Evaluating Performance of Citrus Mechanical Harvesting Systems
2001/02 Season

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During the 2001-02 season, IFAS-SWFREC personnel recorded machine performance and tree data for 151 sample periods. A sample period was defined as the time during which one machine set was followed. Table 1 summarizes the sample periods by machine type and scion variety. The data summarized in this report represent 4,800 acres and more than 4.3 million boxes of harvested oranges.

Data were collected to estimate the performance measures by machine type for each sample period. The performance measures included removal percentage, recovery percentage, harvest speed, machine productivity, and labor productivity. Block and tree characteristics were recorded and included tree height, clear trunk height, skirt height, trunk circumference, tree spacing both down the row and across the bed, and the percentage of tree spaces that were blank or with young resets. Grove owners provided data on tree age, rootstock and scion varieties, and the total yield for the block observed during the sample period.

Performance measures and data describing block characteristics are summarized in Tables 2-4. Table 2 presents data for the Trunk-Shake-Catch (TSC) systems. Table 3 presents data for the Continuous Canopy Shake-Catch (CCSC) systems. Table 4 presents data for the Monoboom Trunk shaker and a Pull-along canopy shaker. The monoboom shaker was observed only on early-mid varities while the pull-along canopy shaker was observed only on late season blocks. Please note that table values represent averages across sample periods and may not correspond to their respective functional relationships. For example, multiplying "Avg Tree Yield" by "Avg Tree Density" does not necessarily equal "Avg Block Yield."

The terms listed below provide addition information as to the data collected and how they were utilized in order to develop measures of performance for each sample period.

1. Available yield. The estimated boxes per tree that would have been harvested by a hand crew.
   Available yield = Harvested + broken fruit + post-gleaning "shiners".
2. Harvest yield. Boxes per tree harvested by both machine and hand-gleaning crew.
   Harvest yield = Total net weight boxes / Estimated harvested tree spaces.

3. Gleaning harvest. Estimated boxes per tree harvested by ground personnel and gleaning crews.

> ***Gleaning harvest = Preharvest fruit drop + Post-harvest tree fruit + Post-harvest ground fruit – Post-gleaning shiners.***

4. Machine harvest. Estimated boxes per tree harvested by the mechanical system. (Note: this pertains only to those system that mechanically catch fruit.)

> ***Machine harvest = Harvest yield – Gleaning harvest***.

5. Removal %. The percentage of available fruit removed from the tree during the shaking action. Preharvest fruit drop is not available to the harvester, therefore is not counted in determining removal percentages.

> ***Removal % = 1 – [post-harvest tree fruit / (Available Yield – Preharvest drop)].***

6. Recovery %. The percentage of available fruit in the tree prior to harvest that is removed ***and*** delivered to the road trailer.

> ***Recovery % = Machine harvest / (Available yield – Preharvest drop).***

7. Machine speed (trees/hr) and productivity (boxes/hr) were estimated on the basis of a calculated value of machine hours observed during the sampling period. Machine hours reflect only time that the system was actively harvesting. Machine hours were based on average speeds recorded for shaking, moving between trees, goat dumps, and row repositioning. These speed observations were summed across the number of trees harvested during the trial period.

> ***Machine speed = number of trees harvested / machine hours.***
> ***Machine productivity = Machine harvest / Machine hours.***

8. System Efficiency. The percentage of time during the trial period that the system was actively harvesting.

> ***System Efficiency = Machine hours / Duration of trial period.***

9. Labor Productivity. These estimates refer only to the personnel involved with the operations of harvesting machines and goat trucks. Ground workers, gleaning crews, mechanics, and field supervisors are **not** included. Also, it is important to note that labor productivity was based on the entire duration of a trial and not on estimated machine hours.

> ***Labor Productivity = Machine harvest / (number of equipment operators * time duration of trial)***

Table 1. Scope of citrus mechanical harvesting project
2001/02 season

	Sample Periods	Blocks	Net Tree Acres	Net Weight Boxes
Total	**151**	**72**	**4,802**	**4,334,612**
Early/Mid		**44**		
Late		**28**		
TSC Coe-Collier				
Total	73	31	2,262	2,968,158
Early/Mid		22	1,460	
Late		9	802	
MB Stackhouse				
Total	18	7	566	357,448
Early/Mid		7	566	
Late		0	0	
Pull-Along Oxbo				
Total	4	3	120	33,323
Early/Mid		0	0	
Late		3	120	
CCSC Oxbo				
Total	50	28	1,587	811,686
Early/Mid		14	798	
Late		14	789	
CCSC Korvan				
Total	6	3	267	164,000
Early/Mid		1	20	
Late		2	247	

Table 2. Performance statistics of TSC (Coe-Collier) Harvesters and block characteristics

	Units	Early/Mids Average	Late Season Average
Number of trial periods	*#*	48	9
Average trial duration	*Hrs*	1.5	1.5
Removal	*%*	95 %	94 %
Recovery (excluding preharvest drop)	*%*	89 %	88 %
Harvest %	*%*	99 %	99 %
Shake time	*Sec*	12	11
System Efficiency (% runtime)	*%*	68 %	62 %
Machine Speed (100% runtime)	*tree/hr*	174	217
Machine Productivity (100% runtime)	*boxes/hr*	412	389
Labor Productivity (operators + goat drivers, no gleaners)	*boxes/hr*	98	85

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	*Tree/ac*	150-275	150-180
Tree age	*Years*	11	13
Avg. Block Yield	*Box/ac*	536	356
Avg. Tree Yield	*Box/tree*	3.2	2.3
Tree height	*Ft*	12	10
Clear trunk height	*In*	18	18
Skirt height	*In*	18	18
Trunk circumference	*In*	19	19

Table 3. Performance statistics of CCSC (Oxbo) Harvesters and block characteristics

	Units	Early/Mids Average	Late Season Average
Number of trial periods	*#*	20	19
Average trial duration	*hrs*	4	4
Removal	*%*	95 %	95 %
Recovery (excluding preharvest drop)	*%*	90 %	90 %
Harvest %	*%*	99 %	99 %
Travel Speed	*mph*	0.6	0.9
Machine Speed (100% runtime)	*tree/hr*	288	398
Machine Productivity (100% runtime)	*boxes/hr*	777	613
System Efficiency (% runtime)	*%*	61 %	66 %
Crew Size (no gleaners)	*#*	4-6	4-6
Labor Productivity (operators + goat drivers)	*boxes/hr*	98	113

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	*Tree/ac*	145-200	145-275
Tree age	*Years*	15	14
Avg. Block Yield	*Box/ac*	429	338
Avg. Tree Yield	*Box/tree*	2.9	2.1
Tree height	*ft*	14	11
Clear trunk height	*in*	18	18
Skirt height	*in*	15	13
Trunk circumference	*in*	21	20

Table 4. Performance statistics of MB (Stackhouse) and Pull-along (Oxbo) Harvesters and block characteristics

	Units	Early/Mids Stackhouse MB	Late Season Pull-along Oxbo
		Average	Average
Number of trial periods	#	18	4
Average trial duration	hrs	3	4
Removal	%	93 %	80 %
Recovery (excluding preharvest drop)	%	99 %	99 %
Shake time		13 sec/tree	1.0 mph
Machine Speed (100% runtime)	tree/hr	134	188
Machine Productivity (100% runtime)	boxes/hr	Na	Na
Size of Pick-up crew	#	15	11
Labor Productivity (pick-up crew)	boxes/hr	19	10

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	Tree/ac	75-150	103
Tree age	Years	21	12/52
Avg. Tree Yield	Box/ac	631	278
Tree height	ft	17	12
Clear trunk height	in	21	14
Skirt height	in	3	5
Trunk circumference	in	27	35