OBJECTIVE II

Evaluation of Mechanical Harvester(s) Efficiency and Effects on Fruit Quality and Value

A. ENE Inc. "Terry I" and "Terry II" self propelled trunk shakers with pistachio catch frames
B. Noli trunk shaker only, without catch frame
C. Agright canopy contact harvester; self-propelled with catch frame

INTRODUCTION of OBJECTIVE II

The two picking technologies currently available for evaluation are the canopy contact heads and trunk shakers. Trunk shaking harvesting of oil olive trees is common in Europe. In the 1960s, the University of California also developed pruning methods, and an 'inertia head" shaker for mature California table olive trees. However, the technology, never widely adapted, was designed exclusively for larger trees, not younger hedgerow orchards. Because a younger hedgerow orchard, developed by Krueger and Ferguson, (discussed under Objective III.B of this report), now exists, there is an opportunity to examine both a canopy contact head and trunk shaking harvesters in young hedgerow table olives.

For trunk shaker harvester evaluations in 2009 the companies and machines selected were two versions of the ENE Inc. trunk shaker, "Terry I" and "Terry II" (**Fig. 2.1**), named for the hydraulic engineer who developed the shaker heads, and a Noli Spanish trunk shaker. The ENE Inc. machines had a double-sided modified pistachio harvester catch frame with a bin take out system. The Noli head was front mounted on an almond shaker cab and therefore had no catch frame or take out system. As a result the trials with the Noli were more limited.

Fig. 2.1. ENE Inc. Terry II modified pistachio trunk shaking harvester with catch frame harvesting at Nickels Soils Laboratory on 5 October 2009. Mr. Terry Tompkins is operating the harvester.

The canopy contact machine evaluated was a modified Agright over the row pomegranate harvester, the Olivia **(Fig. 2.2)**. Due to harvester size limitations only a limited, non-replicated trial was conduced on the Agright. The Agright Olivia harvester in the fully lowered position has a top closure height of 1.6 feet, a bottom picking rod height of 3 feet, a top picking rod height of 8.8 feet and a top closure height of 1.6 feet. The Olivia has a clear passage from the ground of 9.3 feet, a left and right clear passage width of 4.75 feet and 2.6 feet of rod penetration into the tree canopy from both sides. The pruning required to make the trees suitable for the Olivia decreased the yield significantly relative to the trees in which the trunk shaking harvesters were evaluated. Therefore, as both the number of replications, and the canopy of the trees harvested by Olivia were different from those harvested by trunk shakers, the final removal efficiencies of the three trunk shaking harvesters can be roughly, but not statistically, compared to the efficiency of the Olivia.

The objective was to evaluate efficiency, and effects on fruit quality of these four machines. As the analyzed data provided below demonstrates, trunk shaking of young hedgerow orchards has potential, but is currently still below the 80% necessary removal efficiency. Similar, but not strictly statistically comparable analyzed results, were obtained for the Agright Olivia.

Fig. 2,2. Agright Olivia canopy contact head harvester operating in Nickels Soils Laboratory hedgerow olive orchard on 30 September 2009. Mr. Richard Loquaci of Madera Ag Services is operating the harvester.

PROCEDURES of OBJECTIVE II

Locations: Nickels Estate: Greenway Ave, Arbuckle CA
Planted 7-8-01. Tree spacing = 12'x18' or 202 trees/ac
'Manzanillo' cultivar with Sevillano (S) pollinators; center row budded to Sevillano 07-03

May 2009: Trees were trained and chemically thinned.

30 September – 7 October 2009:
Harvest trials were conducted with two ENE Inc. trunk shakers, "Terry I" and "Terry II" , a Noli Spanish trunk shaker, and a modified pomegranate harvester, Olivia.

Harvest Procedure:
Each trunk shaking harvester shook one replication in eight rows.

- catch frame was cleaned
- fruit in bin was weighed in field using a bin scale*
- fruit on ground under tree was collected and weighed in the field using baby scale*
    - held in extra bin for the entire row
- fruit remaining on tree was hand harvested and weighed in the field with baby scale*
    - held in extra bin for the entire row

- mechanically harvested fruit in the bin was sent to Orland Musco grading station for weight and COC grade and value
- two 40 pound samples were drawn from each of the replications and each divided into two 20 lb samples
    - two 20 pound samples each were sent to Musco Olive Company and Bell Carter for
        - Fresh processing
        - Processing after storage
    - These samples will be sent to Dr. Guinard for:
        - Sensory panel evaluation after March 2010
        - Consumer panel evaluations after March 2010

* These three field weights, and their confirming weights at the receiving station, were used to calculate the calculate harvester removal efficiency and final harvester efficiency as follows:

$$\textbf{Fruit Removal Efficiency} = \frac{\textbf{(fruit in harvest bin + fruit on ground)}}{\textbf{(Fruit in bin + fruit on ground + fruit remaining in tree)}}$$

$$\textbf{Final Harvest Efficiency} = \frac{\textbf{(fruit in harvest bin)}}{\textbf{(Fruit in bin + fruit on ground + fruit on tree)}}$$

Data Analysis

A method of analysis sometimes referred to as “box and whisker plots” was used to analyze this data (see **Fig. 2.3**). It is particularly applicable to data in which one wants to see the range of values within treatments.

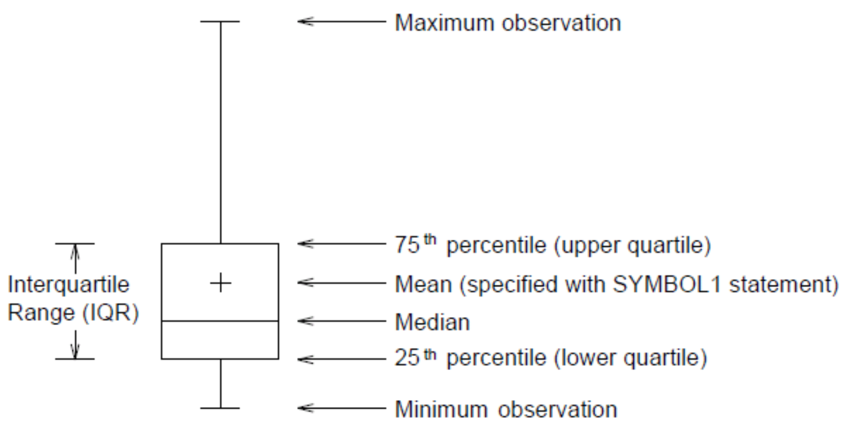

Fig. 2.3. “Box and whisker plots”.

When describing a set of data, without listing all of the values, we can use measures of location such as the mean and median. It is also possible to get a sense of the data's distribution by examining the (1) *minimum*, (2) *maximum*, (3) *median* (or *second quartile*), (4) the *first quartile*, and (5) the *third quartile* (**Fig. 2.3**). Such information will show the extent to which the data is located near the median or near the extremes.

The first quartile is the middle (the median) of the lower half of the data (**Fig. 2.3**). One-fourth of the data lies below the first quartile and three-fourths lies above (i.e., The 25th percentile). The third quartile is the middle (the median) of the upper half of the data. Three-fourths of the data lies below the third quartile and one-fourth lies above (i.e., The 75th percentile). A quartile is a number; it is not a range of values. A value can be described as "above" or "below" the first quartile, but a value is never "in" the first quartile. A ‘box plot’ or ‘box and whisker plot’ describes (graphically) all these summary statistics, giving a graphic of the distribution of the data. The first and third quartiles are at the ends of the box, the median is indicated with a vertical line in the interior of the box, and the maximum and minimum are at the ends of the whiskers.

All data were analyzed by standard statistical analysis using Statistical Analysis Systems software (SAS Institute, Cary, NC) to perform the means separation (Duncan’s multiple range test and LS means; 5% level of significance) and analysis of variance (PROC GLM); distributions analyzed by PROC UNIVARIATE AND PROC BOXPLOT.

RESULTS of OBJECTIVE II

Final Trunk Shaking Harvester Efficiencies and Effect of Harvester on Fruit Quality &Value

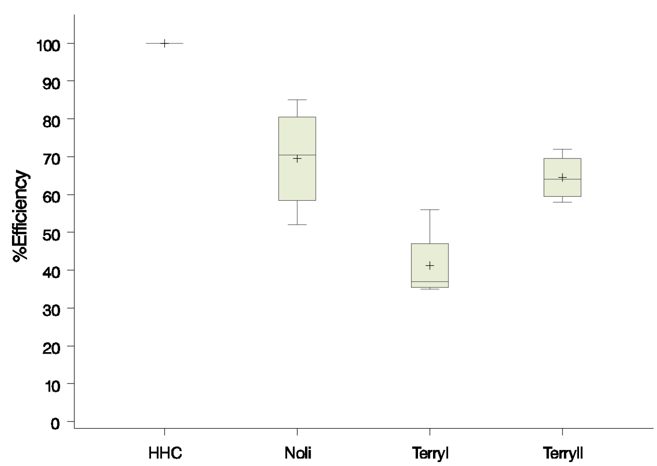

Fig. 2.4. Analyzed final harvest efficiencies of the three trunk shaking harvesters (Noli, Terry I, Terry II) relative to the hand harvested control, HHC.

The analyzed final harvest efficiencies of the three trunk shaking harvesters relative to the hand-harvested control, HHC, are shown in **Fig. 2.4**. The HHC trees were considered to have had 100% of the fruit removed in all four replicates, and therefore the data display no variability for efficiency. There was no significant difference in the final harvest efficiency between the Noli trunk shaker (had no catch frame) and the Terry II, but both had significantly higher final harvest efficiencies than the Terry I. All were significantly less efficient than the hand harvest.

As discussed earlier, the results with the Noli trunk shaker cannot be strictly compared to the Terry I and II because the lack of a catch frame limited the number of replications that could be done. As a result the data from the Noli had the widest distribution of efficiency among the harvest technologies, as results were highly variable from tree-to-tree.

Only the data from the ENE Inc. Terry I and II can be considered to be statistically comparable to the hand harvest control in that sufficient replications were done to produce comparable data. This data demonstrated that the ENE Inc. Terry II was significantly more efficient than the Terry I. Thus far, the ENE Inc. Terry II is the best performing trunk shaker tested. However, it averaged only 64% efficiency, 16% less than the 80% needed.

Loss from the catch frame was minimal; less than a pound per tree and easily equal to that of hand harvest. As a result the harvester removal force and final harvester efficiency are essentially the same.

The previous problem with trunk shaking trees (i.e, trunk barking) was largely eliminated by decreasing shaker head clamping strength below 1000 psi. However, in the future it would be advisable to develop a method of measuring bark strength as a function of irrigation status to ensure barking is totally eliminated. There was little branch damage caused by the trunk shakers. The shakers also sometimes disturbed the soil around the trunk. For this reason all trunk harvesting was followed by a field capacity irrigation.

In summary, the major problem with trunk shakers is the final harvester efficiency of 64%, is not the necessary 80% final removal efficiency our economic analyses demonstrate is needed. In our observations the shakers were more efficient at removing fruit closer to the trunk. Large clumps of olives at the ends of longer branches in the top quarter of the canopy were resistant to trunk shaker harvesting. A possible solution might be to prune these branches off as they are observed during harvest. It also suggests that chemical thinning; both to eliminate these large clumps and increase fruit size as heavier olives harvest more easily, would enhance trunk shaking. Thus, the solution to increasing the efficiency of trunk shakers appears to be to change the tree as well as improve the harvester and harvesting parameters.

Table 2.1 gives the final harvest efficiencies as well as the canning percentages and adjusted price per ton. The data clearly shows there were no significant differences in either canning percentage or adjusted price per ton among the mechanically harvested olives, or between them and the hand harvested olives. Therefore trunk shaking can produce olives with quality and value equal to that of hand harvested olives.

These olives were delivered to Musco and Bell Carter immediately after harvesting for both fresh and stored processing. Lee and Guinard will evaluate the sensory characteristics and consumer acceptability in Spring 2010. Even though these olives were harvested in 2009, versus 2008 for the olives evaluated by Lee and Guinard in Objective I of this report, they have virtually identical canning percentages and adjusted values per ton. Therefore it is expected, that as with olives harvested with the canopy contact head harvester in 2008, these olives, when processed, will be virtually indistinguishable from hand harvested olives. The sensory and consumer evaluations will be available by July 2010.

Final Harvester Efficiency of Agright Olivia Canopy Contact Harvester and Harvester Effects on Fruit Quality & Value

The Agright Olivia, an over the row modified pomegranate harvester, was not evaluated in a randomized replicated trial. However, in two 18-tree rows it produced an average of 67% final harvest efficiency with a canning percentage of 93.5% and an average value per ton of $1071.96 per ton. The olives left in the tree appeared to be primarily closer to the trunk; unlike the better interior fruit removal of the trunk shakers. The harvester damaged 23% of the trees including

Table 2.1. Final Trunk Shaking Harvester Efficiency and Harvester Effects on Olive Quality and Value

Harvest method	Harvest efficiency	%Cannable fruit	Adjusted value per ton ($)
HHC	100.0 a [x]	97.0 a	1178.6 a
Noli	69.5 b	94.1 a	1146.9 a
Terry I	41.2 c	94.8 a	1147.3 a
Terry II	64.5 b	95.6 a	1147.0 a
Significance	***	NS	NS

[x] Means separation within columns by Duncan's multiple range test; *P* = 5%. Where letters are different within columns, means are significantly different; level of significance by ANOVA ***, NS = significant at 0.1% and non-significant, respectively.

pulling one tree from the ground. Had the trees had been properly pruned the harvester would have probably achieved the very high efficiencies observed with the MaqTec Colossus in Argentina in 2007, and inflicted little damage. The Agright Olivia harvester in the fully lowered position has a top closure height of 1.6 feet, a bottom picking rod height of 3 feet, a top picking rod height of 8.8 feet and a top closure height of 1.6 feet. The Olivia has a clear passage from the ground of 9.3 feet, a left and right clear passage width of 4.75 feet and 2.6 feet of rod penetration into the tree canopy from both sides. Successful harvesting with the Olivia would require a tree with no stiff wood above 10 feet high, beyond 4 feet wide and below 4 feet.

As with the olives harvested by both the earlier tested canopy contact harvester and the tree trunk shaking harvesters evaluated this year, the harvested olive's receiving station grade and value demonstrate these olives would also produce processed olives that are indistinguishable from hand harvested olives.

Finally, as with the trunk shaking harvesters evaluated in 2009, it appears the way to improve the final harvesting efficiency of the Olivia is to train young trees into a high-density hedgerow. The Olivia is unsuitable for California's existing olive orchards; the trees are too large.

CONCLUSIONS of OBJECTIVE II

The three trunk shaking harvesters and one canopy contact harvester evaluated this year all produced fruit that, based upon canning percentage and adjusted price per ton, would produce processed olives that are indistinguishable from hand harvested olives. What must be improved is the fruit removal percentage. The data thus far strongly indicates this can be done through both machine improvements and tree training and pruning.