Performance Evaluation of a Canopy Shaker Harvester Monitored by the Olive Yield Monitor (OYM) Developed at UCD. Part III of "Damage Mitigation of California Table Olives Mechanically Harvested"

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ABSTRACT

Manual harvest costs for olives in California account for more than 50% of grower's gross return. Decreasing harvest cost by implementing mechanical harvesting with increased fruit removal efficiency, without bruising fruit, is a promising way to increase the profit margin in olive production. Two mechanical harvesting concepts were analyzed in 2008 to harvest table olives: canopy shaker and trunk shaker.

Field tests with the DSE canopy shaker harvester have produced quality fruit acceptable to the processors, indicating the shaker head has achieved our goal of picking the fruit without producing excessive fruit injury. We do not consider the penalties imposed by the processors for excessive trash and late and shriveled fruit as fundamental problems because these could be solved by fans and harvesting at the proper time. On the down side, however, the in-field tests and field performance of the DSE harvester, as monitored by the on-board Olive Yield Monitor (OYM)(from UC Davis), indicated that the harvester field capacity could not be increased to levels already obtained in 2007. It was a consensus, but not a surprise, because it has been pointed out by DSE that the ideal ground harvesting speed for their harvester was around 0.25 mph. Perhaps, with operator training a speed of 0.5 mph could be attainable. However, 1.0 mph speeds are far beyond reasonable for the tested equipment. Results from our collected GPS and hand-written time losses data also indicated machine reliability needs to be increased. Time lost during the trials, because of conveyor belt overload or machine component reliability, excessively reduced the effective field capacity of the harvester.

Field tests performed with trunk shakers (please see Louise Ferguson's 2008 report for machine evaluation results) have shown that the current California trunk shaker equipment have been developed and work very well for nuts. The adaptation to olives, however, has progressed fast, especially in this year. Olive trees present unique aspects that require some resizing and reengineering of the fundamental aspects of vibrating young olive trees. The fruit harvested by this type of equipment show excellent quality, comparable to hand harvested fruit (please refer to Louise Ferguson's 2008 report). However, it is common sense that if this principle will be extensively adopted in California, trunk shaker bark injury has to be understood and controlled, if not completely eliminated. The progress achieved by one shaker manufacturer at the end of the season was encouraging. We are looking forward to working along with ENE in 2009 to implement a few principles on a new shaker head that intends to mitigate bark damage, increase fruit removal efficiency, and at same time enhance shaker controllability. We have worked closely with ENE and COE to instrument and evaluate the vibration characteristics of their shaker heads and have submitted exclusive technical reports directly to them. Dr. Sergio Castro-Garcia has been instrumental in this analysis. He brought along great experience acquired from testing and using olive shakers adapted for olive oil harvesting that has been employed in Europe for many years.

INTRODUCTION

Manual harvest costs for olives in California account for more than 50% of grower's gross return. Decreasing harvest cost by implementing mechanical harvest with increased fruit removal efficiency, without bruising fruit, is a promising way to increase the profit margin in olive production. Two mechanical harvesting concepts were analyzed in 2008 to harvest table olives: canopy shaker harvesting and trunk shakers.

OBJECTIVES

The objective of this proposal was to collect extensive field performance data with the DSE canopy shaker harvester improved by DSE to operate during the 2008 season. Specific objectives were to:

1. Vary machine parameters such as ground (mph) speed and head speed (rpm) to try enhancing machine productivity; and
2. Evaluate the picking head harvester efficiency on a hedgerow orchard prepared for mechanical harvesting versus an unprepared orchard, and evaluate the effects on fresh and processed fruit quality.

PROCEDURES

Location: Block 17W:Rocky Hill Ranch, Exeter, Ca.
Planted 1998, 13 rows, 83 trees per row, 'Manzanillo' olives with 'Sevillano' pollinators, spaced 11 x 26 ft, 160 trees per acre were available for our evaluation trials originally scheduled for 13 – 24 September 2008 and executed on 29 – 30 September 2008. The testing procedure is completely described in the 2008 Louise Ferguson's proposal to the COC and thus will be omitted here.

RESULTS AND DISCUSSION

Items reported here are: 1) DSE 2008 canopy shaker test results; 2) trunk shaker test results; 3) MaqTec oil olive canopy harvest evaluation for table olives; and 4) demonstrations of emerging pomegranate (and oil olive) harvesters with potential for tests next year.

Section 1. DSE 2008 Canopy shaker Test Results

1.1. Data collected during the 2008 season with the DSE 0007 have been analyzed and are available, partly here within and partly in Louise Ferguson's 2008 final report to the COC. Some points can be drawn from this analysis. It is clear that due to operator response in guiding the picking heads into the canopy that a maximum feasible ground speed can not exceed about 0.5 mph. The ground speed is also limited by tree size and unprepared canopy structure. The fruit quality obtained during the 2008 season seems to be adequate to the processors, although we still need to wait for this year's results from the canned fruit analysis. The problem of excessive amounts of trash produced by the harvester, which were sent within the loads/samples to the grading stations, can be easily solved by installing a proper cleaning fan. However, although the picking principle (i.e., properly padded fingers and catching frame) seems to perform reasonably well, the effective harvester ground speed did not achieve full potential (0.5 mph) as we show in speed maps produced by the on-board Olive Yield Monitor (OYM)(from UC Davis) (**Figs. 1 – 6**). The machine operating reliability limitation was due to the machine difficulties with the steering mechanism and with the conveyor belts to transport loosened broken branches and trash. Constant ground speed also requires constant flow of trash through the conveyors to avoid frequent cleaning stops. The occurrence of maintenance stops lowered the effective picking speed of the machine.

It seems to us, in general, that to be economically viable the canopy shaker needs to harvest faster while maintaining good quality of picked fruit. We think this can be accomplished by properly preparing the canopy structure for the harvester, limiting the tree height, and possibly eliminating one of the operators by using an available automatic canopy following mechanism that guides the picking drum into the canopy. Our 2009 project proposals submitted by Louise Ferguson and Uriel Rosa address these issues.

1.2. This section presents the results and analysis of data collected with our OYM during the evaluation of the six, pruned Rocky Hill rows in which the DSE 2008 performed. It can be seen that the overall field performance of the DSE 2008 is influenced by the mechanical interruptions in the work.

1.2.1. *Olive Data Analysis – (Navdeep S. Boparai)*. The olive harvest for summer 2008 was performed on Rocky Hill Ranch: Block 17-W. The harvester was equipped with the insight yield monitor and a custom-made rabbit yield monitor to collect yield, speed, and machine performance data. In addition, hand written notes were also taken. There were a total of six rows harvested, and each row consisted of six trials, three on each side, for three theoretical speeds of 0.25, 0.5, and 0.75 mph. Each trial consisted of a harvest operation on 14 trees.

Data recorded for each trial were combined with data taken from the yield monitor, and this information was used to analyze the machine performance at each of the theoretical speeds. The

data for the speed of the machine, collected by the yield monitor, allowed us to compare how much the actual speed varied from the theoretical speed.

Theoretical Field Capacity *is the rate of field coverage that would be obtained if the machine were performing its function 100% of time.* Thus, the theoretical field capacity was calculated for each row by using the theoretical speeds. **Theoretical time per acre** *is the time that would be required at the theoretical field capacity, and this was calculated accordingly*.

The analysis of machine performance was based on the comparison between theoretical field time and effective field time. The effective field time for each row was obtained by using the data from the yield monitors, and the hand written data for each trial. Microsoft Excel® was used to make graphs that showed comparisons between effective and theoretical field time for each theoretical speed and each row. SMS spatial software was also used to make a map of the actual machine speed during the harvest.

It is important to note that effective field time includes the period of time that the machine is not operating due to stops because of maintenance and repairs. The frequency and span of these stops contribute to the decrease in operation efficiency. Field efficiency: Therefore, field efficiency was obtained by taking the ratio of theoretical field time to effective field time. Our notes show that the machine was stopped during at least six of the 36 trials due to maintenance or breakdowns. When the machine was not stopped, the effective time may not approximate the theoretical in some cases. This is due to the fact that the actual speed of the machine may have varied from the theoretical at some instances of the trial.

1.2.2. *Definitions and Calculations* — (*Navdeep S Boparai)*

Theoretical field capacity: *is the rate of field coverage that would be obtained if the machine were performing its function 100% of time.* There were 139 trees/acre, and 14 * 3 = 42 trees were harvested each row. Thus, 42/139 = 0.3022 acres of area that were covered in each row. Given six trials in a row, two were at 0.25 mph, two were at 0.5 mph, and two were at 0.75 mph. Given 1 mph = 1.4667 ft/sec. Thus, two were at (0.25)(1.4667 ft/sec**) = 0.367 ft/sec**, two were at (0.5)(1.4667 ft/sec**) = 0.733 ft/sec**, and two were at (0.75)(1.4667 ft/sec) = **1.10 ft/sec.** Fourteen trees were spaced in a distance equal to (14 – 1)*12 ft = **156 ft.** Total time for 42 trees equals 2(156/.367) + 2(156/.733) + 2(156/1.10) = 26 minutes. Thus, 6(26) = 156 minutes; and 6(42) = 252 trees.

Theoretical field capacity = 156 minutes/252 trees. There were 139 trees/acre. Thus, (139/252)(156mins) = 86 minutes/acre = 1 hour 26 minutes/acre ***= 0.6977 acres/hour***

Theoretical time per acre: *is the time that would be required at the theoretical field capacity* = ***1/.6977 = 1.43 hours = 1 hour and 26 minutes***

Effective operating time per acre: *is the time during which the machine is actually performing its intended function. The effective operating time per acre is greater than the theoretical time per acre if less than the full rated width is utilized.* We have data for 252 trees for which the total time is 185 minutes, and there were 139 trees/acre. Thus, ***Effective operating time per acre = (139/252)*(185 minutes) = 102 minutes= 1 hour and 42 minutes***

Effective Field Capacity: *is the actual time it took for the machine to cover the field.*

Total time = (effective operating time) + (time lost in service, repairs)

Total time = (sum of times of all trials from data w/ repairs time included)

Total time = 243.427(minutes)/252(trees). There were 139 trees per acre. Thus, (139/252)(243.427) = **134.27 minutes/acre** = **2 hours and 14 minutes/acre = 0.4478 acres/hour**

Field Efficiency: is the ratio of effective field capacity to theoretical field capacity, expressed as percent. **Field Efficiency = 0.4478/.6977 = 0.6418 = 64%**

1.2.3. **Table 1** provides information on yield, speed, and time recorded with the DSE 2008 for each trial.

1.2.4. DSE performance for Rows 2 to 7.

The reader should note the "stopped" tests indicated in the figures. Due to interruptions and limited trials statistical analysis was not performed.

Visual observation of figures showing the effective field time for trials 2 to 7 indicated when there were no "stops" for repair/ maintenance involved in the trials (14 trees per trial – both sides of tree), and the recorded time to harvest the trial trees corresponded to the expected times indicated. Also, the ground speed was relatively constant and close to the target speed for each set: 0.25, 0.5, and 0.75 mph. However when stops occurred, the time increased and the harvester productivity was reduced in rows 2 – 4 and 6 – 7 (see **Figs. 1 – 6**).

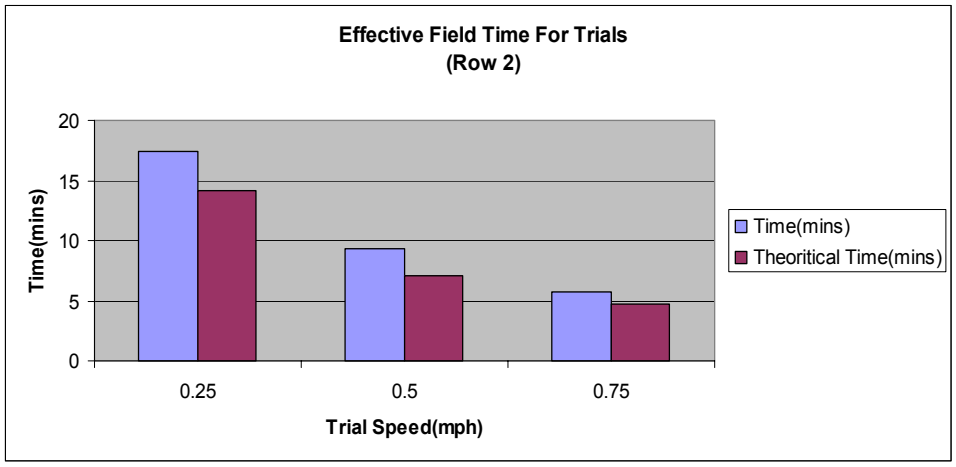


Fig. 1. Effective field time for trials — Row 2.

Accompanying data for **Fig. 1.**

Speed (mph)	Time (mins)	Theoretical Time (mins)
0.25	17.38	14.17
0.50	9.31	7.09
0.75	5.68	4.73

Table 1. Yield, speed, and time recorded with the DSE 2008 for each trial.

Row	Yield (lb)	Speed (mph)	Time (min)
1	143	0.25	9.51
1	60	0.5	4.61
1	113	0.75	2.83
1	232	0.75	2.85
1	109	0.50	4.50
1	177	0.25	7.86
2	56	0.25	10.06
2	43	0.75	3.05
2	68	0.25	8.33
2	154	0.25	5.25
2	40	0.75	3.11
2	139	0.25	7.38
3	114	0.25	9.23
3	63	0.75	2.75
3	121	0.50	3.91
3	247	0.50	3.93
3	139	0.75	2.50
3	232	0.25	8.46
4	46	0.50	3.70
4	116	0.75	2.35
4	86	0.25	8.52
4	274	0.25	9.65
4	192	0.75	2.81
4	111	0.50	4.06
5	54	0.25	6.91
5	48	0.50	3.75
5	59	0.75	2.50
5	135	0.75	2.85
5	107	0.50	3.83
5	113	0.25	8.08
6	56	0.25	7.06
6	51	0.50	3.91
6	74	0.75	2.96
6	193	0.75	2.033
6	120	0.50	3.30
6	114	0.25	7.06

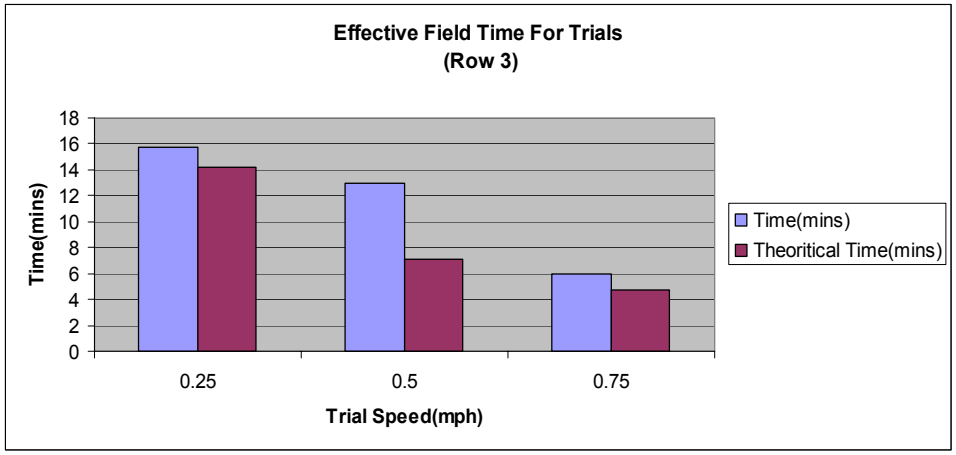


Fig. 2. Effective field time for trials — Row 3.

Accompanying data for **Fig. 2.**

Speed (mph)	Time (mins)	Theoretical Time (mins)	
0.25	15.71	14.17	*stopped for repair/maintenance
0.50	12.93	7.09	*stopped for repair/maintenance
0.75	5.93	4.73	

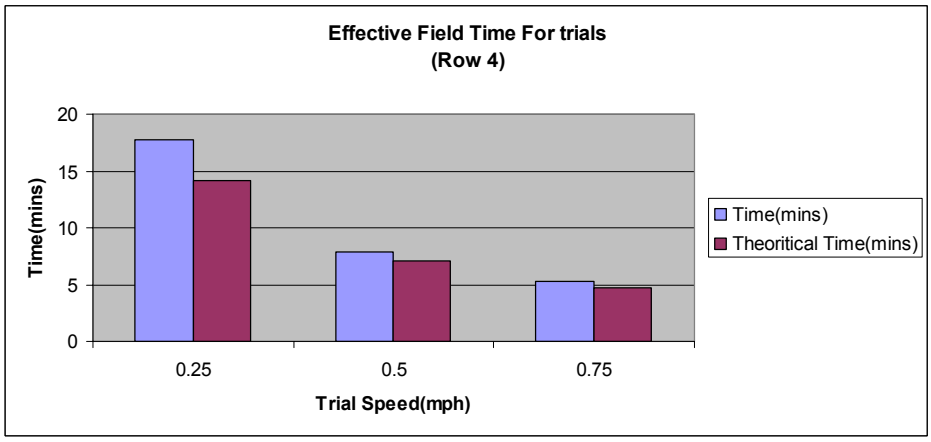


Fig. 3. Effective field time for trials — Row 4.

Accompanying data for **Fig. 3.**

Speed (mph)	Time (mins)	Theoretical Time (mins)
0.25	17.70	14.17
0.50	7.85	7.09
0.75	5.25	4.73

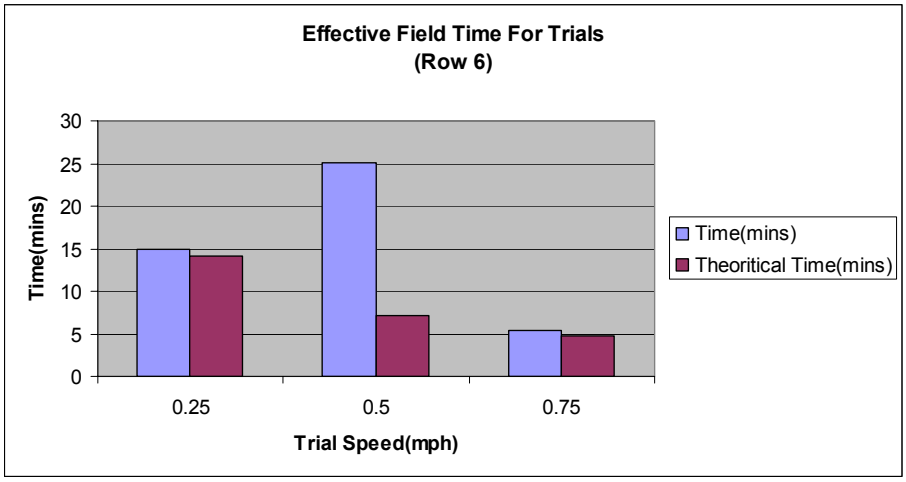


Fig. 5. Effective field time for trials — Row 6.

Accompanying data for **Fig. 5.**

Speed (mph)	Time (mins)	Theoretical Time (mins)	
0.25	38.91	14.17	*stopped for repair/maintenance
0.50	7.76	7.09	
0.75	24.81	4.73	*stopped for repair/maintenance

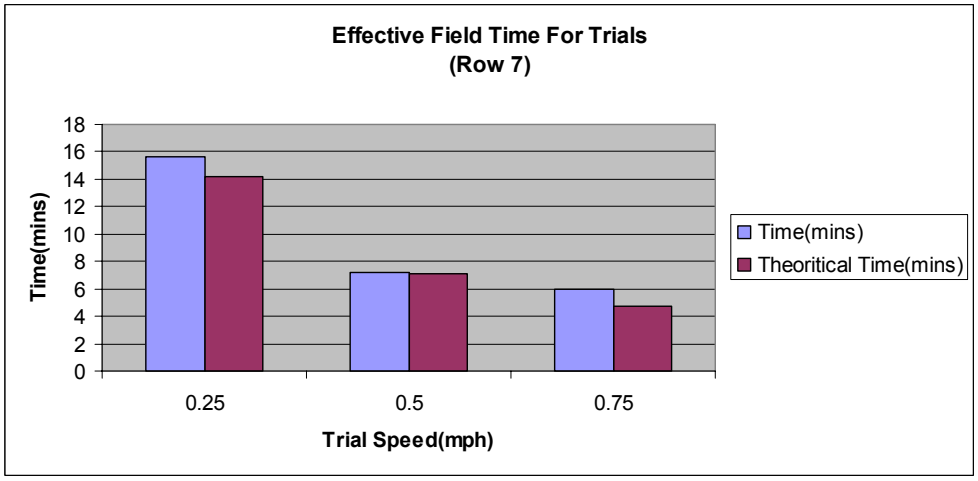


Fig. 6. Effective field time for trials — Row 7.

Accompanying data for **Fig. 6.**

Speed (mph)	Time (mins)	Theoretical Time (mins)	
0.25	15.63	14.17	*stopped for repair/maintenance
0.50	7.21	7.09	
0.75	6.00	4.73	

Figures 7 – 13, theoretical speeds versus harvested yield (lbs), show great data variability. Although it was initially suggested during field tests and the preliminary trials on Row 1 that tree yield would be reduced with increased in ground speed, the variability of the data does not show obvious conclusions on this point.

Fig. 7. Theoretical speeds versus harvested yield (lbs) for Row 2.

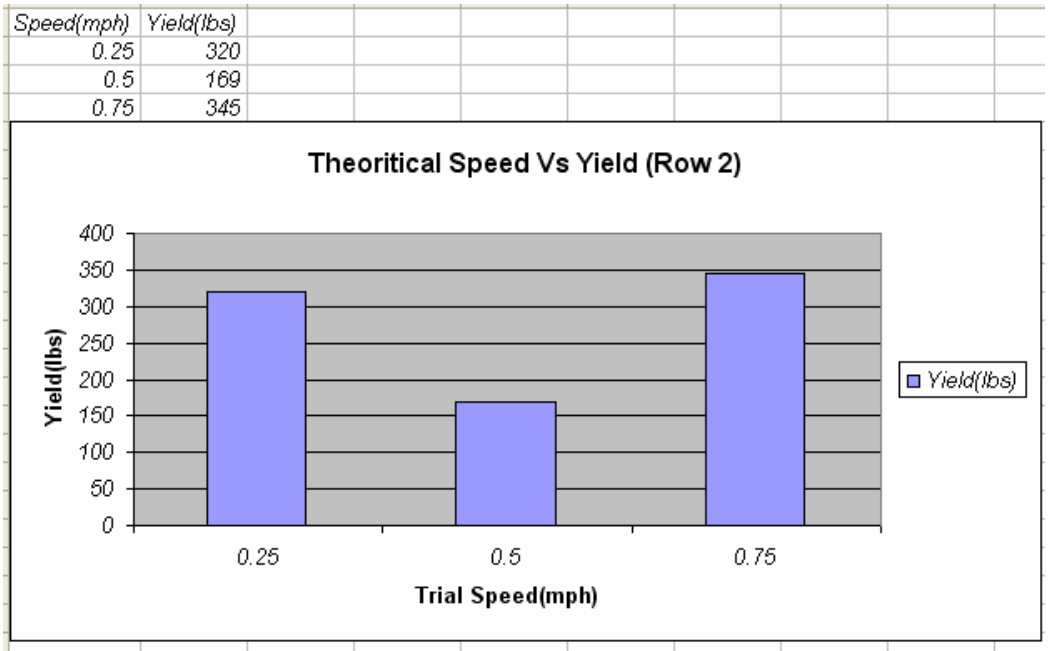


Fig. 8. Theoretical speeds versus harvested yield (lbs) for Row 3.

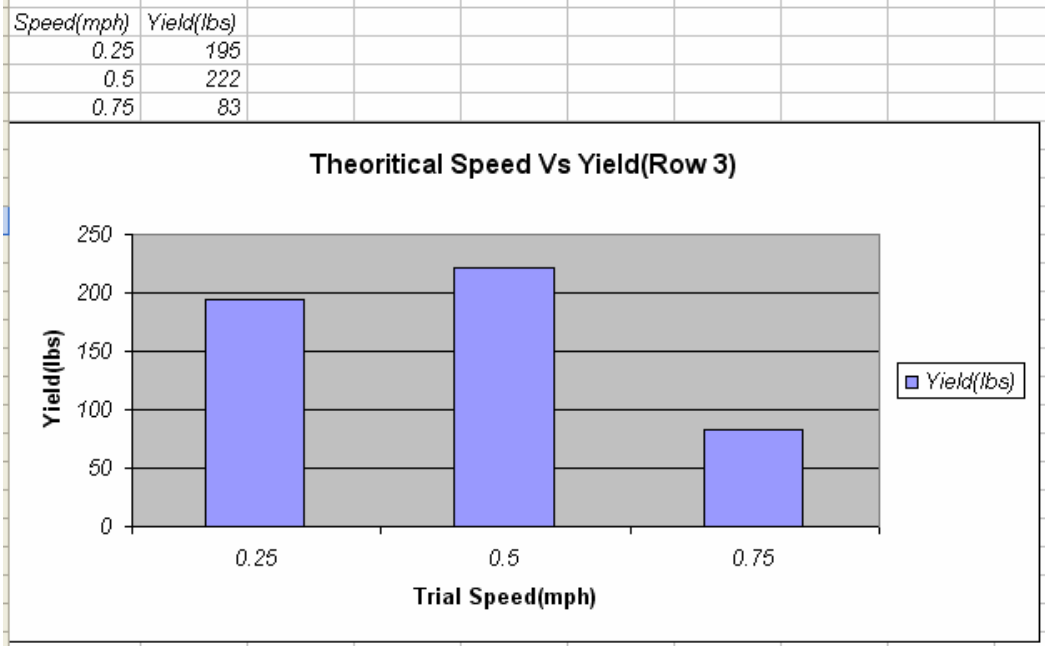


Fig. 9. Theoretical speeds versus harvested yield (lbs) for Row 4.

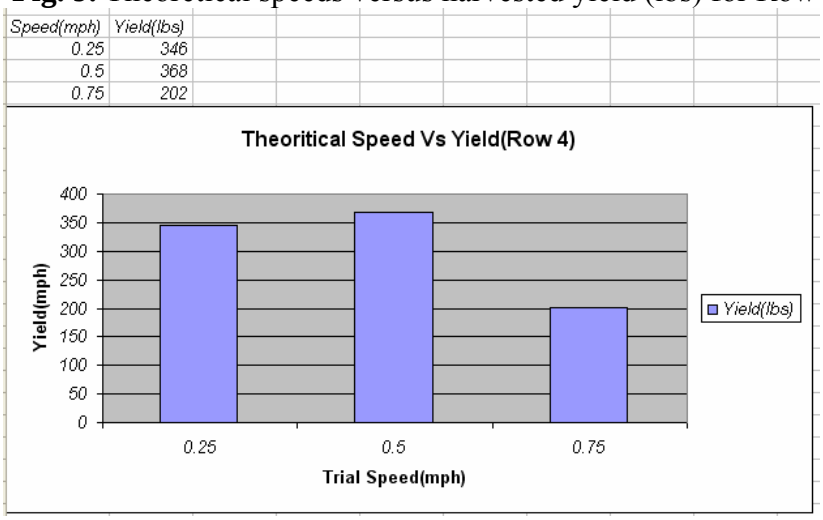


Fig. 10. Theoretical speeds versus harvested yield (lbs) for Row 5.

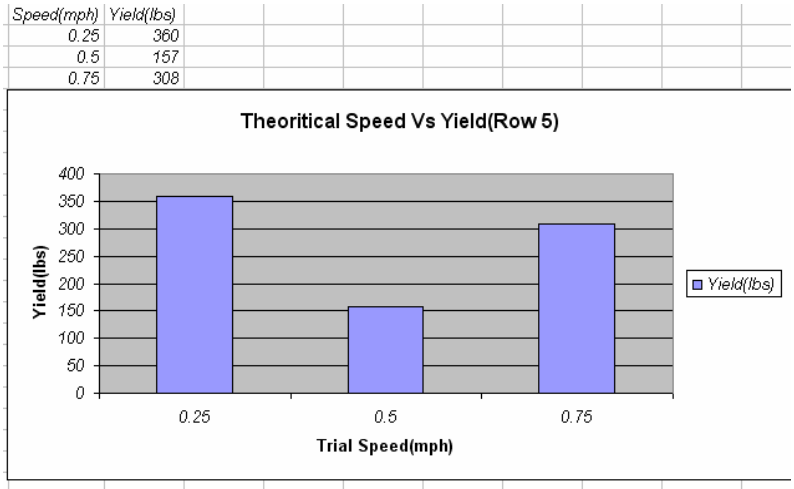


Fig. 11. Theoretical speeds versus harvested yield (lbs) for Row 6.

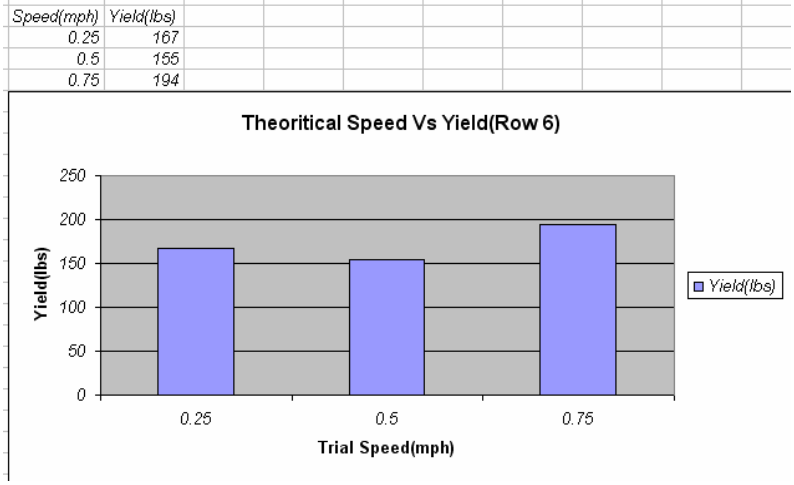
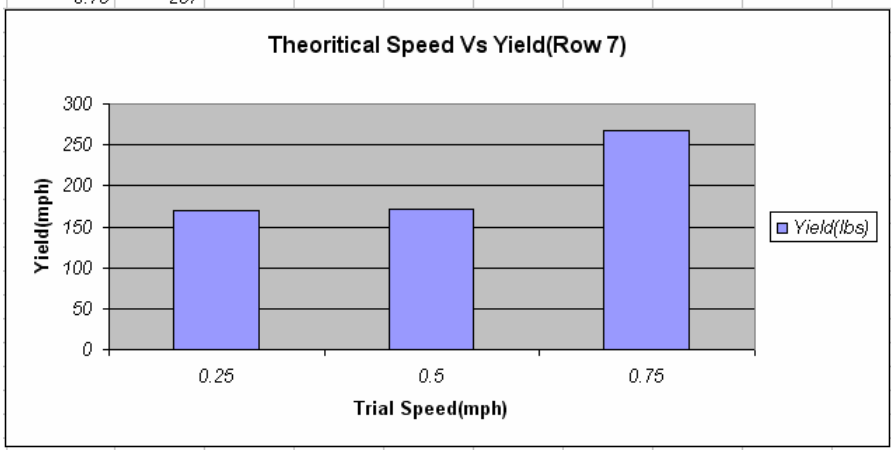


Fig. 12. Theoretical speeds versus harvested yield (lbs) for Row 7.

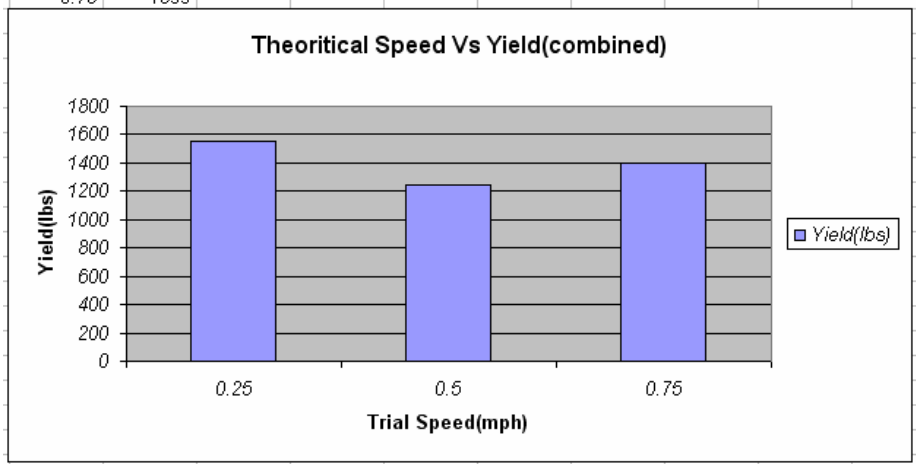
Speed(mph)	Yield(lbs)
0.25	170
0.5	171
0.75	267



The combined average of the data presented in **Figs. 7 – 12** suggests that removal efficiency reduces with increase in speed (**Fig. 13**). Extended tests and data analysis may be required to confirm this assumption.

Fig. 13. Theoretical speeds versus harvested yield (lbs) for Row 7.

Speed(mp	Yield(lbs)
0.25	1558
0.5	1242
0.75	1399



1.2.5. See APPENDIX A for extended maps and row trial explanations.

Section 2. **2008 Trunk Test Results performed by Trunk Shaker Manufactures**

2.1. Field evaluation tests were carried out in a table olive orchard at Nickels Soils Laboratory, Colusa County, to access the ability of commercial trunk shakers to harvest table olives in California. All trees in this orchard were 'Manzanillo' variety, planted in 7/8/01 with a tree spacing of 12' x 18' (202 trees/ac). Eight trees were randomly selected and shaken by the ENE

trunk shaker. Tests were conducted on 7 October 2008 and continued in Erick Nielsen's orchard (ENE) during the following week after shaker adjustments were performed to reduce bark damage. Data were recorded with two accelerometers placed on the shaker head and on the tree trunk close to the shaker arms. Because some shaker manufactures gave us permission to instrument their equipment by placing sensors (two tri-axial accelerometers, one on the shaker head and another on the tree being shaken) on their equipment, we agreed to analyze the data and submit complete reports exclusively to them. It is clear these California nut shakers have been optimized for nut and stone fruit harvesting over the years and work very well on these crops. However, in olives some learning and some adaptations were required and have been studied and started to be implemented. Some general results from this analysis are presented as follows.

The measured trunk shaker mean frequency was low compared with the olive trunk shakers commonly used in Spain, where this technology is largely used to harvest olives (Dr. Sergio Castro, personal communication). Shaking the tree with higher frequency excitation allowed us to remove more fruit. However, we suggest increasing the shaker operating frequency values up to 28-30 Hz (1680-1800 rpm). This frequency range recommendation is based on observations and research done on olive tree vibration behavior under forced vibration and on the extensive experience of some of our team members in performing similar tests.

Acceleration values, as measured on the shaker head in the main direction of vibration, produced around 4 g (starting period) to 8 g (end period). However, in the perpendicular direction, acceleration values ranged from around 2 to 3 g. The acceleration in this direction produced a mean vibration value close to 40% of the value in the main direction. We suggest that an increase in the acceleration value, to about 20 g, in the main vibrating direction will ensure proper fruit detachment.

Displacement. The relative displacement between the shaker and tree trunk is one source of bark damage. Also, frequency and displacement show an inverse correlation (i.e., high frequency, low displacement). Limitation of displacement to reasonable values, as a result of increased operational frequency (also due to power limitation), is expected to reduce bark damage, mainly in the starting and end period of the vibration. During theses periods, relative displacement can increase due to natural frequencies of tree or shaker. Our recommendation of shaking the tree with high frequencies leads to a reduction in bark displacement reduction, which can help reduce damage. Our tests indicate that the mean displacement measured in the main direction of vibration produced values around 0.826 and 0.905 inches on the shaker head and trunk, respectively.

Vibration transmission. Vibration transmission between machine and tree trunk depend on the clamping pressure, padding material, and frequency. These are important parameters that can be adjusted to help to reduce bark damage. The main function of the machine is to completely transmit the input acceleration to the tree. However, some loss can be expected. In general, vibration transmission increases with the frequency increase. For the main vibration direction (Y axis), the mean vibration transmission ratio was 1.1. This shows a low amplification of this transmission. However, in a perpendicular direction (X axis), mean vibration transmission was 0.7, producing acceleration reduction on the trunk. The vibration transmission analysis is important in designing a proper shaker head for olive trees.

Removal efficiency. Removal efficiency values were typically low, with mean values ranging from 50 % to 60%. This is due to the fact the harvester shaker head has been designed and developed for other types of tree crops and has been adapted for olives. Besides that, removal efficiency depends on parameters such as fruit detachment force, frequency, acceleration, displacement, and vibration repetitions. Our experience shows that improved removal can be achieved with specific patterns and other unique ways to shake the trees.

To increase removal efficiency, the shaker needs to be operated with increased motor revolutions to produce a broader frequency range. However, this increase in frequency is limited. One alternative, if bark damage can be limited and reduced, is to make two short vibrations, to break the period movement of the fruit and tree and, thus, it will produce better removal.

Bark damage. Bark damage was evaluated as 1.4 in our scale from 1 to 3, meaning medium bark damage. This is not a good result if the machine needs to be applied to olive trees. More work has to be done in this case to reduce bark damage before trying to increase removal efficiency. All trees were damaged with various levels of damage severity.

After these results were obtained during the initial tests with our collaborative work with the shaker, the manufacturer produced an improved shaker head with encouraging results. Thus, we propose to continue this effort and properly design, fabricate, and test a new high frequency shaker head to better suit the requirements of olive trees.

Due to the willowy nature of olive trees, we propose to design a new shaker head by using known principles and test this machine on tree structures pruned for trunk shakers in orchards properly prepared by Dr. Louise Ferguson.

2.2. Trunk shaker evaluation in conventional training olive orchard: The following report, copied in part here, was sent with a complete analyzed data set as part of our collaborative effort to work with the trunk shaker manufacturers to improve their shakers' heads for working on young table olive trees.

TRUNK SHAKER EVALUATION IN CONVENTIONAL TRAINING OLIVE ORCHARD

Machine tested: (COE or ENE) Trunk Shakers – *individual reports prepared for each manufacturer*

Bio-Automation Lab

Authors: Sergio Castro-Garcia and Uriel A. Rosa

Date: 28 October 2008

Field evaluation tests were carried out in a table olive orchard at Nickels Soils Laboratory, Colusa County, to assess the ability of commercial trunk shakers to harvest table olives in California. All trees of this orchard were of the 'Manzanillo' variety, planted in 7/8/01 with a tree spacing of 12' x 18' (202 trees/ac). Eight trees were randomly selected and shaken by the ENE trunk shaker. Tests were conducted on 7 October 2008.

The shaker head and the tree were instrumented with two triaxial accelerometers (PCB, 356A22) to evaluate the dynamic behavior of the tree-shaker system. The instrumentation

utilized to record the accelerometer signals consisted of PCB charge amplifiers for the accelerometers, a 5 kHz anti-aliasing low pass analog filter, and a Tektronics 3014B storage oscilloscope. The scope was setup to record four simultaneous channels at a scanning rate of 1 kHz. The maximum stored time for a single shaking event was limited to 10 seconds. The single accelerometers signals were AC coupled to the scope. One accelerometer was mounted at the shaker top right arm, close to the eccentric mass, and worked as a reference to measure the vibration produced by the machine. From the three available signals generated by this accelerometer only two were recorded. These two signals corresponded to two orthogonal directions horizontal to the ground. The second sensor was placed on the olive trunk, close to the shaker clamping point, but on the opposite side of the shaker head. In all, four signals were recorded in the horizontal plane (x and y). Vertical accelerations were not measured. The X axis corresponded to the longitudinal direction of the shaker, i.e., perpendicular to the direction of the harvested tree line, and the Y axis corresponded to the direction parallel to the shaker, i.e., parallel to the tree line. The accelerometers were mounted at the height where the clamping system was attached to the trunk, typically 30 inches from the ground (**Fig. 14**).

Fig. 14. Reference system used in the shaking field tests

Channels of measurement:

CH 1 = Acceleration measured on the shaker head in the direction parallel to the shaker head,
CH 2 = Acceleration measured on the shaker head in the direction perpendicular to the shaker head,
CH 3 = Acceleration measured on the tree trunk, in the direction parallel to the harvested tree line, and
CH 4 = Acceleration measured on the tree trunk, in the direction perpendicular to the harvested tree line.

A four-channel scope (Tektronic, TDS 3014B) was used to display and record the accelerometer signals. A fifth channel was used to perform real time FFT on CH2. The FFT data

were also recorded for each run (again, each signal contained 10 seconds in duration with a total of 1000 data points per second). All recorded acceleration signals were analyzed by using specialized software, The OROS NVGate, v.5.1. The resulted parameters obtained from this analysis were:

Frequency (Hz): rotational speed of the unbalance mass. Also, it is expressed as revolutions per minute (rpm). In these tests, this value usually increases during the tree vibration due to increase motor revolution.

Acceleration (g): expresses the RMS acceleration value for each shaker frequency. It is measured in g (gravity acceleration = 9.81m/s^2).

Displacement (millimeters): expresses the movement maximum (peak to peak) of the measurement point for each shaker frequency.

Vibration Transmission: this is the relationship between the acceleration in the trunk to the shaker. When this value is 1, it means that the acceleration generated in the shaker is completely transmitted to the trunk in one studied direction. Values under 1 showed a low vibration transmission, with a of loss acceleration value. Values up to 1 showed vibration amplification during the shaking process. Desirable values are closed to 1.

These parameters were complemented with the Removal efficiency data associated with the induced vibration on the tree trunk, and a four point scale damage evaluation of the tree trunk:

Removal efficiency (%): After shaking, the olives removed were harvested and weighed. Then, the olives remaining on the tree were manually harvested and weighed.

Trunk Damage: visual estimation of bark trunk damage.

0 = No damage
1 = Low-medium damage
2 = Medium-high damage
3 = High and severe trunk and branch damage.

RESULTS

DATA OMMITTED HERE: Directly Reported To Participating Manufacturers

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Section 3

The Maqtec harvester evaluated by our research group in Portugal performed below our expectations for table olives. Extensive modifications will be required if this machine is to be used on table olives. The harvested fruit were virtually one hundred percent bruised, cut, or mutilated. No attempt had been made to test our padding recommendations by the time of our visit to the Portuguese olive site.

Section 4

In late 2008, we visited two field demonstrations of emerging technology that while maintaining the promising canopy shaker picking principle, also had the potential to offer high equipment reliability, increase field capacity, and perhaps attainable equipment costs. The over

the row Ag-Right harvester and the COE canopy shaker and catch frame pair have targeted harvesting of pomegranates with apparent success. We were encouraged by attending a demostration of these two pieces of equipment later in olive oil harvest season in Sanger and Winters, CA. We are looking forward to collaborating with these two companies in 2009 as well.

CONCLUSIONS

The DSE 008 harvester has demonstrated that the picking head technology is viable for table olives. The DSE effective field capacity, however, needs to be improved. The observed ground speeds did not reach the expected 1.0 mph to be economically viable. Typical speed is 0.25 mph and perhaps 0.5 mph, if the operator is trained to quickly react on the controls. Frequent maintenance and reliability stops, however, limit the machine's ability to achieve expected harvest field capacity.

Research should now focus on the currently commercially available trunk shaking and picking head harvesters mounted on double-sided catch frames. These should be evaluated in conventional, mechanically pruned, and hedgerow trained orchards.

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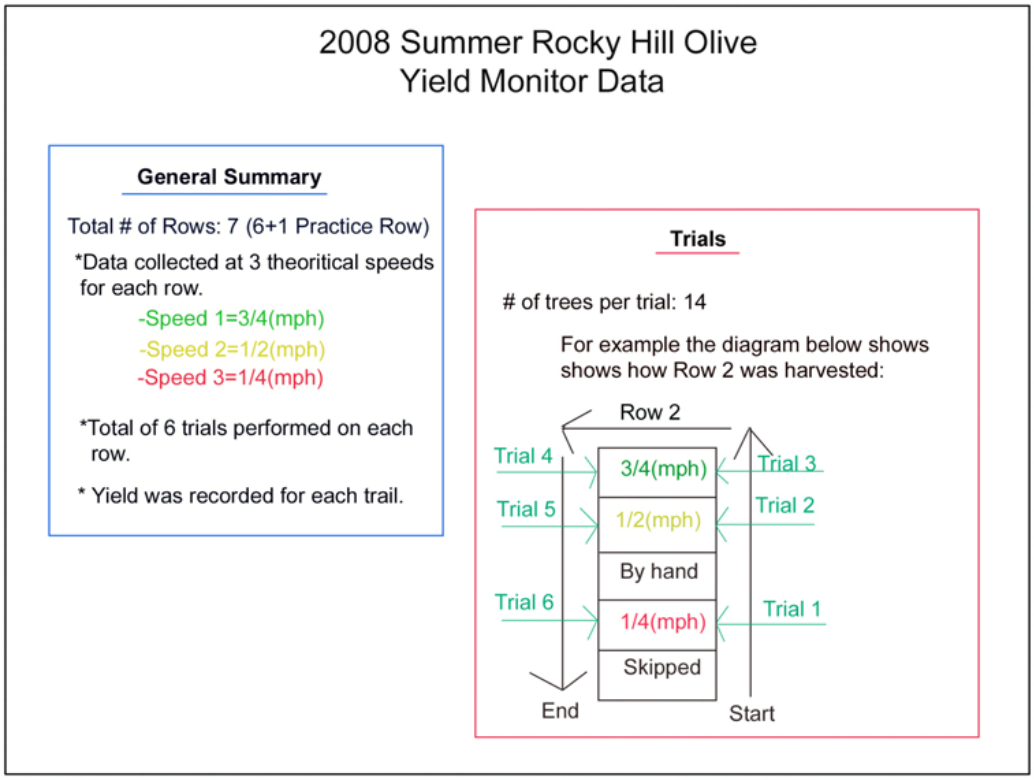
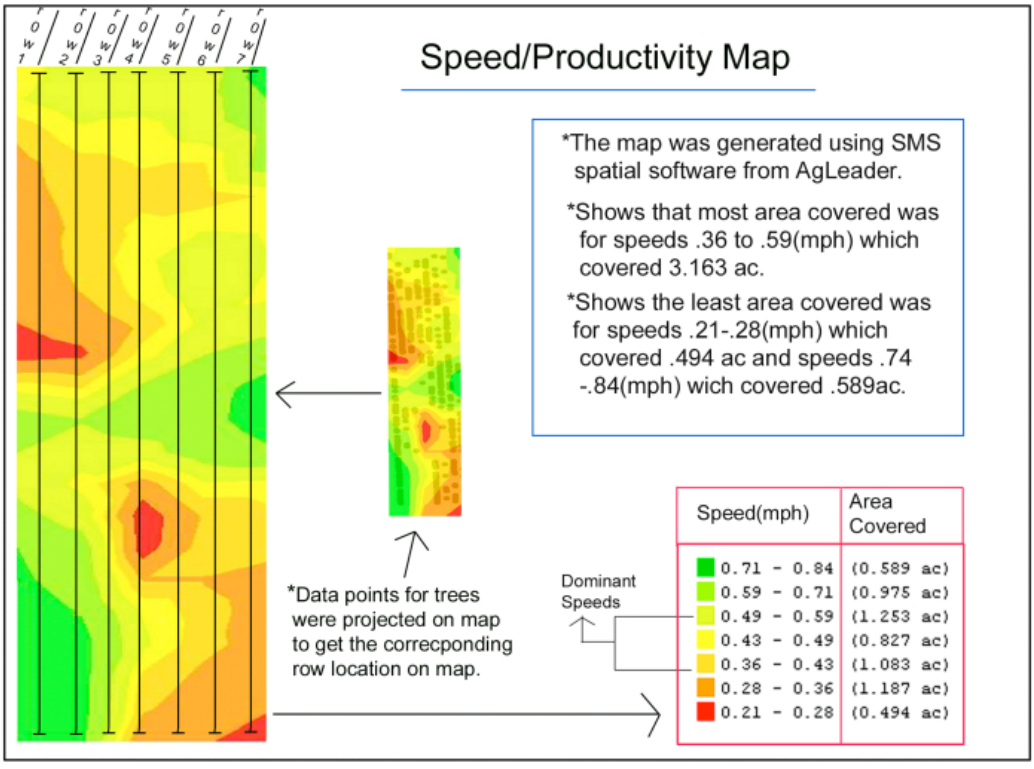
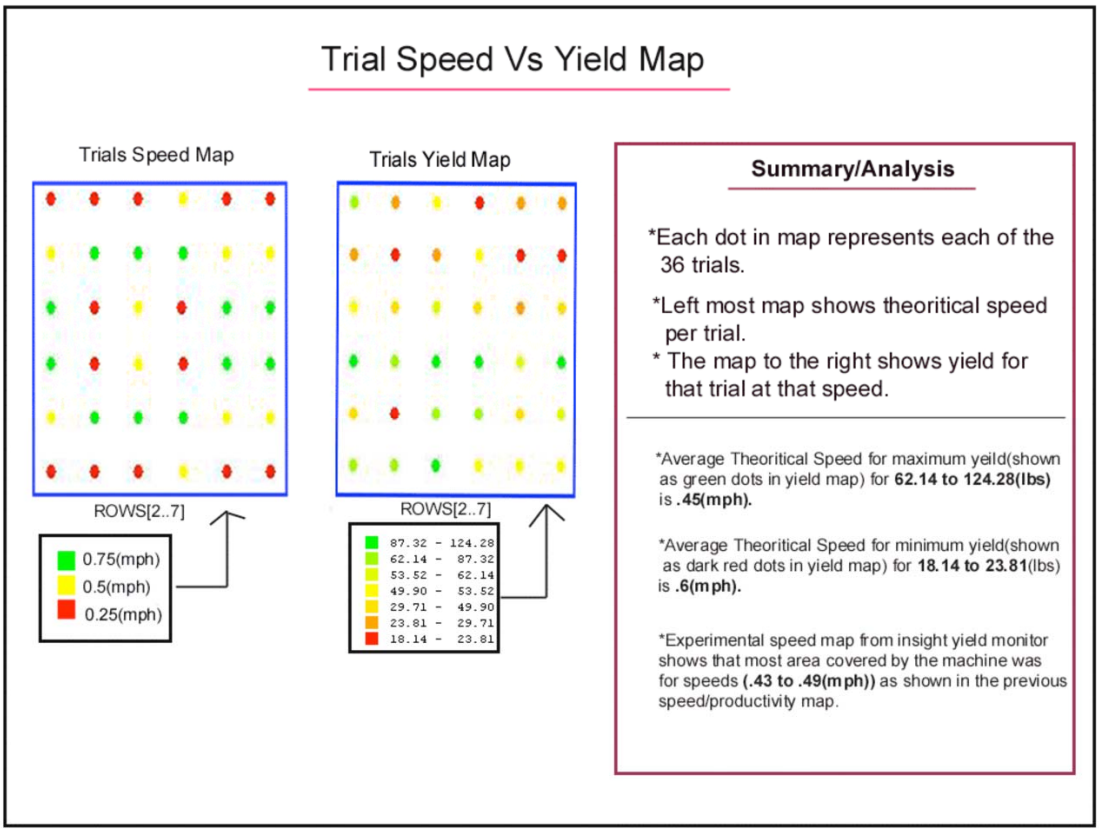
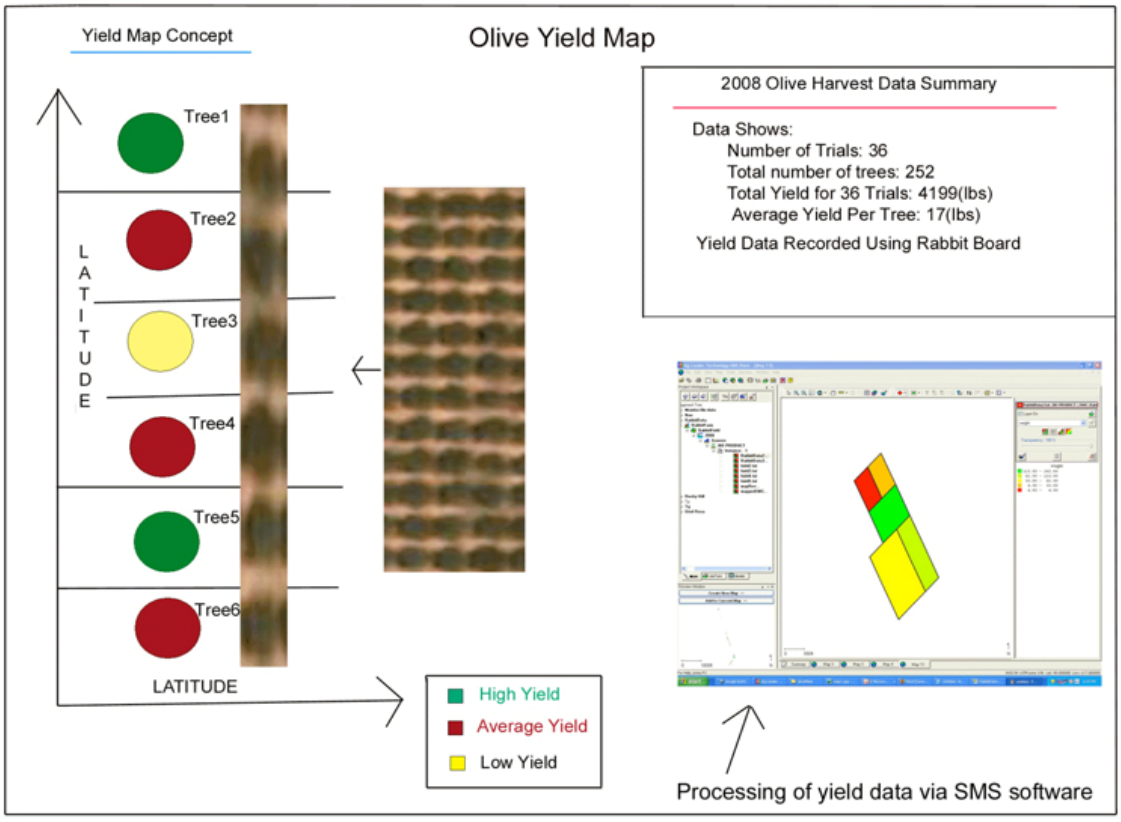
Finally, we thank volunteers John Henry Ferguson BS, MBA, and Peter Kulakow, PhD, for their much appreciated and reliable experimental field and assistance.

Appendix A


2008 Summer Rocky Hill Olive
Yield Monitor Data
General Summary
Total # of Rows: 7 (6+1 Practice Row)
*Data collected at 3 theoritical speeds for each row.
-Speed 1=3/4(mph)
-Speed 2=1/2(mph)
-Speed 3=1/4(mph)
*Total of 6 trials performed on each row.
* Yield was recorded for each trail.
Trials
# of trees per trial: 14
For example the diagram below shows shows how Row 2 was harvested:
Row 2
Trial 4
Trial 5
Trial 6
3/4(mph)
1/2(mph)
By hand
1/4(mph)
Skipped
Trial 3
Trial 2
Trial 1
End
Start


Speed/Productivity Map
*The map was generated using SMS spatial software from AgLeader.
*Shows that most area covered was for speeds .36 to .59(mph) which covered 3.163 ac.
*Shows the least area covered was for speeds .21-.28(mph) which covered .494 ac and speeds .74 -.84(mph) wich covered .589ac.
*Data points for trees were projected on map to get the correcponding row location on map.
Dominant Speeds
Speed(mph)
Area Covered
0.71 - 0.84 (0.589 ac)
0.59 - 0.71 (0.975 ac)
0.49 - 0.59 (1.253 ac)
0.43 - 0.49 (0.827 ac)
0.36 - 0.43 (1.083 ac)
0.28 - 0.36 (1.187 ac)
0.21 - 0.28 (0.494 ac)


Trial Speed Vs Yield Map
Trials Speed Map
Trials Yield Map
ROWS[2..7]
ROWS[2..7]
0.75(mph)
0.5(mph)
0.25(mph)
87.32 - 124.28
62.14 - 87.32
53.52 - 62.14
49.90 - 53.52
29.71 - 49.90
23.81 - 29.71
18.14 - 23.81
Summary/Analysis
*Each dot in map represents each of the 36 trials.
*Left most map shows theoritical speed per trial.
* The map to the right shows yield for that trial at that speed.
*Average Theoritical Speed for maximum yeild(shown as green dots in yield map) for 62.14 to 124.28(lbs) is .45(mph).
*Average Theoritical Speed for minimum yield(shown as dark red dots in yield map) for 18.14 to 23.81(lbs) is .6(mph).
*Experimental speed map from insight yield monitor shows that most area covered by the machine was for speeds (.43 to .49(mph)) as shown in the previous speed/productivity map.


Yield Map Concept
Olive Yield Map
Tree1
Tree2
Tree3
Tree4
Tree5
Tree6
LATITUDE
LATITUDE
High Yield
Average Yield
Low Yield
2008 Olive Harvest Data Summary
Data Shows:
Number of Trials: 36
Total number of trees: 252
Total Yield for 36 Trials: 4199(lbs)
Average Yield Per Tree: 17(lbs)
Yield Data Recorded Using Rabbit Board
Processing of yield data via SMS software