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Harvest Mechanization for Deciduous Tree Fruits and Brambles

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Summary. **Hand-harvesting fruit crops is labor-intensive, and the supply of dependable, skilled labor is a concern of the fruit industry. Only a small portion of all fruit crops is harvested mechanically, primarily for processing. Public funding of mechanical harvesting research on fruit crops has reached a low level. However, there is renewed interest in mechanical harvesting research due to the potential scarcity of hand-harvest labor and new federal laws that may deplete further the labor pool. Much of the research expert-ise in mechanical harvesting of fruit crops has been lost, since most projects have been discontinued. Considerable lead time will be required to develop facilities, personnel, and projects if the decision is made to initiate publicly funded harvest mechanization research. More time will be required before commercially acceptable techniques and methods will be available. A majority of the research described in this paper was conducted outside the United States. The United States will not remain competitive in the world market for fruit crops with the present lack of mechanical harvesting research.**

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Fruit crops are an important component of the diets of consumers in the United States and other developed countries. Fruits in the diets of third-world countries will become more important as those countries' standard of living is raised. In all countries, as the standard of living increases, the demand for fresh fruits also increases. Fruit production is a costly and labor-intensive operation. Harvest labor alone can account for up to 50% of the labor required for fruit production (Brown et al., 1983b).

The availability and quality of a sufficient labor force to hand-harvest fruit crops has been a concern of growers for most of this century (Torres, 1988). As early as 1917, the U.S. Congress enacted "Guest Worker Programs" to permit farm laborers to be brought into the United States for temporary migrant work. In 1942, a "Bracero Program" was enacted by Congress to relieve labor shortages, and it operated formally and informally until Dec. 1964. Since that time, many foreign workers (mainly from Mexico) have continued to harvest fruit crops (Martin and Mines, 1983). Often the harvest labor force has consisted of >50% undocumented workers (Martin, 1985; Mines and Martin, 1983). Large numbers of undocumented workers in the United States have presented a major problem for the Immigration and Naturalization Service (INS). In 1983, 4 to 6 million foreign workers were reported to be living and working illegally in the United States, and the INS apprehended almost 1 million undocumented workers.

To solve the problems of illegal migration into the United States, Congress, in 1986, passed the Immigration Reform and Control Act (IRCA), which authorizes severe fines and potential jail terms for growers and other employers who knowingly hire undocumented workers. Reducing the number of undocumented workers in the United States was expected to decrease the labor supply for harvesting perishable fruit crops. However, Mines (1991) reported that there has been an adequate labor supply since the passage of IRCA. He indicated one of the reasons for the adequate supply of labor is continued migration from Mexico. These undocumented workers are circumventing the employer sanction of IRCA with fraudulent documentation. The 1990 National Agricultural Workers Survey (NAWS) (Mines et al., 1990) found that 25% of agricultural workers in the southeastern United States performing seasonal agricultural service (SAS) were unauthorized. The rest of the country averaged ≈10% unauthorized workers. NAWS also found that although 74% of SAS workers were willing to do more SAS work, only 41% were willing to migrate in search of additional work. One-half of all perishable-crop farm workers are migrants. NAWS also found that nearly half of all SAS workers earn income below the poverty level and work less than half the year. Even though, in general, there appears to be an adequate work force to perform SAS work in the United States, the above facts indicate instability and that labor shortages could occur in areas where perishable crops have to be harvested. Friedland et al. (1979) stated that uncertainty of labor supply is one of the greatest stimuli to increased mechanization. This prospect suggests that renewed interest in research on mechanical harvesting is warranted.

A CAST report (1983) on agricultural mechanization concluded that, in the long run, consumers are the principal beneficiaries of adoption of new agricultural technologies through increased product supply and lower or more stabilized prices. Other mechanization benefits cited were:

- Greater reliability in crop production
- Reduced human physical effort and drudgery
- Increased personal and family income
- Decreased labor–management problems and risks
- Applicability to large and small operations

- Performance of tasks in a more timely manner
- Increase in manufacturing jobs

CAST also concluded that future mechanization of labor-intensive crops, such as fruits and vegetables, could be expected to produce only local and regional labor effects.

The remainder of this paper will discuss for deciduous tree fruits and brambles: 1) The labor situation for hand-harvesting; 2) current status of commercial mechanical harvesting and potential, and 3) recent and current research progress on mechanical harvesting.

Deciduous tree fruits

Labor situation. Hand-harvest labor for deciduous tree fruits comes from a number of sources as typified by the apple industry. In 1987, >42,000 workers were employed to harvest the apple crop in Washington (Stover, 1988). Forty percent of the workers were permanent local residents, and another 15% were state residents beyond daily commuting distances. Thirty-four percent were from other states in the United States, and 11% were foreign workers. In 1990, the Wage and Employment Survey, conducted by the U.S. Dept. of Labor (information gathered from ETA forms 223 and 232 required under federal law for state agencies engaged in recruitment of agricultural workers), showed similar employment patterns for the state of Washington; however, no foreign workers were employed.

Information from similar surveys conducted in 1990 in the northeastern apple-producing area (Pennsylvania, Virginia, West Virginia, and Maryland) showed a very sporadic pattern for the harvest labor source. In the northeast, harvest labor source was 0% to 100% local, 0% to 100% migrant, or 0% to 100% foreign workers, depending on location or state. The uncertainty of a stable available harvest labor supply can be a major frustration for orchardists. During the 1990 West Virginia Horticultural Society Meeting, C. Peters, orchardist and 1990 president of the Washington State Horticultural Assn., and S. Blizzard, Texas orchardist, stated that, during the 1990s, labor supply would be a significant problem for fruit growers. At a 1990 project review at the Appalachian Fruit Research Station, Kearneysville, W.Va., D. Derr, president of the International Apple Institute, emphasized the need for mechanical harvesting techniques to meet the industry's future labor shortages.

At the same review, R. Slonaker, orchardist and 1990 president of the West Virginia Horticultural Society, stated that fruit growers are too dependent on an unreliable supply of hand labor. He emphasized the need for tree designs for mechanical harvesting, and improved methods and equipment for mechanical harvesting. In addition to insufficient harvest labor during the short harvest season, growers face other risks while using hand harvesting, such as strikes by harvest workers, unionization, inadequate supervision, inadequate worker housing, and court settlements brought against the grower by the worker or fines for not meeting legal requirements relative to hired harvest workers (Ricks and O'Brien,1983).

Commercial mechanical harvesting status. With the end of the Bracero Program, two fruit crops that have very high hand-labor requirements, tart cherries and prunes, went from <10% mechanical harvesting to >80% mechanical harvesting in 6 to 8 years (Brown et al., 1983a). Without mechanization or an adequate harvest labor supply, the survival of those industries may have been questionable. Harvest costs might have risen to a point where hand harvesting was no longer economically feasible. Mechanical harvesting was at least 10 times more labor-efficient than hand harvesting.

Brown (1985) and Brown et al. (1983b) summarized the status of commercial mechanical harvesting of horticultural crops. The status has not changed significantly in the interim years. Less than 5% of the apple crop is harvested mechanically, and all of that is for processing. Excessive damage inflicted by commercial shake–catch harvesters prevents wider acceptance for the processing industry and does not meet the higher standards of quality required by the fresh-market industry.

A small percentage of cling peaches for processing in California is harvested mechanically with shake–catch systems, but lack of uniform maturity is a major drawback to increased adoption of mechanized harvest for processing and fresh market. Damage inflicted during machine-harvesting is not a major deterrent to mechanical harvesting of fresh-market quality peaches, since damage levels are comparable to those for hand-harvesting. Plums for the fresh market are hand harvested selectively as they ripen and are not likely to be mechanically harvested commercially in

Table 1. ***Engineers conducting deciduous tree fruit harvest mechanization researach in the United States.***[z]

Project location	Crop	No. research engineers[y] 1971	1981	1991
State				
Davis, Calif.	Peach, prunes	3	2	1
Athens, Ga.	Peach	1	---	---
Ithaca, N.Y.	Apple	2	1	---
Corvallis, Ore.	Apple, cherry	1	2	---
Amherst, Mass.	Apple	1	---	---
E. Lansing, Mich.	Apple, cherry	1	1	1
State College, Pa.	Apple	1	---	---
Clemson, S.C.	Peach	2	2	---
College Station, Texas	Peach	2	---	---
Morgantown, W.Va.	Apple, peach	1	1	---
Madison, Wis.	Cherry	1	---	---
Total		16	9	1
USDA, ARS				
Davis, Calif.	Peach, prune	1	---	---
Byron, Ga.	Peach	2	---	---
E. Lansing, Mich.	Apple, cherry	2	2	---
Kearneysville, W.Va.	Apple, peach	---	1	1
Wenatchee, Wash.	Apple	2	1	---
Totals		7	4	1

[z]*Data compiled from author's experience and survey of past fruit mechanization researchers.*
[y]*May not be full time SYs in fruit harvest mechanization.*

the near future. Sweet cherries destined for the fresh market suffer excessive damage when harvested with present commercial shake–catch systems, preventing acceptance at this time. Both fresh-market and processed pears are picked almost exclusively by hand, since damage levels are excessive when commercial shake–catch harvesting equipment is used. Depending on the crop, labor productivity can be improved by a factor of 5 to 15 by using mechanical harvesting.

Research effort. Public support for research on mechanized harvest of deciduous tree fruits peaked in the 1960s and '70s and then declined (Table 1). Some of that decline can be attributed to acceptance of commercial mechanical harvesting for prunes and tart cherries. Publicly funded research into mechanical harvesting of these two crops (Adrian and Fridley, 1969; Levin et al., 1969) greatly assisted in their successful commercialization.

A significant factor in the decline in publicly funded research in mechanization is the strong antimechanization movement given encouragement by a lawsuit against the Univ. of California for using public funds to support mechanization research (The Grower, 1979) and from political policy during President Jimmy Carter's administration. When asked to to comment on the California lawsuit, then Secretary of Agriculture R. Bergland responded by saying, "I will not put federal money into any project that results in savings on farm labor" (Best, 1980). Secretary Bergland later clarified his comments by stating that research on mechanization may be appropriate if it eases the drudgery of work, or when an adequate and willing work force is not available (Bergland, 1980). The debate on what constitutes an adequate and willing work force is ongoing. In the 10 years following Bergland's statements, the USDA's Agricultural Research Service discontinued 75% of its research effort on mechanical harvesting of deciduous tree fruits (Table 1), their citrus harvesting project [2 significant years (SYs)], and their only vegetable mechanization project (2 SYs).

Despite substantial past efforts on mechanical harvest of tree fruits, damage inflicted on the fruit during the harvesting process is still a major obstacle to commercial adoption. Recent research and present efforts place emphasis on adapting the tree design and machine component design to be compatible. The majority of this work is outside the United States.

Peterson (1985) summarized cultural modifications necessary for mechanical harvesting of tree fruits. The Tatura Trellis training system combined a narrow fruiting canopy (Chalmers et al., 1978) with a mating incline catching surface and customized detachment principles (Gould et al., 1986) in an attempt to minimize damage during peach harvest. Damage levels were very low, but still had the problem of nonuniform maturity. Colorio (1987) used a "multiple basket" position under a "V" trellis with a series of above-limb impacters to harvest apples. Initial results look promising in reducing bruise damage.

The Lincoln Canopy System (Dunn and Stolp, 1980) used a "T"-shaped trellis for apples to present a single horizontal tier for mechanical harvesting. Dunn and Stolp (1980) and Domigan et al. (1988) used an under-limb impacter and catching surface positioned under the trellis to effect mechanical harvesting. Land (1989) used a rotating drum shaker to remove apples from the Lincoln Canopy. Peterson and Miller (1988) used their over-the-row continuously moving shake–catch harvester with specialized catching surfaces and trunk impacter to remove fruit from the Lincoln Canopy. A rod press harvester (Peterson and Miller, 1988) was designed to push fruit off the Lincoln Canopy, and I.R. Domigan (personal communication) is studying an above-canopy limb shaker to effect fruit removal. All types of harvesting systems have potential but have not reached the commercialization stage.

Bennedsen (1986) described a series of foam Xs and Ls that have special pivoting components to enable them to decelerate and transfer fruit. These systems were effective in reducing damage to free-falling apples, but required specialized construction techniques and have not been commercialized. Peterson (1991) developed a specialized catching surface using counter-rotating foam cylinders to decelerate and then transfer free-falling fruit to a conveying system. This catching surface is being evaluated on his experimental over-the-row continuously moving shake–catch harvester. Grand d'esnon et al. (1987) have developed a self-propelled robot harvester to pick apples. The unit is functional, but field losses are high and development is continuing.

Brambles

Labor situation. Barton (1991) indicated that labor to harvest fresh market- quality brambles, a very labor-intensive operation, is becoming more difficult for growers to obtain. Hand-picking brambles requires 600 to 1000 $h \cdot ha^{-1}$. Brambles need to be picked three to four times per week for 3 to 8 weeks, depending on cultivar. The fruit is small and delicate, and often the bramble plant is thorny. Availability of hand-harvest labor for brambles is probably more uncertain than it is for tree fruits.

Commercial mechanical harvesting status. Reviews by Booster (1983), Brown et al. (1983b), and Martin (1985) concluded that mechanical harvesting of certain cultivars of raspberries and blackberries was a commercial reality in many parts of the United States. Labor productivity improved by a factor of 12 to 20 with mechanical harvesting. Nearly all the mechanical harvesting is for the processing industry.

Selective mechanical harvesting of brambles is possible since the detachment force decreases as the fruits mature. Commercial mechanical bramble harvesters employ two types of shaking mechanisms. The first consists of one or more pairs of oscillating horizontal or nearly horizontal beater bars (Littau Harvester, Stayton, Ore.; Korvan Industries, Lynden, Wash.; BEI, South Haven, Mich.). The second principle uses a vertically oriented spiked-drum shaker that is oscillated in a horizontal plane relative to the rotation of the drum. The spiked-drum shaker is activated by either an inertia drive (Weygandt, Canby, Ore.) or an eccentric cam mechanism (BEI).

Research effort. The shortage of harvest labor has prompted equipment manufacturers to look more closely at their harvesters to minimize damage for the more stringent fresh-market quality requirements, and may stimulate public funding for renewed bramble harvest mechanization research. Peterson et al. (1989) are developing a mechanical harvester for Eastern thornless blackberries. A unique shaking mechanism that provides uniform acceleration and displacement within the fruiting canopy shows promise for reducing berry damage. Similar shaker designs, emphasis on improved catching surfaces and conveying systems, and innovative trellis training systems may make mechanical harvest of delicate brambles for fresh-market quality feasible.

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