How to Avoid Cherry Tree Trunk Damage Caused by Trunk Shakers
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How to Avoid Cherry Tree Trunk Damage Caused by Trunk Shakers

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Mechanical trunk shakers, developed in the 1960s, are used to harvest most of the tart and sweet cherry crops in Michigan. These shakers, originally designed for large trees (5-inch diameter and larger trunk), can damage as many as two-thirds of the young trees (1.5- to 5-inch diameter trunk) after the first three years of mechanical harvesting. Trunk damage alone, or accompanied by insect and disease infestation, may lead to a 50 percent decrease in tree longevity, resulting in a total orchard life of only 15 to 20 years.

Over the course of four years, studies were conducted in two young mechanically harvested tart cherry orchards (3 to 7 years of age and 8 to 12 years of age, respectively) to develop improved harvesting procedures that avoid trunk damage, and to study tree response. Standard and improved harvesting procedures were implemented on both irrigated and non-irrigated trees. Trunk damage did not significantly increase for trees under irrigation using the improved harvesting procedures. Less than 7 percent accumulated trunk damage occurred in four years, compared to 73 percent for the standard harvest system.

Large forces transmitted during clamping and shaking may split, crush or shear bark and internal trunk tissues. Such damage is more pronounced with young trees, high bark moisture, and active cell growth. A combination of the following procedures will nearly eliminate this trunk damage, even on continuously irrigated young trees: limit peak

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compressive pressures applied to the bark to 150 psi; replace tubular-type neoprene clamp pads with soft (55 Durometer) neoprene block pads or with particle-filled pads that conform to the trunk; use proper size and type of clamp; install nitrile slip-belts (smooth sides face each other) in place of standard neoprene slip-belts over the pads and use silicone spray lubricant between the slip-belts; and, use one slightly longer shaking cycle instead of two or more short shaking cycles. Proper equipment maintenance and adequate operator training are also essential to avoid trunk damage.

Introduction

Mechanical trunk shaking to harvest large fruit trees began in the mid-1960s. Direct clamping to the trunk was the most efficient method of attaching the shaker. Rubber pads and lubricated neoprene slip-belts placed between the clamp and the trunk were developed to transmit the shaking force from the shaker to the tree, distribute the shaking and clamping forces over a larger area of the trunk, and limit damage that may occur to the bark at the clamp-trunk interface. These shake-harvesters were developed for trees that were generally 9 years and older, with at least a 5-inch diameter trunk. General information describing the factors associated with bark damage have been summarized for growers (Cargill et al., 1982; Brown, 1985). Pruning practices such as a modified central leader structure, removal of pendulant lower limbs, and heading back of willowy branches also help to create a more rigid system to better transmit the energy from the shaker to the fruit and facilitate fruit removal (Westwood, 1978).

In Michigan, over 95 percent of the tart and sweet cherry crops are mechanically harvested each year. This currently equates to over 3.8 million bearing cherry trees (Johnston, 1991). Extensive replanting of cherry orchards in the early 1980s meant that nearly 50 percent of the Michigan tart cherry trees and 30 percent of the sweet cherry trees were in their first years of bearing fruit (Michigan Dept. of Agriculture, 1985, 1986). Increased costs for manual labor and decreasing availability of migrant harvest labor encouraged growers to mechanically harvest three- to five-year-old trees with trunk diameters as small as 1.5 inches. Shake-harvest systems designed for large trees, with or without slight modifications, were used to harvest these young trees. Large forces transmitted during clamping and shaking will split, crush, and shear bark and internal trunk tissues. High bark moisture, active cell growth, and relatively thin, fragile bark tissues of young trees add to the problem (Frahm et al., 1988). Consequently, severe trunk damage became a major problem in the 1980s and reduced the productive life of an orchard by as much as 60 percent (Burton et al., 1988).

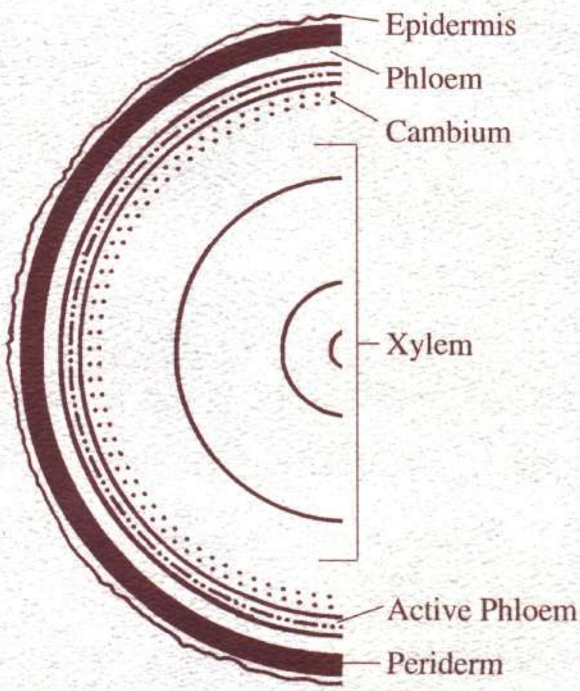
Economically, the loss of mature orchard production may translate into an estimated total net loss of $6500/acre during the typical 15 years of orchard production. This loss assumes a nominal 20 percent yield reduction two years after the tree trunk is severely damaged (Timm et al., 1988).

From 1982 to 1988, our research project conducted several studies to identify the components of the shake-harvest system that were responsible for trunk damage to young cherry trees, and to develop effective mechanical harvesting methods that avoided significant trunk damage to younger, more sensitive trees. Maximum clamping forces, clamp design, pad design and firmness, slip-belt materials and lubrication, and shaker dynamics were all studied.

Cherry trees are harvested in early- to mid-July, midway through the growing season when the bark's ability to resist damage is low, due to high cambial activity. Although the tree is actively growing, only 40 to 50 percent of the total annual increase in trunk diameter has taken place. Trickle irrigation applied throughout the season also promotes cambial activity. These two factors—harvest date and irrigation—lead to high sensitivity to bark damage, especially in young trees.

Cherry bark (Figure 1) consists of 1) a thin outer periderm and epidermis, 2) a large spongy non-functioning phloem in the center, and 3) a thin functioning phloem next to the cambium. Phloem cells have their long axis vertical to the trunk, whereas periderm and epidermis cells have their long axis horizontal to the trunk. These tissues are strongest in the direction of their long axis. Consequently, the inner bark (active phloem) will tend to crush and separate into vertical cracks as a result of excessive compressive, shear and torsional forces. The more elastic epidermis may resist rupture under equivalent conditions, masking the damage to the inner bark at harvest.

Figure 1. Cross section of cherry tree trunk



Damage to the trunk of a cherry tree as a result of mechanical harvesting can be categorized into three types: hidden, slight, and severe. Examples are shown in Figure 2.

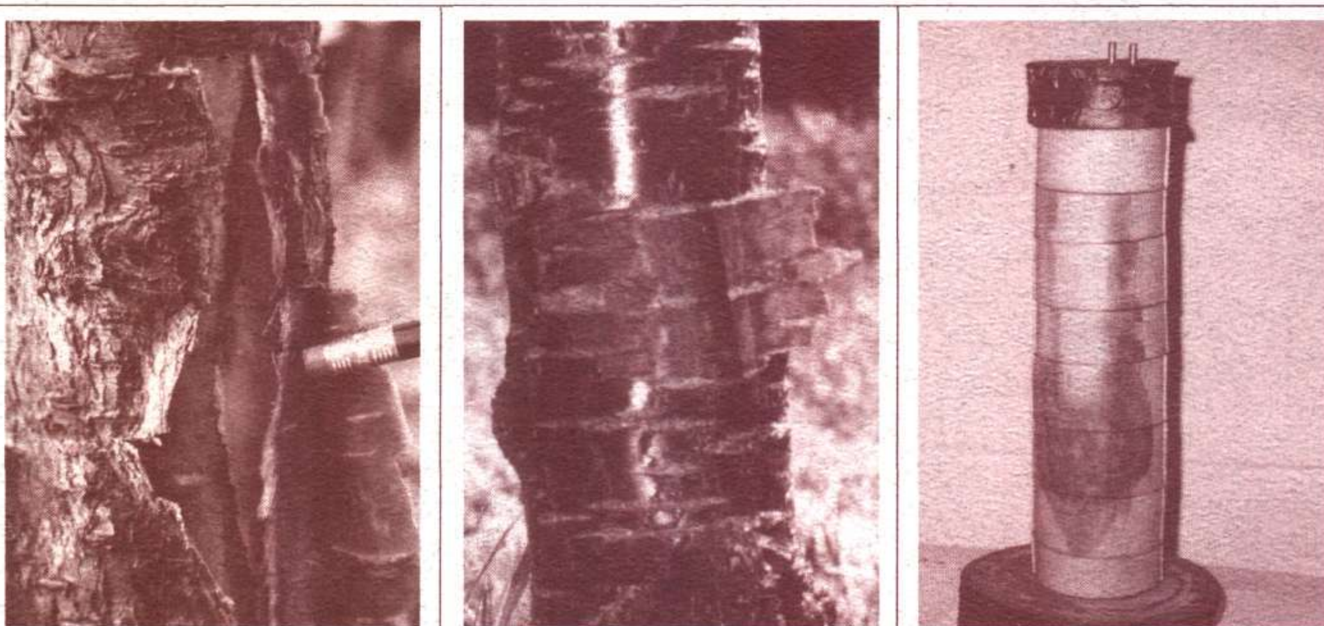
Damage may occur that is *hidden* immediately following shaking. Such damage is in the form of cell crushing of the cambium, as well as young phloem and xylem tissues. Crushing is evident by a permanent browning within one to two days in the damaged area, but it is not visible on the trunk surface.

Slight damage occurs when the outer layer (epidermis) of the bark is also broken, exposing the bright green periderm. Typically, the green periderm will have a darker, water-soaked appearance from excessive compressive or shear force where the shaker was in contact with the trunk. In some cases, cracks occur down to the cambium. Because of the elasticity of the outer periderm, these cracks are not evident until several weeks after harvest or the following season.

Severe damage typically is the splitting or crushing of the entire spongy bark down to the white xylem layer. Depending on the degree of damage, entire portions of the bark may be torn from the trunk, or only vertical splits may be initially evident. The exposed cambium and resulting gumming can then become an excellent host for insects and diseases, which may hamper the healing process and decrease the health of the tree. The resulting callus development and subsequent disfigurement of the trunk may increase the probability of injury in following seasons. All of these types of damage may have long-term effects on tree longevity, as a result of insect and disease infestation, reduced nutrient flow and a predisposition to further damage.

Trunk damage which exposes fresh cambial tissue provides a tremendous habitat for both the lesser peachtree borer (*Lepidoptera : Synanthedon pictipes*) and the American plum borer (*Lepidoptera : Euzophera semifuneralis*).

Figure 2. These photos reveal damage from mechanical harvesting (left to right): 1) severe damage, bark is split and torn to cambium layer; 2) slight damage, bark peeled away from periderm; and 3) hidden damage, browning is revealed in the cambial layer by trimming away the outer bark in sections.



Adult borers, attracted to the damaged trunk, lay eggs around and inside the cracked bark. The larvae develop and feed on the exposed inner bark and cambium of the tree. Once actively feeding inside the wound, borer larvae are nearly impossible to kill. This feeding damage produces gummosis and insect frass (fecal material) that disrupts the formation of normal callus tissue by the tree. Extensive borer tunneling can also cause partial girdling of the trunk and create a favorable environment for other insects and rot fungi. Current borer control practices are directed at the following spring generation, which emerges at petal fall on tart and sweet cherry. One application of a long-residual insecticide to the trunk at this time provides season-long control of both species of borers (Biddinger, 1989). Refer to the current edition of the Michigan State University CES Bulletin E-154 for recommended control materials and rates.

Preliminary studies have outlined the following procedures to minimize obvious bark damage incurred by young cherry trunks during shake-harvesting: 1) reduce the clamping pressure on the bark to 150 psi, and use nitrile covered slip-belts (Polymate Nitrile 135 COS; Globe International, 1400 Clinton St., Buffalo, NY 14240), smooth sides facing each other, that are lubricated with silicone spray to minimize shear force transmission; 2) avoid the use of tubular-type clamp pads. Instead, use either the 55 Durometer (Shore A) neoprene block-type pads manufactured by Friday Tractor Co. (Hartford, Mich.) or Kilby Manufacturing Co. (Gridley, Cal.), or the conforming particle-filled pads manufactured by OMC (Yuba City, Cal.); 3) use a scissors clamp design, or the Friday Tri-clamp (Friday Tractor Co., Hartford, Mich.) fitted with customized 55 Durometer (Shore A) block-type neoprene pads; and, 4) use a single shake instead of several short shakes, to avoid the large shaker displacements that occur during start-up and shut-down. The basis for these recommendations are detailed by Affeldt et al. (1989), Al-Soboh (1986), Brown et al. (1987, 1988a, 1988b and 1988c), Esch (1988), Esch et al. (1989a, 1989b and 1989c), Frahm et al. (1988), Khorasanizadeh (1988), and Timm et al. (1988).

Objectives

From 1985 to 1989 we conducted studies to observe the tree yield, growth rate and trunk damage response of young tart cherry trees to various mechanical harvesting and irrigation regimes. For a more detailed description of the studies, see Burton et al. (1988).

The objectives of our study were: 1) to compare mechanical trunk damage on young cherry trees using the *standard harvest system* (tubular-type neoprene pads, neoprene slip-belts, gear grease lubrication, Friday Tri-clamp) and the *improved harvest system* (55 Durometer neoprene block pads, nitrile slip-belts, silicone lubrication, reduced clamping pressure in a scissors-kit clamp); 2) to determine what effect various irrigation regimes have on the incidence of harvesting trunk damage, as well as yield and growth rates of young tart cherry trees under commercial production; and, 3) to develop a set of guidelines by which young tart and sweet cherry trees can be effectively harvested with minimal trunk damage.

Study Procedures

Our tests were conducted in two commercial Montmorency tart cherry orchards located near Hart, Michigan. The first plot (plot A) consisted of a group of 450 trees, observed at 8 to 12 years of age. Mechanical harvesting began five years after planting, using the standard Friday Tri-clamp harvester at manufacturer recommended circuit pressure (1800 psi), and with several experimental clamp and pad designs at reduced clamping circuit pressures (Burton et al., 1988).

The second plot (plot B) was an 800-tree block arranged in a randomized split-plot 2-factor factorial design with: three harvest treatments (hand, standard Friday Tri-clamp, and the improved scissors-kit clamp); and three irrigation treatments (natural rainfall only, trickle irrigation off two weeks before harvest and back on immediately after harvest, and continuous trickle irrigation throughout the growing season). The experiment was implemented the third year after planting and was evaluated through the seventh growing season. The harvester clamp circuit pressure was 1300 psi for the Friday Tri-clamp and 850 psi for the scissors-kit clamp. Irrigation was applied by 2 trickle emitters (1 gal/hour per emitter) per tree at an initial rate of 4 gal/day, and the rate was increased 1 gal/day each following year (Kenworthy, 1974).

The following information was recorded in plot B throughout the growing season: 1) trunk damage at harvest and expressed over time (cumulative); 2) presence of borer (American plum borer; *Lepidoptera: Euzophera semifuneralis* and lesser peachtree borer; *Lepidoptera: Synanthedon pictipes*) infestation in wounded trunks, 3) cross-sectional trunk area at 20 inches above the orchard floor at bloom, harvest, and dormant dates; 4) terminal shoot growth averaged over four dominant shoots per tree; 5) total tree yield, and 6) 100 fruit-count weight.

Results

In plot A, after six years of mechanical harvest with the standard harvest system operated at manufacturer-recommended clamping pressures (Friday Tri-clamp with slight modifications), nearly all of the trees had visible trunk damage (Table 1). Severe damage (cracks, crushing or tears to the xylem) was evident on 47.1 percent of the trunks during at least one harvest season. Nearly all trunks with severe injury had

Table 1. Accumulated trunk damage and related problems as a result of shake-harvesting with the standard harvest system on young tart cherry trees.

	Accumulated Trunk Damage, % of Trees			Problems Caused By Severe Damage, % of Trunks		
	None	Slight*	Severe*	Swelling	Borer Present	Girdling
Plot A (Year 6)	12.2	40.7	47.1	79.7	46.4	26.6
Plot B (Year 4)	29.9	41.7	28.4	92.0	25.0	na

*Slight = bark epidermis broken, periderm exposed. Severe = bark split, crushed, or torn down to the xylem.

na = data not taken because bark removal would have killed these young trees.

noticeable swelling at the clamp site. Borers were present in 46.4 percent of the severely damaged trunks. Trunks with borers present appeared unable to form adequate callus (necessary to close over the wound site), due to borer feeding and tunneling in the cambial zone and the presence of excess gummosis and frass. At least 25 percent of these trunks had extensive girdling of cambial tissue. This damage was only evident after bark removal. After four years of using the standard harvest system in plot B, with three irrigation regimes, nearly 70 percent of the trees already had visible trunk damage. Of the severely damaged trunks, 92 percent exhibited swelling and 25 percent had borers. Not all damage was evident at the time of harvest. Swelling became evident several weeks later, or the following spring. The number of severely damaged trunks found the following spring doubled for the third and fourth year of harvest, in comparison to the observations immediately after harvest. Irrigated trees were three times as likely to incur severe trunk damage, compared to those receiving only natural rainfall (Figure 3).

Removal of irrigation two weeks prior to harvest, thought to toughen the bark tissues and thereby resist damage, did not reduce severe trunk damage compared to continuously irrigated trees.

The improved harvest system in plot B was able to successfully harvest with minimal trunk damage regardless of irrigation treatment. The total average accumulated trunk damage was less than 7 percent over four harvest seasons for the improved harvest system, compared to 73 percent for the standard harvest system.

Trees receiving continuous trickle irrigation had a significantly greater increase in annual trunk cross-sectional area, average shoot growth and tree yield, when compared to trees with natural rainfall or trickle irrigation removed two weeks prior to harvest (Figures 4, 5, and 6). The weight of 100 cherries did not appear to respond to irrigation in a consistent way, possibly due to spring frosts which reduced fruit set and thus increased fruit size, and rainfall and ambient temperatures preceeding harvest (Figure 7).

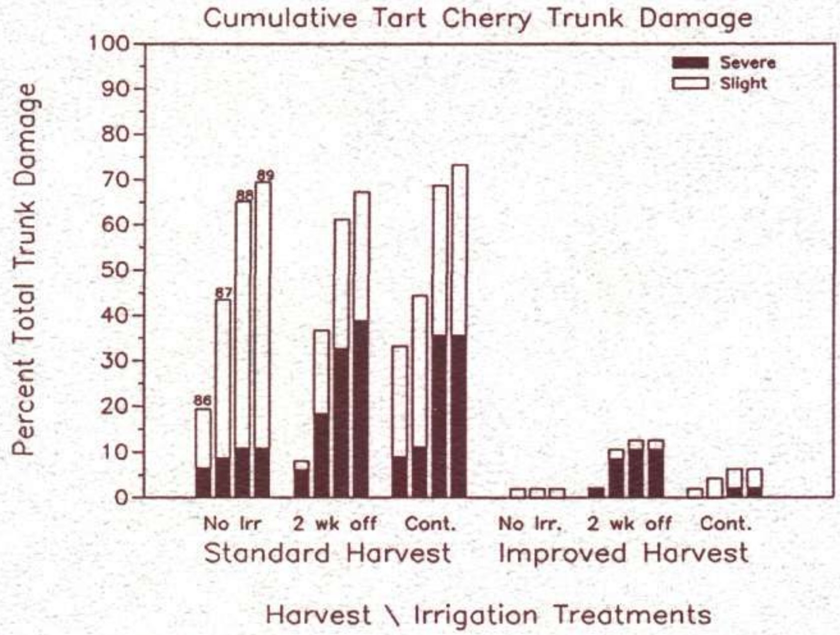


Figure 3. Plot B, accumulated trunk damage and severity, 1986 through 1989, in response to harvest system (standard vs. improved) and irrigation regime (natural rainfall, 2 weeks off prior to harvest, and continuous).

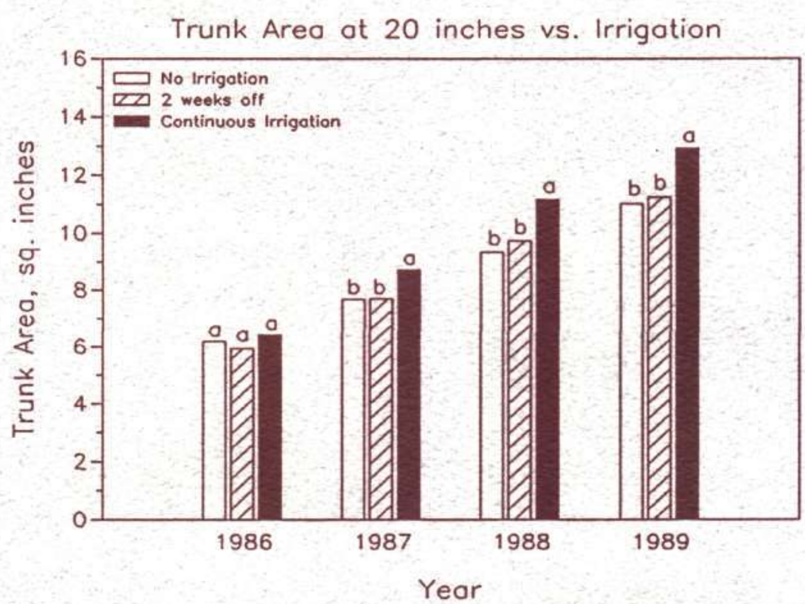


Figure 4. Plot B, trunk cross-sectional area for three irrigation treatments (natural rainfall, 2 weeks off prior to harvest and continuous). Within year mean separation (a and b) by Duncan's multiple range test, p = 0.05.

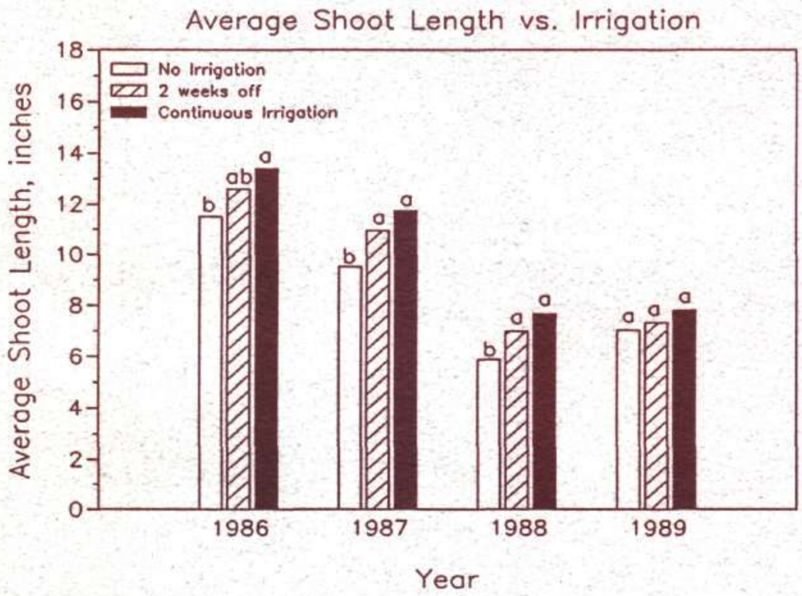


Figure 5. Plot B, average shoot growth for three irrigation treatments (natural rainfall, 2 weeks off prior to harvest and continuous). Within year mean separation (a and b) by Duncan's multiple range test, $p = 0.05$.

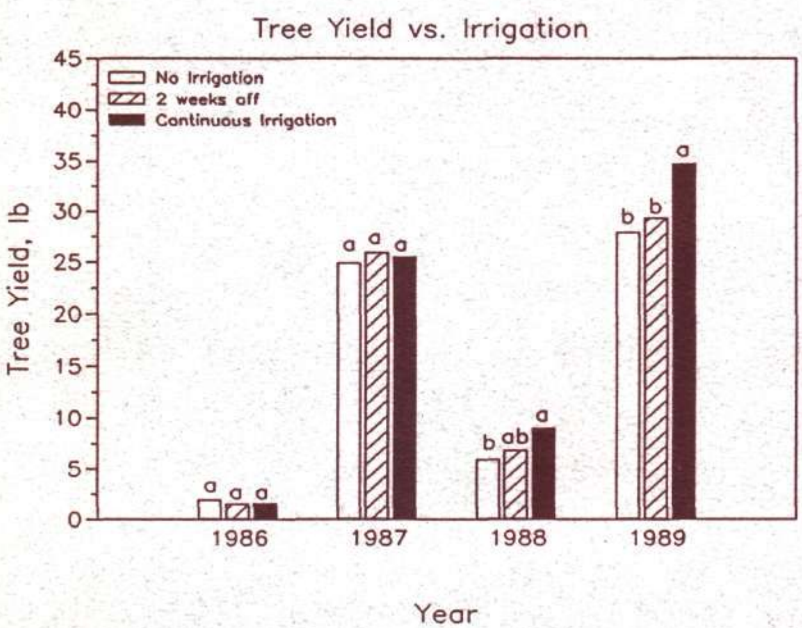


Figure 6. Plot B, yield for three irrigation treatments (natural rainfall, 2 weeks off prior to harvest and continuous). Within year mean separation (a and b) by Duncan's multiple range test, $p = 0.05$.

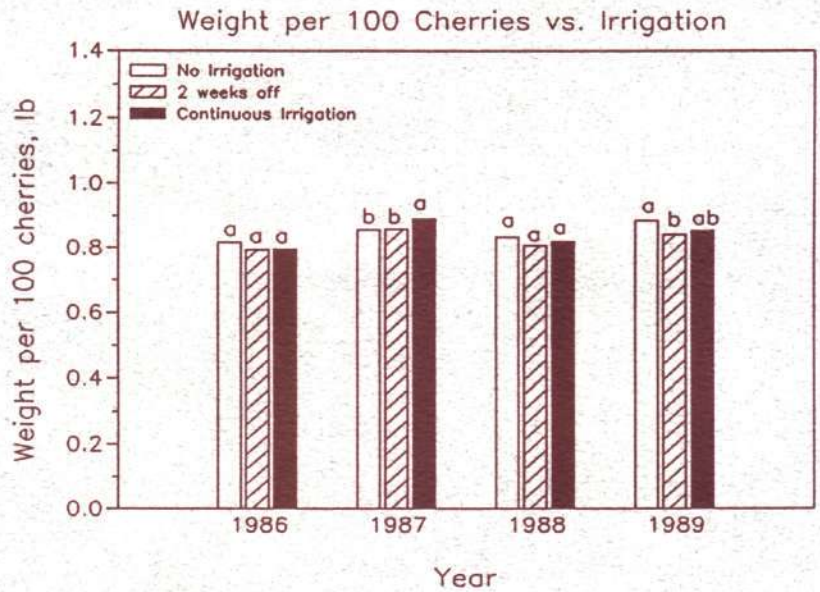


Figure 7. Plot B, weight of 100 cherries for three irrigation treatments (natural rainfall, 2 weeks off prior to harvest and continuous). Within year mean separation (a and b) by Duncan's multiple range test, p = 0.05.

Discussion

It was apparent that mechanical harvesting of young tart cherry trees with the standard harvest system at manufacturer recommended clamping pressures would lead to nearly all of the trees having trunk damage within a few years. These injuries, many severe, presented an excellent environment for borer infestation and secondary rots and diseases. The amount of severe damage from this system was three times greater on irrigated trees, even when irrigation was removed two weeks prior to harvest.

The improved harvest system caused only minimal trunk damage on young trees, even those on continuous trickle irrigation. In addition, the use of trickle irrigation resulted in a significant increase in vigor (trunk cross-sectional area, shoot growth) and yield of young tart cherry trees. Limited studies have also shown that the same principles (the improved harvest system and reduced clamping forces) apply to sweet cherries as well. In response to high clamp forces that do not result in visible damage, sweet cherries appear to develop localized knotty swellings under the bark which later exude gum and easily split during following harvests.

Management Suggestions to Avoid Bark Damage

1. Develop trees with a straight trunk, with at least 30 to 36 inches before the first scaffold limbs. Remove volunteer seedlings, trunk suckers and thick stemmed weeds from around each trunk prior to harvest.

2. Adjust hydraulic pressure on the shaker clamp to the minimum levels recommended for trunk diameter, shaker brand and pad type (Table 2).

Table 2. Maximum[1] suggested clamping circuit pressure by shaker model and pad type.

Trunk Shaker	Cherry Tree Trunk Diameter, inches			
Make and Model	2 - 3	3.5 - 5	5.5 - 7	Over 7
FMC C-clamp,w/Std Pads	NOT RECOMMENDED			100 psi/in. to 1500 psi max[2]
w/Kilby or OMC Pads[3]	500	600	700	100 psi/in. to 1500 psi max
w/D-55 Pads[4]	500	650	NOT RECOMMENDED AT THIS TIME[5]	
FMC Scissors,w/Std Pads	NOT RECOMMENDED			150 psi/in. to 2000 psi max[2]
w/Kilby or OMC Pads[3]	700	900	1100	100 psi/in. to 2000 psi max
w/D-55 Pads	700	900	NOT RECOMMENDED AT THIS TIME[5]	
Friday C-clamp,w/Std Pads	NOT RECOMMENDED			150 psi/in. to 2000 psi max[6]
w/Kilby or OMC Pads[3]	600	800	900	125 psi/in. to 2000 psi max
w/D-55 Pads	600	800	NOT RECOMMENDED AT THIS TIME[5]	
Friday Tri-clamp,w/Std Pads	NOT RECOMMENDED			200 psi/in. to 2000 psi max[6]
w/Scissors-Kit	850	1350	NOT RECOMMENDED AT THIS TIME[5]	
w/Tri-55 Pads	800	1000	1200	100 psi/in. to 1600 psi max
Halsey Scissors				
w/Martin or FMC Pads	NOT RECOMMENDED			100 psi/in. to 2000 psi max
w/Kilby or OMC Pads[3]	550	650	750	125 psi/in. to 2000 psi max
w/D-55 Pads	550	650	NOT RECOMMENDED AT THIS TIME[5]	
Kilby C-clamp,w/Std Pads	500	600	700	100 psi/in. to 1500 psi max
w/D-55 Pads	500	600	NOT RECOMMENDED AT THIS TIME[5]	
Kilby Scissors,w/Std Pads	550	650	750	125 psi/in. to 1500 psi max
w/D-55 Pads	550	650	NOT RECOMMENDED AT THIS TIME[5]	
OMC C-clamp,w/Std Pads	600	700	750	125 psi/in. to 1500 psi max
OMC Scissors,w/Std Pads	600	700	800	125 psi/in. to 1500 psi max
Shipley Scissors				
w/Martin Pads	NOT RECOMMENDED			100 psi/in. to 1500 psi max
w/Kilby or OMC Pads[3]	1050	1350	1500	1500 psi
w/D-55 Pads	1050	1350	NOT RECOMMENDED AT THIS TIME[5]	

[1] Use less pressure without sliding on the bark, if you can.

[2] Use only the FMC soft tubular-type pad; the standard tubular-type pad is too hard.

[3] When OMC particle-filled pads are used, make-up oil must be provided to the clamp during shaking. Consult your dealer for required circuit changes.

[4] D-55 pads are 55 Durometer neoprene block-type pads made by Kilby or Friday (different designs).

[5] Continued use on large trunks will result in cracking and early failure of these soft pads.

[6] Applies to the standard tubular-type Friday pads.

3. Keep the area between the slip belts (flap and sling) properly lubricated and free of debris where the flap directly contacts the trunk (low shear force transmitted between the lubricated flap and sling will minimize shear in the bark). The slip belts will need to be relubricated after every 50 to 150 trees.

4. Maintain the shaker pads in good condition. Use only the soft neoprene block pads or the particle-filled pads. Replace the pads if they are cracked. Replace the slip belts if the nitrile surface has holes because they will cause high shear in the bark.

5. Test the hydraulic relief valves and the check valves in the shaker clamping circuit before the harvesting season, to confirm that the set pressure can be maintained.

6. In young trees or trees in a "bark slipping" condition, reduce clamping pressure, shaking force and frequency to the minimum effective level. Don't shake young trees that are too small for the clamp.

7. Avoid multiple shaking cycles. Operators sometimes use several short duration shaking cycles to remove the last few fruits or those that are slightly immature. This will cause excessive torque on the bark compared to one continuous shake cycle.

8. On high scaffold trees (scaffolds 30 inches or higher) with trunks of 3 inches diameter or more, locate the clamp at the center, or just above center, of the trunk to reduce the power required to shake the tree (the lower the attachment the greater the force and power required to obtain equivalent tree vibration). On very young trees (1.5- to 3-inch diameter trunk), locate the clamp at ground level to obtain an effective shake.

9. Attach the clamp perpendicular to the trunk (the tendency for a very high clamp attachment is to have the shaker arm angled up to the tree, creating a high longitudinal shear).

10. Use sod culture between rows to provide a firm orchard floor for harvester operation (sod culture helps prevent carrier settlement during the shaking operation).

11. Trickle irrigation, an asset to tree growth and vigor, will predispose the trunks to bark damage unless an improved harvest system (with soft neoprene block pads or the particle-filled pads) is used.

12. Harvester operator training is essential if bark damage is to be avoided. Operators must understand the harvester as well as the bark strength limitations of the trunks.

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