Also, if the long-range, complex problems of mechanical harvesting of horticultural crops are to be solved, research must be focused upon finding new information about flowering and fruiting, fruit development, and maturation, abscission, growth regulation, environmental stress, and numerous other factors.

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