Feasibility Study of Using Spiked-Drum Canopy Oscillator for Fruit Thinning

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Introduction

A canopy shaker testing unit was fabricated and assembled on a dedicated UC Davis restored loader to investigate the feasibility of implementing the innovative spiked-drum canopy shaking technology for thinning peaches, or other stone fruits. Exploratory field tests were conducted in May 2006 in the orchards of the UC Kearney Research and Extension Center, in Parlier, followed by tests performed in the orchards of the UC Wolfskill Experimental Orchards, in Winters. These tests had the intent of identifying whether the spike drum canopy shaker had the ability to remove and space fruits on the trees according to grower's expectations.

Material and Methods

Research apparatus. The research apparatus (Fig. 1) was composed of a free rotating spiked drum. Rotation resistance could be added to the shaft of the drum by adjusting the settings of an electronically controlled trailer brake mounted on the base end of the drum shaft. The drum was constituted of five horizontal whorls spaced 8 inches on the drum vertical shaft. Each whorl had 16 equally spaced nylon rods with diameter of 0.75 inches. The nylon rods were padded by the insertion of tygon tubing along their entire length to mitigate fruit bruising caused by occasional rod impacts. The drum diameter was approximately four feet and the drum height approximately three feet. The drum frame was driven by a 10" stroke linear servo-electric motor which was computer controlled for easy adjustment of testing parameters, such as drum sweeping amplitude, oscillating frequency and thinning duration. The entire apparatus was assembled to be easily readjusted in field conditions. The drum resistance to rotation was controlled by an adapted electronic trailer break system, and the machine forward speed was controlled by the hydrostatic transmission of a loader. A restored UCD loader from the Bio. & Ag. Eng. dept was used as the base vehicle for the tests. A 10 kW tow able generator served as the power source to the electric and electronic circuits. The research apparatus will be replaced by a dedicated machine prototype after appropriate operating conditions have been identified in the forth coming research.

Identification of appropriate parameter values. During the initial tests at Kearney, parameter values were randomly chosen and its impact on thinning amount and fruit distribution on the shoots were evaluated. Based on scarce existing canopy shaking literature on fruit thinning, various combinations of sweeping amplitude and oscillating frequencies were incorporated in the writing of the computer programs used to quickly switch among various field operating settings. The thinning duration was controlled by the operator of the loader. Various speeds were

experimented to identify optimum speed conditions. The angle of attach of the spike drum on the canopy was also adjusted to search for optimum values. The hydraulic arm of the loader had the capability to easily adjust the pitch, roll and yaw angles of the platform where the drum system was mounted, and to adjust the drum's height up to the top of the tree canopy. Tests were conducted to verify the effectiveness of the drum brakes on thinning amount and resulted fruit spacing. The breaks were applied at full capacity, turned off, and set at partial loadings between the two extreme conditions.

Study of acceleration of the shoots and rods. A parallel study has been conducted to quantify the acceleration of points located on the drum frame, on the spikes, and on various positions on tagged tree shoots. Accelerometers were attached at the required locations on the shaker and on the shoots. These tests were introduced to compare the amount of shaking received by fruits located at the edge of the shoots versus those located close to the base of the shoots. Data have been acquired, but this is an ongoing study. Hopefully, the results of this study will help improve machine and quality of thinning in future developments.

Results and Discussions

Initial tests were performed on a number of selected trees, at Kearney, by experimenting with various spiked-drum set up parameters while observing the interaction of rods with the shoots and fruits. The oscillating speed, stroke, and yaw, pitch and roll angles of the spiked-drum frame were changed accordingly to search for optimum set up parameters. The quality of thinning was assessed by random evaluation of resulted fruit spacing on the shoots and by counting the number of fruits before and after the shaker had passed. For most of the tests it was found that the part of canopy that was accessible to the rods showed better thinning job (i.e., medium fruit removal level, and resulted uniform fruit spacing on the shoot) than at parts where the rods did not reach the shoots directly, therefore not fully transmitting the vibration to the shoots and fruits.

After considerable experimentation, the most reasonable set up parameters resulted from the tests were 0.2 inch stroke at shaft of the linear motor (displacement is amplified at the rod tips) while vibrating a 12 Hz frequency, with no break resistance applied to the drum and with no significant pitch, row, and yaw angles. More extensive studies are required to completely evaluate the effects of these parameters on thinning quality. The set up was also adopted in the peach and prune orchards at Wolfskill in the follow up tests (Fig. 2). The entire test was conducted at one stretch. In total 16 continuous trees were chosen in a row, and five random shoots were marked from each tree. Before the thinning operation was performed, the number of fruits in each of the marked shoots were counted and noted. After the thinning operation was performed the number of fruits left on the respective shoots were observed, counted and noted. Table 1 shows the compiled results of these tests. It was found that shoots presenting fruit removal levels of 30% and below occurred in 28% of the cases. Shoots presenting fruit removal levels of 70% and higher occurred in 45% of the cases. Consequently, shots presenting fruit removal levels higher than 30% and lower than 70% occurred in approximately 28% of the cases (Fig. 3). It has also been observed that about 10% of shoots were left with fruit clusters, and also around 10% of the shoots were not reached by the rods. It should be mentioned the system may work better for properly trained trees.

Also, it should be valuable to compare this thinning method with hand thinning and shaker thinning, rather than using this absolute standard.

Conclusions

In general, the spiked-drum canopy shaking technology has great potential to be adopted for fruit thinning. However, more studies are required to further refine the technology and apply the learned concepts to the design of a dedicated thinning machine prototype.
The following conclusions can be derived from this study.

1) The spiked-drum oscillator has the ability to go into the tree canopy and remove fruits from specific spots in a branch that is accessible to the rods.

2) For most of the tests, it was found that the part of canopy that was accessible to the rods showed better thinning job (i.e., medium fruit removal level, and resulted uniform fruit spacing on the shoot) than at parts where the rods did not reach the shoots directly.

3) The driving speed has significant influence on the thinning quality and needs to be properly adjusted.

Ideas for future development

Some of the following suggestions could be considered in future studies to make this equipment more successful.

1) The distance between the whorls may be reduced from the actual 8 in to around 6 in.
2) Study the use of longer rods to improve the reach to the inner parts the shoots. This should increase removal of more fruit clusters.
3) Rods can be further padded by the insertion of another layer of tygon tubing on top of the existing layer.
4) The edge of the existing tygon tubing needs to be rounded.
5) Investigate the use of smaller (shorter) drums that may have the capability to move deep in to the canopy. A smaller spiked-drum would have the ability to thin the entire tree canopy by moving the platform that holds the drum around the tree.
6) Improve the existing research apparatus by adding power and rearranging the existing drive unit to make the vibration on the rod tips smoother.
7) It is recommended that an extended evaluation of the existing research apparatus, equipped with few improvements learned from the 2006 tests, be used to collect extensive data. If trees are available, evaluate the performance of the apparatus on well trained trees and compare the results with the performance on commercial trees.
8) It is recommended to compare this thinning method with hand thinning and shaker thinning to get some sense of a more relative standard.

Table 1. Fruit removal resulted after one pass of the UCD experimental spiked drum canopy shaker thinned 80 randomly marked shoots selected from 16 peach trees at the Wolfskill Experiment Station in Winters, CA, in May 31, 2006.

Shoot	Fruit removal, %	Field observations
Tree 1		
A	84	Left a cluster
B	87	Good fruit spacing
C	85	Good fruit spacing
D	94	Excessive removal
E	100	Excessive removal
Tree 2		
A	25	Left a Cluster
B	9	Rod did not reach shoot
C	100	Excessive removal
D	77	Good fruit spacing
E	75	Good fruit spacing
Tree 3		
A	100	Shoot shaken for too long
B	100	
C	67	Good fruit spacing
D	64	Left a Cluster
E	100	Excessive removal
Tree 4		
A	76	Good fruit spacing
B	44	Poor fruit spacing
C	17	Rod did not reach shoot
D	100	
E	17	
Tree 5		
A	71	
B	83	Left a Cluster
C	86	
D	71	Left a Cluster
E	27	Rod did not reach shoot
Tree 6		
A	69	Left a cluster
B	47	Good fruit spacing
C	14	
D	18	Rod did not reach fruit
E	14	Rod did not reach fruit
Tree 7		
A	30	
B	85	Left a Cluster
C	33	Left a Cluster
D	100	
E	100	
Tree 8		
A	33	Good fruit spacing
B	40	Good fruit spacing
C	88	
D	41	Left inside clusters
E	100	Shoot shaken for too long

Tree 9		
A	24	
B	10	
C	32	
D	40	
E	40	Good fruit spacing
Tree 10		
A	9	Rod did not reach shoot
B	29	
C	28	
D	56	
E	21	
Tree 11		
A	46	Good fruit spacing
B	77	Good fruit spacing
C	43	
D	14	
E	100	
Tree 12		
A	57	
B	83	
C	0	
D	79	
E	33	
Tree 13		
A	92	Shoot shaken for too long
B	0	Rod did not reach shoot
C	40	Good fruit spacing
D	31	
E	79	Good fruit spacing
Tree 14		
A	29	Good fruit spacing
B	33	
C	22	
D	15	
E	7	
Tree 15		
A	38	Good fruit spacing
B	100	
C	100	
D	87	
E	79	Good fruit spacing
Tree 16		
A	86	Damaged shoot
B	33	
C	100	
D	73	
E	90	

Fig. 1. Research apparatus assembled to evaluate the spiked-drum canopy shaker for using in the thinning of stone fruits at UC Kearney Experiment Station, (a: linear electric servo-motor, b: spiked-drum unit, c: UCD restored loader, d: electric and electronic power systems, e: 10kW three-phase generator).

Fig. 2. Typical peach tree and shoot representing one of the 16 trees where the evaluating thinning tests were conducted at Wolfskill in May 31, 2006, to assess the capabilities of the spiked-drum canopy shaker in producing expected thinning quality (Zoom: shoot where an accelerometer was mounted for vibration studies).

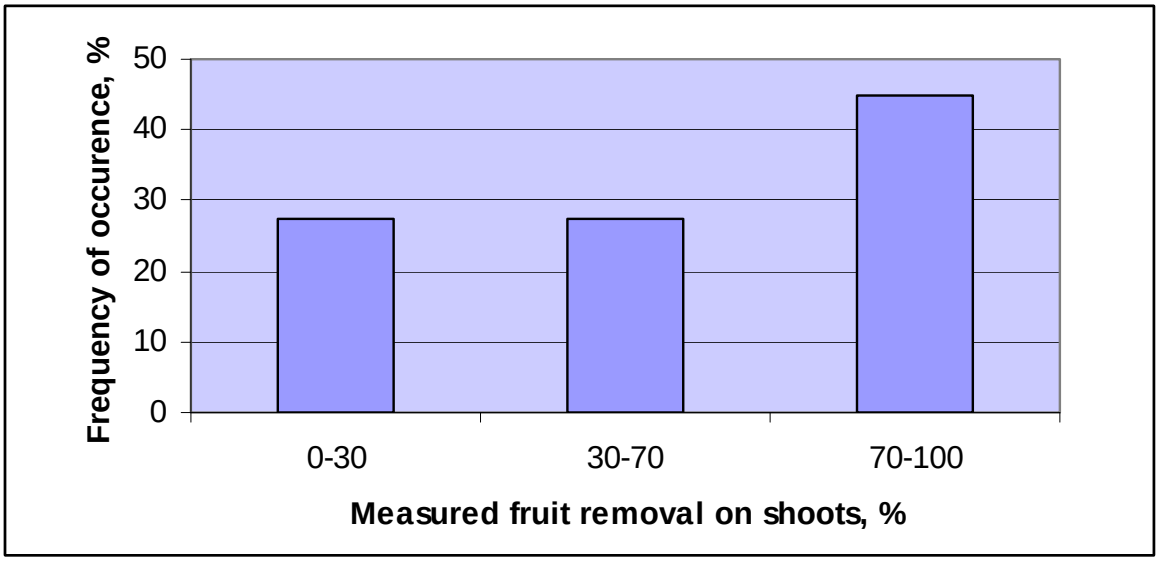

Fig. 3. Frequency of occurrence of fruit removal resulted after one pass of the UCD experimental spiked drum canopy shaker thinned 80 randomly marked shoots selected from 16 peach trees at the Wolfskill Experiment Station in Winters, CA, in May 31, 2006, (compiled from data shown in Table 1).