California Olive Committee 2007 Annual Report

Developing of Mechanical Harvesting for California Olives: 2007-2010

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ABSTRACT

The research from 2007 produced four conclusions. First, most mature trees need to be trained for picking head harvesters. Second, we should be evaluating currently available harvesters for both younger and older trees. Third, we should be observing, and incorporating information from other harvesters into the current picking head harvester, DSE 007. Fourth, the screening of abscission compounds should continue, but as a long term objective.

The DSE 007 was tested in two orchards in 2007. In a 21-year old traditionally trained, 24' X 24' Manzanillo orchard with an 5.5 ton per acre crop, the DSE 007 harvested 60 trees in 10 hours with a final efficiency of 11% . Fruit value in price per ton was decreased an average of 29% relative to controls. Approximately 73% of the trees were damaged.

In a 9-year old hedgerow, 12' X 26' orchard carrying a 9.5 ton per acre crop the harvester had 81% removal and 73% efficiency by weight. Mechanically harvested values per ton were 68% to 93% of hand harvested values per ton. Approximately 13% of the trees were damaged by the harvester.

In a test of young trees, a test of a wrap around catch frame trunk shake harvester removed 53% of the fruit.

Commercial size processing samples from the hedgerow orchard were submitted to food technologists at Bell Carter and Musco Family Olives. These samples were intensively evaluated as fresh fruit, were processed, and will be re-evaluated intensively after processing. The fresh fruit evaluation will be correlated with the processed fruit evaluation. This data should be available in March 2008.

The abscission trials demonstrated ethephon and a numbered compound, # 901, had the best potential for decreasing fruit detachment force. However, ethephon was erratic in performance and had leaf loss. Developing an abscission agent remains a long term goal.

Early yields demonstrate hedgerow orchards produce as well as conventionally trained trees. A 6-year old trellised canopy measuring 12' tall X 6' wide and skirted up 3' produced as well, within a ton over a cumulative 4-year period, as conventionally pruned trees. A preliminary test with three different trunk shakers indicated trunk shakers have potential for harvesting younger hedgerow trees.

In summary, to develop mechanical harvesting of table olives we need to focus simultaneously on tree pruning, further improvements in the DSE 007, evaluate other machines for direct use and whatever innovations can be incorporated into the DSE 007.

INTRODUCTION

The California table olive industry will need to develop mechanical harvesting if it is to survive economically. Hand harvesting costs are remaining above $350.00/ton, and the gross return per ton is sure to drop from the 2007 peak $1050.00/ton price. Current immigration legislation suggests hand labor pools will decrease, and become more expensive.

The major obstacle in mechanical harvesting is developing a harvester that can harvest the 27,548 acres of existing orchards. Manzanillo olives are borne on 1-year old, vertical flexible shoots. The olives are harvested physiologically immature with fruit detachment forces over 500 grams relative to their 10-15 gram weight. With modification current pistachio and prune trunk shaker plus catch frame tandem units could successfully harvest young olives. However mature olive tree canopies require contact for efficient fruit removal. The current picking head harvester, the DSE 007, has demonstrated removal efficiency as high as 98% removal by weight, **if the tree is properly pruned.** However, poor final harvester efficiency, due to inability to contact some fruit in the canopy, incompetent fruit catching, and fruit damage are also problems.

An abscission compound could alleviate the above problems by decreasing fruit removal force. However, trials thus far show the most likely ethylene releasing compound, (ERC), ethephon, to perform erratically. Further, developing and registering an abscission compound is a minimum 10 year process.

Antioxidant pre- and post-harvest compounds can possibly decrease fruit damage development, and are demonstrating some promise.

In summary, the most rapid path to successful mechanical harvesting will mean using the tools we have available to us now, and continuing to work on the longer term prospects. Short term goals should focus on shaping existing trees for picking head and trunk shaker harvesters, and evaluating, improving and adapting from all existing harvesters. Longer term goals include developing an abscission compound and pre- and post-harvest compounds to decrease fruit damage.

This project has four sections; the procedures and results will be described within each section.

I. Evaluating Harvester Fruit Removal, Efficiency and Effects on Fruit Quality
II. Screening and Testing Abscission Compounds
III. Screening and Testing Antioxidant Pre and Postharvest Treatments
IV. Developing Hedgerow Orchards for Mechanical Harvest

Parts I, II and IV are reported here. Part III is reported in a separate report by Kitren Glozer.

I. Evaluating Harvester Removal, Efficiency and Effects on Fruit Quality.

Prior to the harvest season it was established with Bell Carter Olives and Musco Family Olives that to accurately demonstrate the effects of mechanical harvesting on processed fruit quality required 5 and 10 ton samples respectively. Because the limiting factor in developing successful mechanical harvesting is processed fruit quality we agreed to deliver 5 and 10 ton samples. This limited the number of samples we could take. Therefore, all harvesting was done at one ground speed and head CPM, and could not be truly replicated or randomized in the field. Bin sub sampling was done at both processors to produce replication in the fruit samples.

Steve Sibbett and Neil O'Connell retired and current Tulare County Farm Advisors secured Rocky Hill Ranch as field cooperators in March 2007. In May 2007, based on bloom, two orchards were selected and rows tagged.

1. A 21 year old, 24' X 24' diamond spacing, 76 trees per acres traditional orchard. Completely randomized block design: 11, single row replications 80 trees/row.
2. A 9-11 year old 12' X 26', hedgerow, 139 trees per acre orchard. Completely randomized block design: 8, single row replications of 70 trees/row.

OBJECTIVES

Our objectives for this section were to evaluate:

- Fruit removal efficiency
- Final harvester efficiency
- Tree damage
- Effect on fruit value and quality at the receiving station
- Processed fruit quality and value.

PROCEDURES

Harvester Evaluation

Hand harvested samples, 5 and 10 tons respectively, from both orchards were delivered to both processors. The control samples from the traditional orchard were delivered 9/18-19/2007 and samples from the hedgerow orchard were delivered 9/28-10/1/2007. Harvesting dates were based on orchard maturity. The traditional orchard had an 8.5 ton per acre crop versus 13.5 tons per acre for the hedgerow orchard.

In both orchards the mechanical harvesting procedure was as follows:

- The harvester was run at 0.25 mph and picking head amplitude of 180 CPM as steadily as possible, filling all bins to 6 inches below the rim. The minutes required to fill each bin was determined.
- In 1 row of the 5 harvested rows, tarps were placed below the trees before mechanical harvesting, and the fruit collected after the harvester passed and the fruit weighed.
- After mechanical harvesting all five rows were hand gleaned and weighed.
- These bin weights were used to calculate the % removal and % final harvester removal.

Percent fruit removal was calculated as follows:

$$\frac{\text{(bin weights) + (weight retrieved from ground tarps after mechanical harvesting)}}{\text{(bin weights) + (\{weight retrieved from ground\} + \{gleaned from tree\} after harvester)}}$$

Percent fruit removal efficiency was calculated as follows:

$$\frac{\text{(bin weights)}}{\text{(bin weights)} + (\{\text{weight retrieved from ground}\} + \{\text{gleaned from tree}\}\ \text{after harvester})}$$

Harvester Efficiency Visual Evaluation

After harvest the harvested rows were visually evaluated and rated for how and where unharvested fruit remained in the canopy. The tree was sectored into six quadrants: upper leading, center and trailing canopy and lower leading, center and trailing canopy. A simple fruit present/fruit not present discriminator was used.

Tree Damage Evaluation

The hand and mechanically harvested rows were evaluated by counting all trees in the rows with 1 or more broken branches.

Fresh and Processed Fruit Quality Evaluation

Four types of fruit samples were delivered for fresh evaluation; hand harvested fruit, mechanically harvested fruit, fruit dropped on the ground after mechanically harvesting, and fruit gleaned from the tree after mechanically harvesting. Fruit was delivered to the Gene Welch at the Orange Cove receiving stations for transport to Dr. Jane Yegge at Bell Carter Olives and to Mr. Ed Melansio at the Exeter receiving station for transport to Abdul Sigal MS at Musco Family Olives. Grade sheets on each delivery were received from each receiving station.

At the Bell Carter and Musco processing plants the bins comprising the 5 and 10 ton hand-harvested and mechanically-harvested samples were sampled individually with a detailed procedure the two food technologists developed together. The samples were processed on a commercial scale, were tank sampled throughout the processing, and were canned in January 2008. The canned samples will be evaluated by both technologists cooperatively with Dr. Diane Barrett, Food Science and Technology, UC Davis. After laboratory evaluation the samples will be evaluated by the industry at a meeting in March 2008.

Harvest Record

1. Traditional Orchard Harvest. Machine harvesting for the traditional orchard started October 1 and completed October 3, 2007. One side of 40 trees and both sides for 40 trees were mechanically harvested; thus only 0.75 of the 11 rows originally selected were harvested mechanically. The 10.25 rows remaining were hand-harvested October 4-9, 2007. Ground fruit was collected under 40 trees and weighed, but due to the small amount samples were not sent to the processor. Broken branches were counted on October 4, 2007.

2. Hedgerow Orchard Harvest. Machine-harvesting was done October 8–10, 2007. Five rows were mechanically harvested followed by hand-gleaning; the mechanically-harvested samples were delivered to both processors on October 8 and 9, the hand-gleaned samples only to Musco on October 10. On October 9, one row was tarped below the trees and the fruit collected after mechanical-harvesting and before hand-gleaning. This sample was delivered only to Musco on October 10. A broken branch count and a visual evaluation of fruit remaining in the trees were done October 10, 2007.

RESULTS

In the results given below the unprepared pruning status of the trees prevented an accurate evaluation of the DSE 007. As a result only 0.75 of one row of 11 in the traditional orchard was able to be harvested. In the hedgerow orchard the tree canopies were more amenable to mechanical-harvest and 5 of 8 rows were harvested.

Table 1 below gives the average calculated % harvester fruit removal and % final harvester efficiency. As can be seen in this table, traditional orchard canopy shape and size greatly adversely affected the harvesting efficiency of the DSE 007. The efficiency of the DSE 007 in the hedgerow orchard was higher by a factor of 7, demonstrating the importance of tree pruning.

The average time to harvest a half ton bin, if no problems developed, ranged from 13 to 18 minutes. Conservatively, the DSE 007 could harvest 1.5 tons per hour. These trees were unprepared for mechanical harvesting and had a particularly heavy crop. With proper pruning and a lighter crop the DSE 007 could potentially move as fast as 0.50 MPH and harvest 2.5 tons per hour.

Table 2 below is a visual evaluation of tree sectors with fruit remaining in the canopy after mechanical harvesting. The data strongly reinforces canopy shaping and thinning will be necessary for effective mechanical harvesting. As can be seen from the data, the top of the tree was more completely harvested than the bottom half of the canopy and the canopy center was much more easily harvested than the leading and trailing edges, in that order.

Based upon this data, tree quite specific suggestions can be made for shaping olive trees for mechanical harvesting. First, trees should be skirted to remove the lower canopy that the DSE 007 harvested poorly, and trunk shakers could not remove at all. Second, the if the in-row canopy surface can be hedged, mechanically or by hand, it would eliminate the necessity for the DSE 007 head to extend into the canopy as this resulted in the tree branches clumping in the heads, damping head motion, decreasing fruit removal, and often breaking limbs.

The % of broken branches in Table 3 demonstrates that tree training method strongly affected tree damage by the harvester. As can be seen below a traditionally trained orchard, particularly if well cropped, had a much higher chance of sustaining broken branches. This data could not be analyzed as the treatments were not randomized and replicated, however, the magnitude of the difference between harvesting treatments within an orchard type and between orchard types strongly suggests traditionally trained trees are unsuitable for the DSE 007. As with harvester efficiency data from Table 2, this data strongly suggests olive trees must be shaped for efficient harvesting with picking head harvesters.

Table 1. Harvester % Removal Efficiency and % Final Efficiency by Weight*.

Traditional Orchard	Hedgerow Orchard
* total removal not measured	**81 % removal efficiency**
11% final efficiency	**73% final efficiency**
60 trees total	350 trees total

Table 2. Visual Evaluation of Tree Sector Harvest Ability as a % of 350 Hedgerow Orchard Trees.

Tree Sector	**% of Trees with Remaining Fruit**
Top leading	7%
Top center	4%
Top trailing	10%
Bottom leading	35%
Bottom center	30%
Bottom trailing	41%

Table 3. Tree Damage as % of Trees with 1 or More Broken Branches within Orchards.

Traditional *		**Hedgerow****	
Hand	**Mechanical**	**Hand**	**Mechanical**
11%	73%	8%	13%

*100 trees of each

** 350 trees of each

Table 4. Effect of Harvest Method on Olive Value per Ton.

Orchard Type	**Traditional**		**Hedgerow**	
Processor	***Bell Carter***	***Musco***	***Bell Carter***	***Musco***
Hand harvest	976.07	1031.14	880.24	870.90
(date)	(9/18/2007)	(9/19/2007)	(10/1/2007)	(9/28/2007)
Mechanical harvest	698.11	737.91	596.19	806.56
(date)	(10/3/2007)	(10/4/2007)	(10/8/2007)	(10/8/2007)
(% of hand harvest value)	(72%)	(71%)	(68%)	(93%)

The data in Table 4 demonstrates that mechanical harvest decreased olive crop value at both processors. Both processors graded mechanically-harvested olives from the traditional orchard as worth 72% (Bell Carter) and 71% (Musco) of the paired hand-harvested sample. Mechanically-harvested olives from the hedgerow orchard were not graded as equally by the processors. Musco graded the mechanically-harvested olives at 93% of the value of hand-harvested olives whereas Bell Carter graded the olives as worth only 68% of hand-harvested olives. The grade sheets for these samples showed these decreases in value were the result of increases in unspecified culls (Musco) or mutilation, bruised, broken skin, and overripe, (Bell Carter).

Dr. Uriel Rosa’s data from the 2006 harvest demonstrated the majority of damage sustained by olive fruits was a result of the olives contacting the harvester rods and the harvester frame. Hopefully, changes in the structure and operation of these factors decreased this damage in 2007.

A much more detailed grade analysis, along with that for processed olives, from both processors will be available in March, 2008. Hopefully, a better correlation of the freshly harvested and processed olive quality will enable us to judge processing quality without processing the 5 and 10 ton samples processed this year.

The data obtained in 2006 and 2007, particularly the harvester efficiency difference between traditional and hedgerow trees suggests fruit removal and final harvester efficiency are a function of fruit accessibility to the picking head rods. Therefore, tree skirting, hedging, topping and thinning, factors that make the olives more accessible to the harvester picking head, are the factors that could potentially improve harvester removal and final efficiency.

Dr. Rosa's analysis of fruit damage in 2006 indicated most fruit damage was sustained when the olives were struck by the harvester rods and harvester frame. Therefore fruit damage could potentially be decreased by changes in the harvester or its operating parameters. These could include decreasing the number and density of the picking head rods, and increasing frame padding. Operating the harvester at a faster groundspeed and decreased head amplitude could also decrease damage.

IV. Developing Hedgerow Orchards for Mechanical Harvesting

A number of trunk shaking harvesters already exist for other crops; oil olives, pistachios, prunes and almonds. If an olive tree could be properly trained these shakers might have potential, particularly for trees. With this objective, a hedgerow orchard with four training methods was established at Nichols Estate in 2001.

OBJECTIVES

Our objective for this section were:

- To evaluate yield of hedgerow trained trees versus conventionally trailed olive trees.
- To demonstrate preliminary harvest ability with three different trunk shaker harvesters.

PROCEDURES

The orchard was planted 7/08/2001 on a N-S axis at a 12' X 18' spacing at 202 trees per acre. The center row of 7 was a Sevillano pollinator row. The 6 flanking rows had the following training treatments replicated 4 times in 3 parallel sections of 8 trees per row.

1. Conventionally trained trees
2. Free standing espalier
3. An espalier woven between three horizontal wires at 1, 2, and 3 meters.
4. An espalier trained and tied to the three horizontal wires at 1, 2, and 3 meters

The middle 8 tree row of the 3 rows was hand-harvested, the aggregate 8 trees weighed and delivered to the processor for a dollar per ton value. Hand-harvesting commenced in 2004, and we now have four years of yield, 2004 – 2007, given in table 7 below. This experiment will not be definitive until the yields plateau at full maturity. However, thus far the results indicate yield is not greatly diminished by training to an espalier shape to facilitate trunk shaker harvesting. As can be seen by the data below, all the training treatments were within approximately one ton per acre, over a four year harvest period, of the conventionally trained trees. While this is promising it remains to be demonstrated whether on not olive trees can be maintained as the 12' tall tree with a 6' wide canopy, skirted up 3' off the ground, that we predict will be ideal for mechanical harvesting, and still produce well enough to be profitable.

Table 7. Effect of Training Method on Young Orchard Productivity in Tons/Acre.

Harvest Year	**2004**	**2005**	**2006**	**2007**	**Cumulative**
Treatment	T/A	T/A	T/A	T/A	T/A
Conventional	4.09	1.75	2.81	6.39	15.04
Free Standing Espalier	3.66	1.51.	2.26	6.40	13.81
Trellised, woven espalier	4.21	1.68	2.26	6.07	14.24
Trellised, tied espalier	3.58	3.45	1.76	7.51	16.30

On October 11, 2007 three different trunk shaker harvesters, a wrap around catch frame trunk shaker, a pistachio plus catch frame harvester and a prune trunk plus catch frame harvesters were demonstrated on 3 of the woven trellis treatment trees. This preliminary evaluation demonstrated sufficient removal, visually estimated at over 50%, good enough results to warrant more complete trials in 2008. A more complete trial with the wrap around trunk shaker harvester produced 53% fruit removal on younger unprepared trees.

CONCLUSIONS

This is the first year of a four-year project. The combined results from 2006 and 2007 have produced the following conclusions. These conclusions should also be the priorities, in the given order, of the olive mechanical-harvesting research program.

1. To obtain meaningful data with the DSE 007, and any other harvesters tested, the trees will need to be prepared with skirting, topping and hedging, and perhaps canopy thinning. Therefore, our primary goal should focus on how to prune mature trees, and train young trees, for mechanical harvesting. This pruning should be evaluated for its effect on yield.

2. Intensive engineering evaluations of how the DSE 007 removes fruit and causes damage should continue to determine how to improve these parameters.

3. Other available harvesters should be evaluated, and any of their advantages adapted if possible.