FRUIT, NUT, AND VEGETABLE HARVESTING MECHANIZATION

Proceedings of the
International Symposium on
Fruit, Nut, and Vegetable
Harvesting Mechanization

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PREFACE

Modern agriculture, with its diminishing labor supply, makes it imperative to mechanize the harvesting of fruits, nuts and vegetables.

However, although much research has been carried out in various parts of the world, most fruits and vegetables are still being picked by hand. Nevertheless, we should not view this state as a threat, but rather as a challenge that can lead us to better methods, less investment in manpower and to the same - if not superior - quality of the produce.

The idea of an International Symposium on Fruit, Nut and Vegetable Harvesting Mechanization was initiated by the Institute of Agricultural Engineering (ARO), Bet Dagan, Israel, as a result of numerous discussions with colleagues in the U.S.A. and Europe, all realizing the benefit of technical interaction and international cooperation.

Several groups were instrumental in making the Symposium a reality, among them A.S.A.E., C.I.G.R. and I.A.A.E.

Eighty people from 19 countries participated in the Symposium, presenting more than 60 invited papers covering most of the current research on fruit and vegetable harvesting.

No attempt is made to give the impression that the Symposium - successful and rewarding as it was - provided the answers to all the problems. Nevertheless, the small contribution that was made may lead to more in the future until the final frontier will ultimately be crossed.

More challenges still await us.

Bet Dagan, Israel,
November 1983.

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FRUIT MECHANIZATION IN THE USA -- CURRENT AND FUTURE

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Fruit harvesting mechanization has been in a gradual process of adoption in the USA for at least 4 decades. Mechanization interest and attempts were initially stimulated by agricultural labor shortages during World War II and were renewed by similar shortages during the Korean Conflict. The termination of the Bracero Program (U.S. Dept. Agr. 1965) in December of 1964, a program for admitting thousands of Mexican workers into the Country to perform agricultural work, established a clear need to have alternative food harvesting methods available that were labor and cost efficient. Obtaining enough hand labor for harvesting had always been a problem.

The history of developments in fruit harvest mechanization can in large part be traced by reviewing research papers listed in bibliographies periodically prepared by the Fruit and Vegetable Harvesting Committee, PM-48, of ASAE (Tennes et al. 1971, Booster et al. 1977), buyers' guides provided by magazines serving the fruit industry (eg., Amer. Frt. Grow. 1983), and selected comprehensive technical publications (Cargill and Rossmiller 1969). The status of harvest mechanization for fruit, nut, and vegetable crops has recently been described (Zahara and Johnson 1979, Brown et al. 1983). The principles and practices for harvesting and handling fruits and nuts in the USA have also recently been summarized in detail (O'Brien et al. 1983). The above publications should be consulted for complete details on fruit harvest mechanization. This paper will briefly overview the subject.

Two types of approaches to harvesting mechanization have been used: (1) the development of labor aids to mechanically assist hand harvesting, and (2) the development of mechanical harvesters to perform the harvesting function. Successful development and application projects have often involved growers, manufacturers, engineers, plant scientists, food scientists and economists, working in a cooperative effort to perfect the final system.

CURRENT EXTENT OF MECHANIZATION

Today, there are over 40 major and minor fruit crops grown on 1.5 million ha in the USA (U.S. Bur. Cen. 1979). About 66 percent of the production is used for processing. About 11 percent of the total ha are mechanically harvested, so the fruit industry is not highly mechanized (Brown et al. 1983). Nearly all of the mechanically harvested fruit is processed.

Table 1 lists the major and minor fruit crops grown commercially and groups them according to the percent of hectarage which is mechanically harvested. In the highly mechanized group, cranberries are the only crop that is nearly 100 percent mechanically harvested. The others range from 50 to 85 percent.

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In the least mechanized group, 28 of the 30 crops have essentially no commercial use of mechanical harvesting, although a few use labor aids. The harvesting of some major crops, such as citrus and pears, is not mechanized, although harvesting research is being conducted.

An average of 500 worker-h/ha would be required to hand pick the 8 highly mechanized crops, compared to an average of 6.5 worker-h/ha required for mechanical harvesting (Brown et al. 1983). Labor productivity, kg/worker-h, affects grower profitability, agricultural worker earnings, and the price consumers must pay. Labor productivity must increase if the grower is to operate profitably and provide both food and employment, if workers are to earn more, and if the consumer is to benefit through a plentiful supply of fruit at reasonable prices. Agricultural labor costs will probably increase rapidly in the future. If a reliable supply of hand workers is not available, economic realities may force the fruit industry into more mechanical harvesting. Competition for fruit and product sales in the world market requires continued USA efforts at production efficiency and cost reduction. These facts suggest that additional mechanical harvesting methods are needed in the future.

Several limitations presently prevent greater use of mechanical harvesting in fruit crops (Brown et al. 1983). Probably the greatest technical limitations are excessive product damage for either processing or fresh market, lack of adequate selectivity for crops that do not mature uniformly, and lack of adequate product recovery for economic feasibility. These and other limitations suggest that new cultural practices should also be evaluated in a systems approach to efficient production.

Growers generally use hand labor as long as it is available when needed, at a reasonable cost. Mechanical harvesting is usually adopted when hand labor is likely to be unavailable or when appreciable savings will result. Mechanization often requires a large capital investment and can reduce the growers' flexibility to change from one crop to another or from one market to another. The adoption of mechanical harvesting technology requires a very specific analysis of economics when an adequate supply of hand labor is available.

Mechanical harvesting equipment for horticultural crops is built primarily by small and "short-line" manufacturers. The annual national production of each harvester type, in most instances, amounts to fewer than 100 units. These manufacturers do not have large R&D budgets and frequently rely on a combination of publicly supported research results, growers' inventiveness, and their own ideas to develop new and improved equipment. The low volume of production implies that many machines are almost custom built. Very few are built under production line conditions. Therefore, these manufacturers attempt to make the machines simple to construct and maintain, thus limiting costs. The small production volume does permit the addition of special features to the machines when necessary.

Bulk handling systems are almost always necessary with mechanical harvesting. Mechanical harvesters deliver several times more crop/min than can be delivered by individual hand pickers. The resulting greater product flow usually cannot be efficiently containerized in the customary manner used for hand picking. The bulk handling system used must be compatible with the quality requirements for a particular crop. The choice of container depth is related to the intended crop utilization, its physical properties, transit time, storage time, and container and handling costs. Research on handling characteristics has formed the basis for an ASAE Standard on agricultural pallet bin sizes (Anonymous 1969). Cross-sectional outside dimensions of 1200 X 1200 mm or 1200 X 1000 mm and overall heights of 720 or 1330 mm are recommended by this Standard.

MECHANICAL HARVESTING APPROACHES

Several methods for mechanically harvesting fruit have been proposed by growers, researchers, inventors, etc. Some examples are combing devices, rollers, augers, pulsating air, water jets, high and low level electrical current, sound waves, mechanical fingers or hands to duplicate the human hand motion, brushes, high-speed shaking (eg. 50 to 170 Hz), vibrating tines, vacuum picking heads, and sensor-controlled cutting devices (Tennes et al. 1971). The only commercially used harvest systems for tree fruit and bush berries involve some method of mechanical shaking to successfully loosen the fruit.

Mechanized tree fruit harvesting for processing (prunes, tart cherries, apricots, ripe olives, peaches, sweet cherries, apples, citrus) is performed with a shaker and catching frame system in most cases. Trunk shakers are generally used for prunes, cherries, apricots, peaches and apples. A recent survey disclosed that shaker manufacturers no longer offer limb shakers for these crops. Limb shakers are generally used for olives and citrus because a high-power long-stroke shake is required. Shaking frequencies of a 2 to 30 Hz and input strokes of 8 to 125 mm, depending on fruit type, are typical for fruit trees (O'Brien et al. 1983, p. 162). Catching frames offered now are generally of the sloping-surface or wrap-around types. Roll-out catching frames are less popular because their harvest rate and worker productivity are low.

Mechanized bush berry and grape harvesting for processing (blackberries, black raspberries, highbush blueberries, wine and juice grapes, and red raspberries) are usually performed with continuously moving over-the-row style harvesters. Most harvesters use vibrating rods to strike the canes and remove the fruit, although special trunk shakers using rails are becoming popular for grapes. A high degree of selective harvesting is possible with some harvesters and species of berries, so a berry patch may be harvested about 3 times instead of only once.

Cranberries are harvested either from a "wet" or "dry" bog, depending on whether the bog is flooded or dry during harvest. The berries can be mechanically combed from the plants in either bog, but damage and losses may be high. A water reel harvester is often used on wet bogs to knock the berries from the plants, allowing them to float and be skimmed from the water surface. Only dry harvested berries supply the fresh market.

Semi-dry and dry dates may be mechanically harvested using a man-positioner to lift the worker to the bunch area of the palm so mature bunches can be cut from the palm. At ground level each bunch is placed in a vertical shaker for a few seconds and the fruit are shaken into a bulk bin.

Figs are allowed to naturally fall to the ground when ripe. The ground is smoothed before the fruit ripen. Fresh figs are picked up by hand, but those for drying and processing are gathered with pickup machines that are driven through the orchard about 3 to 5 times during the 2- to 3- week maturity period.

Strawberries are just coming to the point of having a totally successful system for mechanical harvesting and processing. Using certain varieties and a solid-set flat-bed culture, the entire crop is mowed from the field, loose leaves are blown out in the harvester, and the crop is placed in shallow bulk bins. The bins are transported to a processing plant where special equipment separates the trash and berries, breaks the clusters, decaps each fruit, and color sorts the mature and immature berries. Yields and quality for processing are superior to those for conventional cultural practices and hand harvesting (Hansen et al. 1984).

LABOR AID APPROACHES

Blueberries for fresh market and processing may be harvested with a hand-held vibrator. As the fingers on the vibrator are pressed against each cane, ripe berries are shaken loose and fall into a small catching frame under the bush. The berries must be sorted to remove plant debris as well as undesirable berries. This simple labor aid approach to harvesting can increase the productivity of each picker by up to 10 times.

Pineapple for processing are commercially harvested with conveyor-type labor aids which span at least 10 rows of plants, allowing workers in each row to conveniently deposit harvested fruit on the conveyor instead of inefficiently carrying them from the field.

Papaya, avocados and dates for fresh market and processing are all harvested using a man-positioning machine to lift the worker to the tall tree or palm for harvesting. The machine for papaya is designed and equipped specifically for that crop. Those for dates and avocados are modifications of lift machines designed for similar lift operations in agriculture and industry.

MECHANIZATION OF THE FUTURE

In the next few years the crop area harvested mechanically for processing will probably increase considerably, and the number of fresh-market and minor crops harvested mechanically will increase to some extent. The pace at which these advances will develop is impossible to predict. If appreciable advances are to be made toward mechanizing the harvesting of fresh-market and minor crops, multidiscipline research and development will be needed. The growers and equipment manufacturers involved with most of the fresh-market and minor crops do not appear to possess the financial resources required to conduct such high-risk research.

USA agriculture is rumored to be using thousands of illegal alien workers. If these workers are in fact removed, crop losses and economic realities may force the fruit industry into more mechanical harvesting. A reliable supply of domestic or legal foreign workers, however, may delay increased adoption of mechanical harvesting.

Some mechanical harvesting methods adopted years ago to overcome labor shortages should be improved to meet today's standards for product quality, cost to consumers, workers' wages, and economic return to growers. Public agency research on harvesting methods for a specific crop often stops soon after commercial manufacture of the equipment begins. This practice permits the redirection of research resources to other crops and to unsolved problems, but can also result in an accumulation of new, unresearched problems for crops that are mechanically harvested.

Through ongoing plant science research, many of the horticultural crops are undergoing fundamental changes at the farm level. Harvesting and handling technologies must keep pace with, in fact be ahead of, these changes. The opportunity and need may soon occur to manage the horticultural crop production system so that substantially more volume and numbers of crops may be produced in small geographical regions. Harvesting will need to be confidently scheduled, using a mix or balance of fully employed hand labor together with labor-aids and mechanical harvesting. Whether or not even the harvesting-method/product-quality relationships are well enough understood to successfully manage such a production system are not clear at this time.

Automated fruit and vegetable quality grading technology (for detecting bruise, cut, puncture, scab, hail, etc. defects) is becoming a reality.

Improved decay prevention technology, using better fungicides and environmental control systems, is also available. Application of these technologies may allow new applications for mechanical harvesting.

Within the next 20 years, tree fruit crops that are presently hand picked for both processed and fresh-market utilization may undergo a considerable change, in all production areas, to naturally shaped, size-controlled trees and high-density plantings (Carlson 1979). With the change to high-density plantings the mechanical harvesting systems used must also change -- from stop-and-go to continuously-moving operating at 150 to 300 trees/h. Information on the cultural management of unconventionally shaped fruit trees that are better adapted to efficient hand or mechanical harvesting than are conventionally shaped trees is becoming available (Alper et al. 1980, Chalmers et al. 1979, Hudson 1971, Dunn and Stolp 1976, Norton 1980, Tukey 1978, Van Oosten 1979). These intensive management systems are being developed and adopted in Europe, New Zealand, Australia, Japan and Israel, but wide adoption of these techniques in the US within the next 20 years seems unlikely.

Food availability at reasonable cost is important to all consumers. The 1975 Conference On Research To Meet US And World Food Needs stressed that new varieties, machinery, and methods for mechanized production are among the most important research needs. The US is not alone in efforts to mechanize the labor-intensive tasks in agriculture (Brown 1982). The international population growth and the competition in food production and marketing will necessitate continued efforts at improving production efficiencies, working conditions, and income of agricultural workers.

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