Feasibility of Mechanically Harvesting Fresh Market Quality Eastern Thornless Blackberry

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Abstract. *A harvesting system was developed to determine the feasibility of mechanically harvesting fresh market quality eastern thornless blackberries. An over–the–row harvester utilized a direct–drive spiked–drum shaker for selective fruit removal and an energy–absorbing catching conveyor to collect the berries. The catching conveyor transferred the fruit to an inspection conveyor where five people graded the berries. A rotatable trellis training system was used to position the fruiting canes in a harvestable position. The eastern thornless blackberry cultivar 'Chester Thornless' was machine harvested on 2–day intervals. The packout of fresh market quality fruit ranged from 8 to 56% of harvested berries. However, the shaker was removing only 38 to 40% of the fresh market quality berries. Hand sorters were unable to keep up with machine capacity when fruit was harvested at a rate exceeding 4 kg/min (8.8 lb/min). Machine harvest of fresh market quality eastern thornless blackberry does not appear feasible. Factors to improve feasibility of machine harvesting were identified as: uniform fruiting canopy, cultivars that have significant differences in detachment force between mature firm berries and immature berries, and cultivars that retain higher fruit firmness in mature berries.*

Keywords. *Mechanical harvester, Blackberry, Bramble, Trellis, Quality.*

Blackberries (Rubus subgenus Rubus) destined for processing have been mechanically harvested since the 1960s (Booster, 1983). Generally as blackberries mature the force required to detach them decreases, which allows mechanical harvesters to be selective and harvest mainly ripe berries. Commercial blackberry production typically uses a vertical trellis. Mechanical harvesters straddle these trellised rows and use either spiked–drum inertial shakers (Littau Harvester, Stayton, Ore.; Weygandt Inc. Canby, Ore.; Korvan Industries, Inc., Lynden, Wash.), or one or more pairs of oscillating horizontal beater rods (BEI, Inc., South Haven, Mich.) to remove the fruit. Since the detached berries fall through the shaker and canopy, and are caught by rigid surfaces such as steel or plastic conveyors, the fruit does not possess acceptable quality for the fresh market. Hand harvesting brambles for the fresh market is very labor intensive requiring 600 to 1000 person–h/ha (240 to 400 person–h/acre) (Brown et al., 1983) and is the single largest expenditure in bramble production. High costs and scarcity of labor, along with the lack of cultivars with long post–harvest shelf life have prevented increased production of fresh market quality blackberries. Eastern thornless blackberries, developed by the U.S. Department of Agriculture, are vigorous, high yielding brambles [24,000 kg/ha (21,400 lb/acre)] that are utilized mainly on small acreage (Takeda and Peterson, 1999). It is estimated that there are now 200 to 300 ha (500 to 740 acre) of eastern thornless blackberries in the East and additional 50 ha (125 acres) in California, Oregon, and Washington. These blackberries are grown for U–Pick customers [$0.50/kg ($0.23/lb)] as well as hand–harvested for wholesale fresh–market distribution [>$3.00/kg ($1.35/lb) (personal communication, 2002, Charles and Ann Geyer, Westmoreland Farms, Oak Grove, Va.)]. For the fresh–market distribution, the mature fruit are hand–harvested at two–day intervals. With accepted production practices (chemical control of insect pests and fungal fruit rot) and experienced pickers, more than 95% of the fruit can be hand–harvested and packed for fresh–market sales. Researchers at the Appalachian Fruit Research Station, Kearneysville, West Virginia, have attempted to develop a system for mechanical harvesting eastern thornless blackberries (Takeda and Peterson, 1988; Peterson et al., 1989, 1992; Takeda and Peterson, 1999). Ineffective selective removal of mature berries and low fruit firmness in most eastern thornless cultivars has prevented successful mechanical harvesting.

Objectives

The objectives of this article were to summarize the progress in developing a mechanical harvesting system for fresh market quality eastern thornless blackberries grown on a rotatable trellis. Key components to develop were: (1) effective shaker for selectively removing mature berries, and (2) fruit catching/conveying system that minimized damage and allowed space for human sorting.

Article was submitted for review in March 2002; approved for publication by the Power & Machinery Division of ASAE in August 2002.

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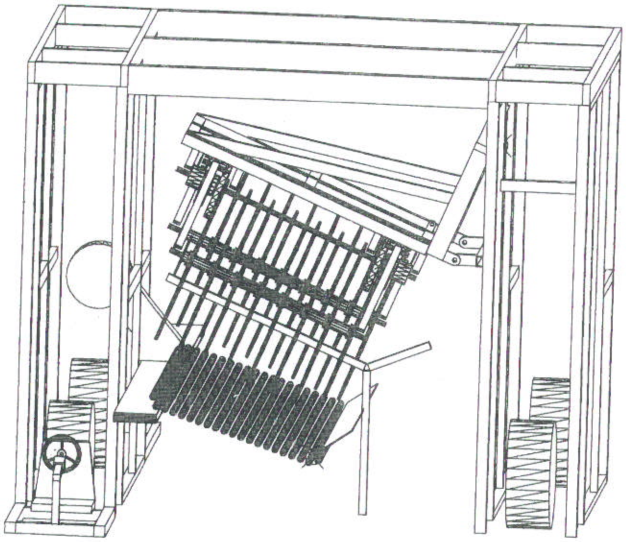

Figure 1. Schematic of experimental mechanical blackberry harvester.

Mechanical Harvesting System

The mechanical harvester was developed on an over–the–row frame (figs. 1 and 2). A rotatable trellis system was developed to place the fruiting canopy directly below a spiked–drum shaker and directly above an energy absorbing catching–conveyor. Takeda and Peterson (1999) described the trellis and training system that keeps the developing primocanes separated from the floricanes. Manipulation of the long arms of the trellis that supports the floricanes (before harvest starts) forces the fruiting laterals to hang below the main canes and trellis grid.

2000 Harvester Design

The positive displacement spiked–drum shaking principle developed by Peterson and Kornecki (1988) was modified to improve reliability. The 2000 harvester used a single spiked–drum shaker with counterbalance cylinder to achieve dynamic balance (fig. 3). The spiked–drum was 122 cm (48 in.) in diameter with 16 whorls spaced 9 cm (3.5 in.) apart on a center shaft. Each whorl had 24 nylon (nylon 66) rods, 16 mm (0.625 in.) in diameter and 56 cm (22 in.) long.

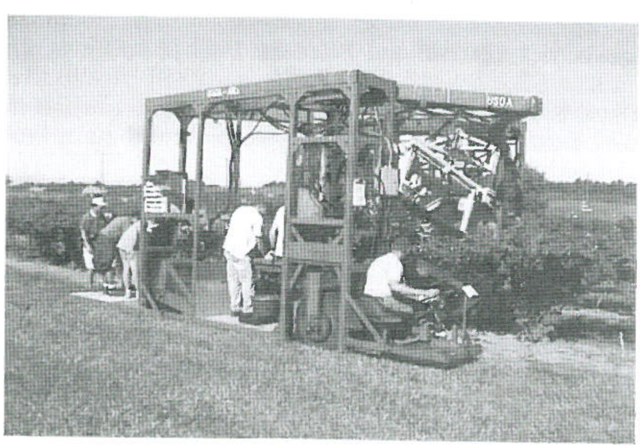

Figure 2. Experimental mechanical blackberry harvester.

Maximum penetration of the rod into the fruiting canopy was 48 cm (19 in.). The spiked–drum and counterbalance cylinder were both bearing–supported by two support arms that were bearing–supported to the shaker frame. Each pair of support arms was oscillated by connecting rods that were driven by ball–bearing eccentrics to generate the shaking action in the fruiting canopy. The front counterbalance and rear spiked–drum eccentric drives were driven by a common shaft, but keyed 180° apart. This arrangement permitted the movement of the spiked–drum and counterbalance cylinder to be synchronized in opposite directions for dynamic balance. A 10–mm (0.375–in.) throw on the eccentrics resulted in a potential 12–cm (4.75–in.) maximum displacement at the tip of the shaking rod. A caliper disc brake, at one end of the spiked–drum shaft, could be adjusted through a hydraulic pressure reducing valve to impart up to 140 N–m (103 lbf–ft) of drag torque to resist drum rotation and transmit more of the shaking action to the canopy. A hydraulic motor powered the eccentric driveshaft and shaker frequency was adjustable up to 8 Hz (480 r/min). The shaker shaft was mounted in the harvester frame at a 22.5° angle from horizontal to conform to the fruiting canopy orientation of the trellis and could be rotated ±3° to account for irregularities in the trellis or ground. The shaker could also be raised or lowered up to 35.5 cm (14 in.) to control the penetration of the rods into the canopy. The over–the–row frame of the harvester was also adjustable 46 cm (18 in.) vertically to provide flexibility for positioning the rods into the canopy.

In 2000, the fruit catching conveyor was 3.05 m (120 in.) wide, 1.12 m (44 in.) long, and angled to conform to the trellis (fig. 4). The conveyor was supported by three 2050 chains with one in the center and two at the outer edges. The center chain had extended pins every link and on both sides. The outer chains had extended pins every link, but only toward the inside. The chains supported flights made from 150 cm (59 in.) long schedule 40 aluminum pipes [1.37 cm od., 0.93 cm id. (0.54 in. od, 0.364 in. id.)] that were covered by 10–mm (0.375–in.) thick Armaflex pipe insulation (Armstrong World Industries, Lancaster, Pa.). This design resulted in no spacing between the flights.

A 20– × 20–cm (8– × 8–in.) foam strip [64–kg/m^3 (4–lb/ft^3) density open–cell polyester foam, Wm. T. Burnett Co., Baltimore, Md.] attached at the lower edge of the conveyor permitted close positioning to the cane trunks. The outer vertical surface of this foam strip was protected by a 20–cm (8–in.) wide slick belt that presented a smooth surface for canes rubbing against it. The top surface of the foam strip was angled 30° to the horizontal to feed berries into the conveyor.

The catching conveyor transferred the berries onto an inspection conveyor that used a 30–cm (12–in.) wide series 900 Flush Grid plastic perforated belt (Intralox, Harahan, La.) that transported the fruit to the rear and allowed space for up to six workers to sort the harvested material. Up to three workers operated in a 152–cm (60–in.) section of the belt near the outlet of the catching conveyor. The belt then went under a fan, which extracted leaves and other light debris. A final 152–cm (60–in.) section of the belt near the rear of the harvester permitted final sorting before the berries were containerized.

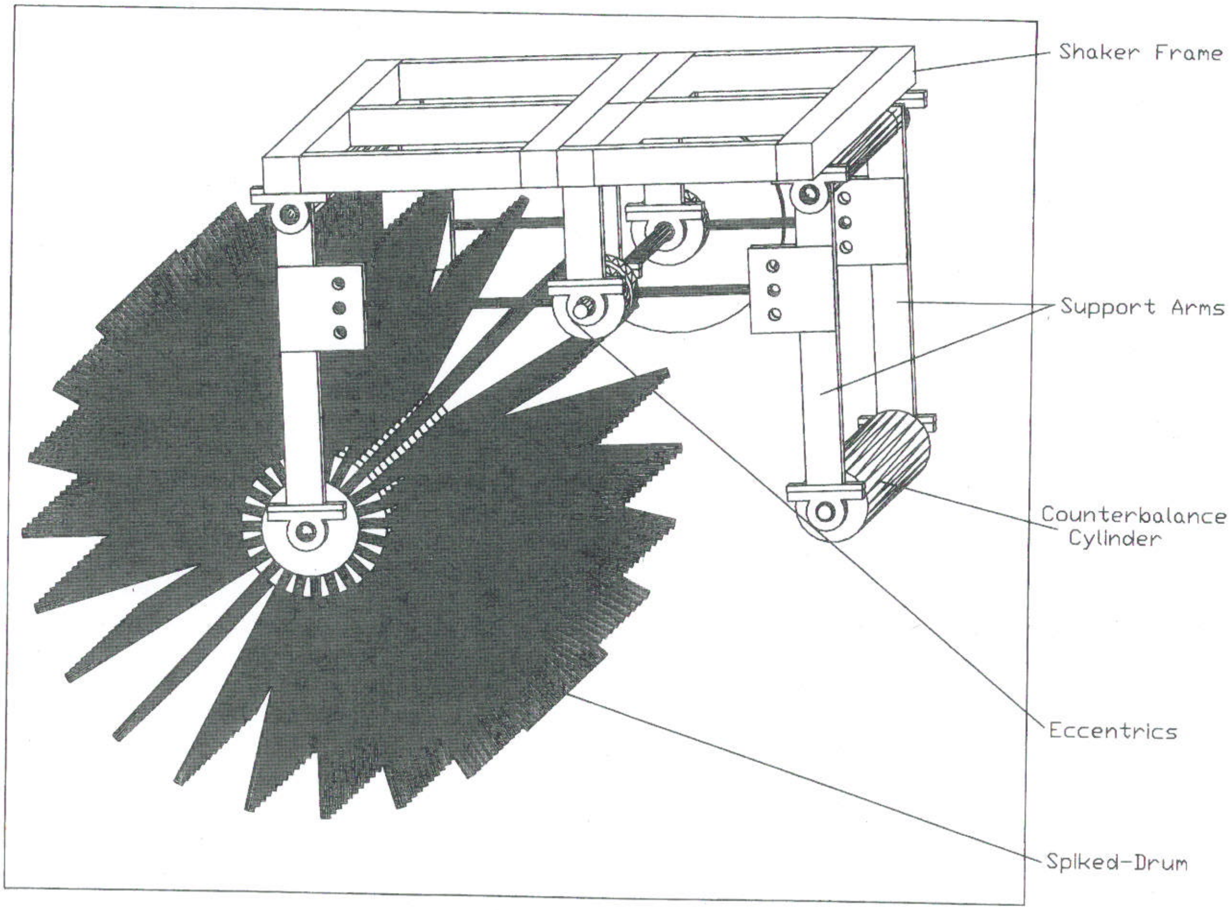

Figure 3. Schematic of 2000 blackberry shaker with counterbalance cylinder.

2001 Harvester Design

In the 2001 shaker, the counterbalance cylinder was replaced with another spiked drum (fig. 5). The same number of whorls were used, but with 8 whorls/spiked–drum spaced at 18-cm (7 in). The whorls of the two drums were offset by 9 cm (3.5 in.) from each other to yield the same combined whorl density as one drum in 2000. A 12.5–mm (0. 5–in.) throw on the eccentrics resulted in a potential 16–cm (6.3–in.) maximum displacement at the tip of the shaking rod.

In 2001, the conveyor remained the same size and orientation as in 2000, but the flights were changed to 3.05 m (120 in.) long schedule 40 aluminum pipes [2.7 cm od., 2 cm id. (1.05 in. od, 0.824 in. id.)] that were covered by 10–mm (0.375–in.) thick pipe insulation (fig. 6). The pipes were supported at the ends by 2050 chain with B–1–1 attachments on every other link [6.35 cm (2.5 in.)]. This design resulted in a 1.9 cm (0.75 in.) gap between the flights. The purpose of the gaps was to allow small immature berries to drop between the flights, in–order to reduce the load on the hand sorters.

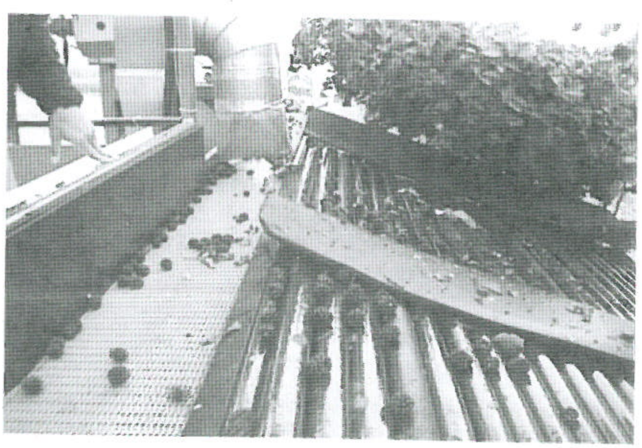

Figure 4. Fruit catching/conveying system for 2000 harvest.

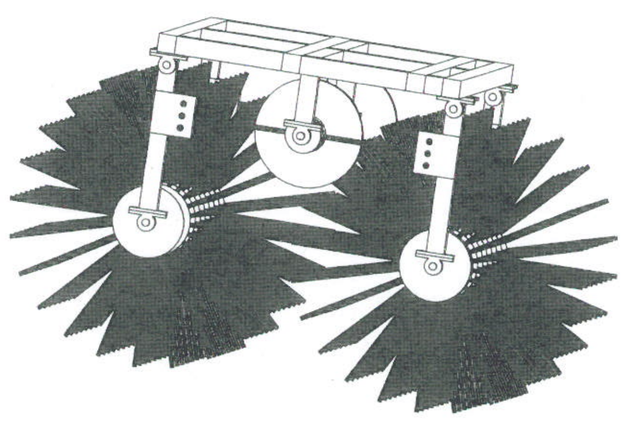

Figure 5. Schematic of the 2001 double–drum blackberry shaker.

Test Procedures

The eastern thornless blackberry cultivar 'Chester Thornless' was used to evaluate the harvesting system. Previous experience (Takeda and Peterson, 1999) showed that 'Chester Thornless' might be the eastern thornless blackberry with the best prospects for machine harvesting for the fresh market because its fruiting canopy was more compact and fruit more firm than other eastern thornless blackberry cultivars. Six trellised rows 30 m (100 ft) long, each with 20 plants, were used in the experiment. Rows ran northeast to southwest and there were three rows each with the trellis/canopy support arm positioned on different sides. Each half–row plot (10 plants) was treated as a replication. Two harvesting treatments (randomized and 6 replications/treatment) were selected and plants were harvested every other day. For both years the harvester ground speed was 0.8 kph (0.5 mph) and the harvested fruit were weighed. On selected days (two to three times/week) the fruit were hand sorted on the harvester. The fresh market quality fruit (firm–nonbruised, black berries) were manually picked off the inspection conveyor and the remaining berries were collected at the rear of the harvester. The remaining berries consisted of processing quality and over–ripe or immature fruit. Processing grade were any other black berries except for overripes.

In 2000, treatment one (Tmt 1) had shaking frequency range from 5.8 to 7.9 Hz (350 to 475 rpm), brake torque ranged from 105 to 140 N–m (77 to 103 lbf–ft), and the shaking rods penetrated the fruiting canopy only 10 to 15 cm (4 in. to 6 in.) so the lateral cane would be shaken, but the rods would not contact the berries. Treatment two (Tmt 2) had shaking frequency ranged from 5 to 7.9 Hz (300 to 475 rpm), brake torque ranged from 63 to 140 N–m (46 to 103 lbf–ft), and the shaking rods were fully inserted into the canopy. Shaking frequency and brake torque were gradually increased during the harvest season since it was determined that a more aggressive shaking action was needed. On four days in 2000, selected plants were hand harvested, after mechanical harvesting, to gauge the amount of harvestable fruit left by the machine.

In 2001 the shaking rods penetrated the fruiting canopy only 10 to 15 cm (4 to 6 in.) in both treatments since that treatment in 2000 looked most promising. Treatment one (Tmt 1) shaking frequency was 7.5 Hz (450 rpm) and brake torque was 140 N–m (103 lbf–ft). Treatment two (Tmt 2) shaking frequency was 6.7 Hz (400 rpm) and brake torque was the same as Tmt 1. During a three–day period in 2001 (6, 7, 8 August), plants were mechanically harvested every day to try to improve fruit quality. SAS statistical software (Version 7, SAS Institute Inc., Cary, N.C.) was used to analyze the data.

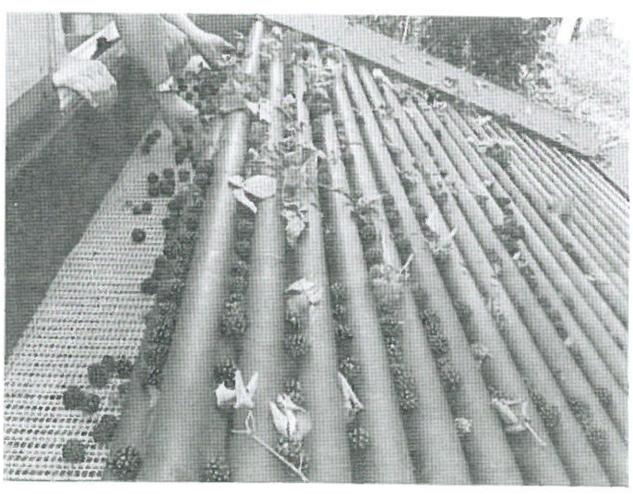

Figure 6. Fruit catching/conveying system for the 2001 harvest.

Results

All machine components operated efficiently without serious breakdowns. The catching conveyor was effective in minimizing damage. With the machine travel speed of 0.8 kph (0.5 mph), the hand sorters had a difficult task effectively sorting when the fruit load on the conveyors exceeded 4 kg/min (8.8 lb/min). The harvester's forward movement would often need to be stopped in the middle, and always at the end, of the treatment to have the sorters complete their task.

In 2000, neither harvest treatment produced consistently more significant fruit removal throughout the season, but the high frequency/partial rod penetration (Tmt 1) tended to remove more fruit than the low frequency/full rod penetration (Tmt 2) (fig. 7). Of the fruit removed, 55% was the highest amount of fresh market quality fruit, but normally this grade was much lower (48 to 8%). Except for the first harvest date, the higher frequency/partial rod penetration (Tmt 1) also tended to yield a slightly higher proportion of fresh market quality fruit than the low frequency/full rod penetration (Tmt 2). The day after the first harvest 6.5 cm (2.56 in.) of rain fell and another 6.5 cm (2.56 in.) in the next two weeks. We know from experience that rain during the harvest reduces the amount of fresh market quality berries. The results from the hand picking after machine harvesting showed that the shaker removed only 38 to 40% of the fresh market quality berries. It was felt that these fresh market quality berries left on the canes would become processing quality by the next machine harvest because of over ripening. Statistical analysis yielded no significant differences in treatments ($P = 0.05$, Duncan's Multiple range test).

In 2001, neither harvest treatment produced consistently more fruit removal throughout the season (fig. 8). The grades from the two treatments were also similar, ranging from 36 to 56% fresh market quality with no apparent trend or significant differences ($P = 0.05$, Duncan's Multiple range test). The harvest season was drier than in 2000 with 5.1 cm (2 in.) falling during the harvest period. Harvesting every day (6 to 8 August) did not yield significantly higher fresh market packout. The gap between conveyor flights in the 2001 version was effective in eliminating small immature berries; but a slightly wider gap might have been even better. Berries that passed thought the gap in the top of the conveyor also fell out the bottom of the conveyor. No fresh market size berries fell through the gap. Hand sorters were still not able to keep up with harvester capacity.

Conclusions

During the 2000 harvest season, packout of fresh market quality fruit ranged from 8 to 55% of machine harvested berries. However, the harvester removed only 38 to 40% of the fresh market quality berries on the canes. Hand sorters

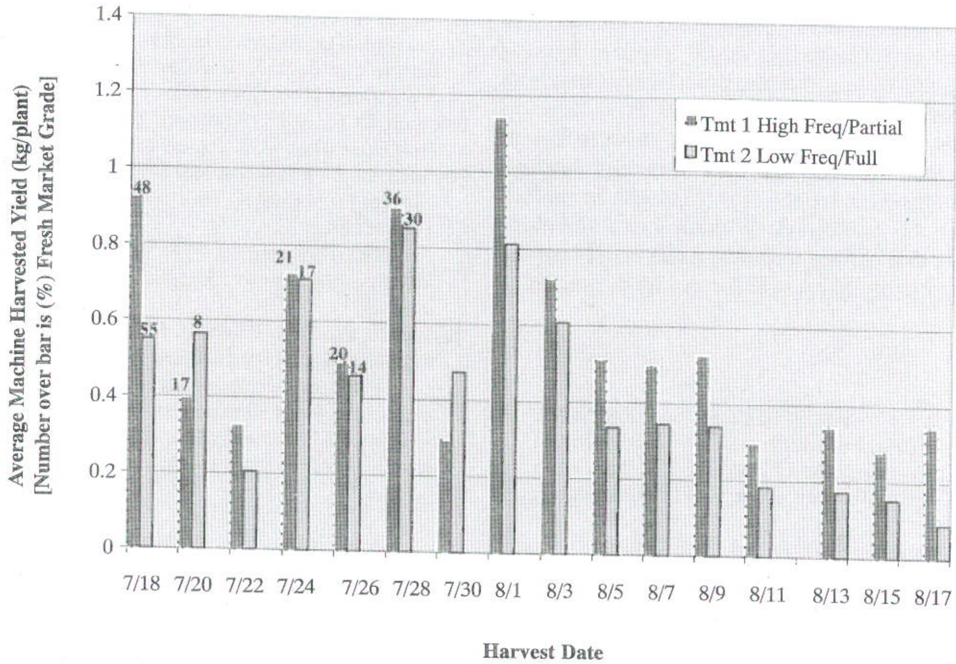

Figure 7. 2000 machine harvest results on 'Chester Thornless' blackberry.

were unable to keep up with machine capacity when the fruit load on the conveyors exceeded 4 kg/min (8.8 lb/min). During the 2001 harvest season, packout of fresh market quality fruit ranged from 36 to 56% of machine harvested berries. Improvement in the percent of fresh market quality fruit harvested in 2001 verses 2000 was attributed to a drier harvest season, more aggressive shaking action, and removal of immature fruits through the catching/conveyor. Mechanically the harvester operated satisfactory, and no obvious modifications were identified to improve selective removal of mature firm berries, or improve manual sorting efficiency. An economic evaluation of machine harvesting blackberries for the fresh market indicated that a packout of at least 72% would be needed to equal the return of a conventional "I" trellis system that was hand harvested (Harper et. al., 1999). With the results to date, it is unlikely that mechanical harvesting of fresh market quality of eastern thornless blackberries is feasible.

Discussion

Eastern thornless blackberries have longer fruiting laterals near the center of the trellis, which become shorter near the outer edge of the trellis. This characteristic makes it difficult to transmit a uniform shaking action to the entire

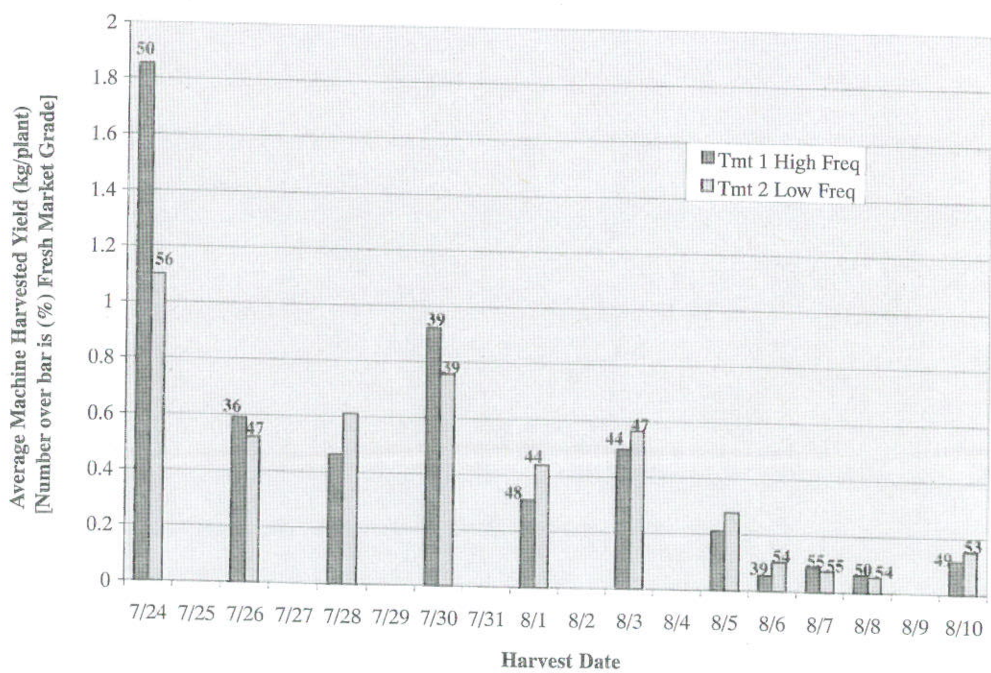

Figure 8. 2001 machine harvest results on 'Chester Thornless' blackberry.

fruiting canopy. Uniform structure of the fruiting canopy was therefore identified as a factor that might improve harvest results. Another factor to improve the potential for machine harvesting blackberries for the fresh market is to develop cultivars that have a significant difference in detachment force between mature firm berries and immature berries. Cultivars that would retain higher fruit firmness in mature berries would also be beneficial. Without these developments, it is unlikely that eastern thornless blackberries can be successfully mechanically harvested for the fresh market.

References

Booster, D. E. 1983. Berry harvesting: III. Cane and high bush berry harvesting. In *Principles & Practices for Harvesting & Handling Fruits & Nuts*, eds. M. O'Brien, B. F. Cargill, and R. B. Fridley, 503–524. Westport, Conn.: AVI Publishing Co., Inc.

Brown, G. K., D. E. Marshall, B. R. Tennes, D. E. Booster, P. Chen, R. E. Garrett, M. O'Brien, H. E. Studer, R. A. Kepner, S. L. Hedden, C. E. Hood, D. H. Lenker, W. F. Millier, G. E. Rekugler, D. L. Peterson, and L. N. Shaw, 1983. Status of harvest mechanization of horticultural crops. Special Publication 3–83. St. Joseph, Mich.: ASAE.

Harper, J. K., F. Takeda, and D. L. Peterson, 1999. Economic evaluation of improved mechanical harvesting systems for eastern thornless blackberries. *Applied Engineering in Agriculture* 15(6): 597–603.

Peterson, D. L., and T. Kornecki. 1988. Shaking mechanism for fruit harvesting. U. S. Patent 4,860,529.

Peterson, D. L., F. Takeda, and T. S. Kornecki. 1989. New shaking concept for brambles. *Transactions of the ASAE* 32(4): 1165–1168.

_____. 1992. Harvester for "T", "V", and "Y" trellised eastern thornless blackberries. *Applied Engineering in Agriculture* 8(1): 9–12.

Takeda, F., and D. L. Peterson. 1988. Machine harvest of eastern thornless blackberry cultivars. *HortScience* 23(1): 120–123.

_____. 1999. Considerations for machine harvesting fresh–market eastern thornless blackberries: trellis design, cane training systems, and mechanical harvester developments. *HortTechnology* 9(1): 16–21.