

Mechanized Harvest of Southern Highbush Blueberries for the Fresh Market: An Introduction and Overview of the Workshop Proceedings

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The development of mechanical devices to assist in harvesting cultivated blueberries (*Vaccinium* species and hybrids) began in the late 1950s. In 1958, U.S. Department of Agriculture engineers located at Michigan State University developed handheld shakers that were used with fabric-lined catch frames as aids for harvesting processed blueberries (Hedden et al., 1959; Monroe and Levin, 1966). These devices substantially increased worker productivity and reduced harvest costs by ≈55% (Monroe and Levin, 1966). By 1963, 35% of the Michigan crop and 20% of the New Jersey crop were harvested in this fashion. Later Monroe and Levin (1966) described their early attempts to develop a continuous over-the-row blueberry harvester, which required a driver and two additional workers. Testing of over-the-row harvesters began in the late 1950s and by 1966 over-the-row harvesters were available commercially in the United States. Eck (1988) reported that over 100 such machines were in use in the United States by 1971. One of the earliest commercial models, the Harvey Harvester, was featured in an article entitled “Fantastic New Farm Machines” in *Popular Mechanics* in 1970 (Lamm, 1970). Over time, various harvesters were developed that used different methods to remove ripe berries from canes and they were

generally classified as slappers, sway shakers, and rotary shakers (Brown et al., 1996; Mainland, 1993). In their review, Dale et al. (1994) provide a detailed account of blueberry harvester designs up through the early 1990s.

Over-the-row harvesters were reported to increase worker productivity by almost 60 times and reduce the cost of harvesting by up to 85% (Brown et al., 1996). However, numerous problems were soon identified with harvesting blueberries mechanically. The primary ones were 1) ground loss of otherwise marketable fruit, 2) detachment of immature berries, 3) reduced berry firmness and quality, and 4) increased postharvest decay and reduced storage life. Machine harvest necessitates increased handling of fruit during grading and sorting, and on blueberries most postharvest decay occurs at the detachment point—the newly exposed stem scar (Ballinger et al., 1978). When both fungal spores and moisture are present on packing lines, this extra handling can greatly increase postharvest decay caused by fungi (*Alternaria*, *Colletotrichum*) due to the exposure (rolling) of berries over contaminated surfaces (Cline, 1996).

In the first comprehensive report directly comparing the effects of machine and hand harvesting on highbush blueberry (*V. corymbosum*), Mainland et al. (1975) found that losses of marketable fruit of ‘Wolcott’, ‘Jersey’, ‘Morrow’, and ‘Murphy’ were from 19% to 44% greater for machine harvesting than for hand harvesting.

Machine-harvested fruit were 10% to 38% softer than hand-harvested fruit, and soft berries were difficult to identify and remove during grading. Moreover, after 7 d of storage at 21 °C, there was 11% to 41% more postharvest decay for the machine-harvested fruit. They concluded that the inability to remove bruised fruit during grading and sorting presented serious problems for maintaining quality during storage. Similar reductions in marketable yield from mechanical harvesting were reported in Michigan by Howell et al. (1976). In general, increased berry softening and decay during storage have been widely reported in association with mechanical blueberry harvesting (Ceponis and Cappellini, 1979; Dale et al., 1994; Howell et al., 1976; Mainland et al., 1971, 1975; Millholland and Jones, 1972). Ballinger et al. (1973) studied factors affecting blueberry firmness and emphasized the importance of careful harvesting and handling procedures, noting that blueberries are easily bruised, leading to softening and subsequent decay during storage. In a review of the literature, Morris (1983) stated that “decay of machine-harvested blueberries during postharvest holding is perhaps the biggest problem of the industry.”

Reductions in berry firmness and marketable yield were also found for machine-harvested rabbiteye blueberry (*V. virgatum*). Using the rabbiteye blueberry cultivar Tifblue, Austin and Williamson (1977) reported increased ground loss of marketable fruit, reduced fruit firmness, and more than twice the amount of unmarketable fruit from machine harvesting vs. hand harvesting. Increased berry softening following machine harvesting was also noted for ‘Climax’ and ‘Woodard’ (Miller and Smittle, 1987) and ‘Brightwell’ (NeSmith et al., 2002), although depending on cultivar, the softer machine-harvested fruit may still be considered marketable as fresh fruit. NeSmith et al. (2002) proportionally attributed the causes of ‘Brightwell’ rabbiteye berry softening to the following harvest activities: 20% to 30% loss of firmness due to

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
$(^{\circ}\text{F} - 32) \div 1.8$	$^{\circ}\text{F}$	$^{\circ}\text{C}$	$(^{\circ}\text{C} \times 1.8) + 32$

mechanical harvesting; 10% to 15% loss of firmness due to grading and sorting; and 4% to 8% loss of firmness due to storing fruit at ambient temperature for 24 h after harvest compared with cooling fruit immediately.

Three postharvest innovations have greatly increased the feasibility of machine-for-fresh blueberry harvesting: the development of color sorters to remove underripe fruit, the development of soft berry sorters to remove damaged and overripe fruit, and the use of postharvest forced-air cooling to rapidly stabilize and dry fruit immediately after harvest. Early work on sorting by ripeness included both light transmittance and optical sorting, and these methods form the basis of current color sorting technology (Ballinger and Kushman, 1971; McClure and Rohrbach, 1971). Soon afterward, advances in mechanized soft berry sorting were reported by Hamann et al. (1973) and Bower and Rohrbach (1976). Color and soft berry sorters are now commonly used in blueberry packing lines. Forced-air cooling procedures developed for fresh blueberries are also standard throughout the blueberry industry (Boyette et al., 1993).

Mechanical harvesters have been reported to cause damage to blueberry plants (Mainland et al., 1975; Howell et al., 1975). Skinned areas and broken canes caused by harvesters may serve as entry points for disease organisms such as *Botryosphaeria* sp. (Mainland et al., 1975). Howell et al. (1975), working with 'Jersey' highbush blueberry, attributed cane loss from winter injury to wounds from mechanical harvesters. They found that the amount of wood lost was proportional to the vibration rates of the harvester. At high rates, loss of fruiting wood was sufficient to reduce production the following year. Mainland (1993) emphasized the importance of hand pruning to narrow the plant base and remove old canes with many branch shoots if plants are to be harvested mechanically. Strik and Buller (2002) reported a reduction for ground loss during mechanical harvesting by using a two-wire trellis system on 'Bluecrop' highbush blueberry in Oregon.

Experimental harvesters have been developed to address the problems associated with mechanical harvesting of blueberries for fresh consumption.

Peterson and Brown (1996) reported results from an experimental mechanical harvester that used an angled shaker, a cane spreading and repositioning system to spread canes away from the plant crown and reduce the fruit drop distance, and padded surfaces designed to reduce drop impacts. They concluded that the experimental harvester resulted in better fruit quality than a conventional harvester but there was need for further improvement. One year later, Peterson et al. (1997) reported results from another experimental harvester designed for fresh fruit harvest known as the V45 harvester. It also used a cane dividing system, an angled shaker, and padded catching surfaces but was narrow enough to maneuver effectively in cultivated blueberry plantings. Ground losses were reduced by 44% compared with a conventional harvester. The pack outs for the V45 were as good as or better than those obtained from a rotary harvester and internal berry quality was superior to the rotary harvester. In 2005, Takeda et al. (2008) evaluated the V45 harvester using specially pruned rabbiteye blueberry and southern highbush blueberry (*V. corymbosum* hybrids) plants with v-shaped canopies. For rabbiteye, internal bruising and skin splitting were less for the V45 harvester than for a sway harvester and nearly equal to hand-harvested fruit. They concluded that the V45 harvester had potential for harvesting some rabbiteye blueberry cultivars for fresh fruit consumption. However, cane pruning and training requirements and limited ground speed has prevented widespread commercialization of the v-45 harvester (Takeda et al., 2008).

Despite the many challenges, a trend toward increased machine harvesting of blueberries for fresh markets has been noted during the past two decades. A 1992 survey of the North American blueberry industry revealed that 40% of the North American blueberry crop was machine harvested, of which 77% was used for processing, and 23% was sold for fresh consumption (Moore, 1994). Almost all respondents in the larger-producing states expected machine harvesting to increase in the future. From a similar survey conducted about a decade later, Strik and Yarborough (2005) concluded that a major change

in the last 10 years was the use of machine harvesting for fresh blueberries. For most states with significant blueberry production, a substantial percentage of berries grown for fresh consumption were machine harvested and this trend was expected to continue. Examples of companies currently producing self-propelled, over-the-row commercial blueberry harvesters include BEI International (South Haven, MI), Oxbo International (Lynden, WA), and Littau Harvester (Stayton, OR).

Further transition from hand-harvesting to machine-harvesting blueberries for fresh consumption appears inevitable. The problems associated with mechanical harvesting of blueberries were identified decades ago for processed fruit but are now intensified because of the higher quality requirements for fresh fruit. The challenges moving forward include but are not limited to 1) improved cultivars with characteristics that lend themselves to machine harvesting; 2) modifications of cultural and postharvest practices needed to reduce losses of marketable yield that occur during and after machine harvest; and 3) improvements in harvester design needed to increase harvest efficiency, improve berry quality, and minimize plant injury. The scope and nature of these problems require a multidisciplinary approach. The following proceedings represent findings and opinions of leading researchers from a variety of disciplines, all with the common goal of developing an integrated system for mechanically harvesting southern highbush blueberries for fresh markets. Specifically, the following topics are discussed: 1) use of sparkleberry (*V. arboreum*) in breeding to improve traits of southern highbush blueberry for mechanical harvesting; 2) effects of mechanical harvesting on postharvest quality of southern highbush blueberry; 3) cultural practices and other preharvest considerations to improve mechanical harvesting efficiency; and 4) analyses of points of impact to berries during harvesting with a rotary mechanical harvester.

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