

# Evaluating Performance of Citrus Mechanical Harvesting Systems 2002/03 Season

Fritz Roka

University of Florida/Southwest Research and Education Center

Report to the Citrus Harvesting Research Advisory Council  
Lakeland, FL  
September 11, 2003

During the 2002-03 season, IFAS-SWFREC personnel collected data on machine performance for 89 sample periods. A sample period is defined as the time during which IFAS personnel follow one set of harvesting machines. Table 1 summarizes the sample periods by machine type and scion variety. The data summarized in this report represent more than 4,700 acres and nearly 1.4 million boxes of harvested oranges.

Data were collected to calculate average performance measures by machine type for each sample period. The performance measures included removal percentage, recovery percentage, harvest speed, machine productivity, labor productivity, and percent runtime. Removal percentage refers to the amount of available fruit pulled from the tree during the harvesting operation. Recovery percentage refers to the amount of fruit that the harvest system removed from the trees and delivered to the bulk trailer for hauling to a processing plant. Recovery percentage *does not* include “gleaned” fruit. Harvest speed and machine productivity are based solely on active harvesting periods and include shake times, travel speeds, and minimum time requirements to change rows or off-load fruit to field goats. The percent runtime was determined for each sample period and reflects the amount of time engaged in active harvesting only during the IFAS sample period. Reasons why runtime percentage is less than 100% include, repairs, crew breaks, and extra time waiting on field goats. Runtime percentage *does not* include time spent “engaged-to-wait.” Harvesting crews are “engaged-to-wait” because of scheduled maintenance, transportation and set-up between new harvest sites, and bulk trailer availability.

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. These data are being further analyzed to determine effects of tree characteristics and grove conditions on mechanical harvesting performance.

Performance measures and data describing block characteristics are summarized in Tables 2-6. Tables 2 and 3 present data for the Coe-Collier and FMC Trunk-Shake-Catch (TSC) systems, respectively. Tables 4 and 5 summarize performance data for the Oxbo

and Korvan Continuous Canopy Shake-Catch (CCSC) systems. Table 6 presents data for the Oxbo Pull-along canopy shaker. 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.”

Tables 7 and 8 summarize average performance statistics for the past three seasons (2000-02 to 2002-03). These tables highlight how performance statistics for the TSC and CCSC systems have changed since the 2000-01 season.

The terms listed below provide additional 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 = Recovered fruit + broken fruit + missed ground & tree 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 systems 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)*

## **OBSERVATIONS**

1. Generally, yields were down from the 2001-02 season. Lower yields depress labor and machine productivity measures, which are dependent upon available boxes to be harvested.
2. The 2002-03 season was the first season of extended use for the FMC (TSC) and Korvan (CCSC) systems. Their lower labor productivity measures reflect the lower average runtime percentage. Similar performance measures were observed by Coe-Collier and Oxbo systems during the 2000-01 season (Tables 7 & 8). With field experience, runtime percentages should increase and the accompanying performance statistics.
3. The Pull-Along (PA) Oxbo equipment operated in grove conditions significantly different from conditions found by TSC and CCSC systems. Generally, trees were older, less dense, and larger. Tree yield, especially in early-mid blocks, were larger. Most trees in blocks harvested by the PA were not skirted. It was noted that most of the fruit not removed by the PA was located below the skirt line (36 inches).
4. Since the 2000-01 season, removal and recovery percentages have remained the same for both TSC and CCSC systems. This suggests that the technology for removing and catching fruit has not significantly changed. The major performance improvements have come in the way equipment operators have managed their crews and maintained the equipment. Increasing runtime percentage directly correlates to increasing harvest speed, machine and labor productivity.

**Table 1. Scope of citrus mechanical harvesting performance evaluation  
2002/03 season**

	<b>Sample Periods</b>	<b>Net Tree Acres</b>	<b>Net Weight Boxes</b>
<b>Total</b>	<b>89</b>	<b>4,756</b>	<b>1,392,421</b>
<b>Early/Mid</b>	<b>51</b>		
<b>Late</b>	<b>37</b>		
<b>TSC Coe-Collier</b>			
<i>Total</i>	<b>30</b>	<b>1,314</b>	<b>599,571</b>
<i>Early/Mid</i>	<b>26</b>	<b>1,050</b>	<b>510,295</b>
<i>Late</i>	<b>4</b>	<b>264</b>	<b>89,276</b>
<b>TSC FMC</b>			
<i>Total</i>	<b>8</b>	<b>45</b>	<b>19,690</b>
<i>Early/Mid</i>	<b>5</b>	<b>28</b>	<b>16,885</b>
<i>Late</i>	<b>3</b>	<b>17</b>	<b>2,805</b>
<b>Pull-Along Oxbo</b>			
<i>Total</i>	<b>14</b>	<b>582</b>	<b>159,601</b>
<i>Early/Mid</i>	<b>10</b>	<b>357</b>	<b>107,628</b>
<i>Late</i>	<b>4</b>	<b>225</b>	<b>51,973</b>
<b>CCSC Oxbo</b>			
<i>Total</i>	<b>28</b>	<b>1,670</b>	<b>453,217</b>
<i>Early/Mid</i>	<b>5</b>	<b>463</b>	<b>53,777</b>
<i>Late</i>	<b>23</b>	<b>1,207</b>	<b>399,440</b>
<b>CCSC Korvan</b>			
<i>Total</i>	<b>8</b>	<b>1,145</b>	<b>300,342</b>
<i>Early/Mid</i>	<b>5</b>	<b>774</b>	<b>216,222</b>
<i>Late</i>	<b>3</b>	<b>371</b>	<b>84,120</b>

**Table 2. Average performance statistics of TSC -Coe-Collier and harvest block characteristics, 2002/03 season**

		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Number of trial periods</b>	<i>#</i>	26	4
<b>Average trial duration</b>	<i>Hrs</i>	2.0	1.75
<b>Removal</b>	<i>%</i>	94%	95%
<b>Recovery</b> (excluding preharvest drop)	<i>%</i>	87%	88%
<b>Shake time</b>	<i>Sec</i>	8	11
<b>System Efficiency</b> (% runtime)	<i>%</i>	54%	60%
<b>Machine Speed</b> (100% runtime)	<i>tree/hr</i>	187	210
<b>Machine Productivity</b> (100% runtime)	<i>boxes/hr</i>	420	246
<b>Crew Size</b> (not including gleaners)		3	4
<b>Labor Productivity</b> (operators + goat drivers, no gleaners)	<i>boxes/hr</i>	82	42

<b>Block Characteristics</b>		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Tree Density</b>	<i>Tree/ac</i>	162	155
<b>Tree age</b>	<i>Years</i>	13	12
<b>Avg. Block Yield</b>	<i>Box/ac</i>	492	338
<b>Avg. Tree Yield (Block)</b>	<i>Box/tree</i>	3.1	2.0
<b>Avg. Tree Yield (Sample)</b>		3.3	1.7
<b>Tree height</b>	<i>Ft</i>	114	15
<b>Clear trunk height</b>	<i>In</i>	17	23
<b>Skirt height</b>	<i>In</i>	25	33
<b>Trunk circumference</b>	<i>In</i>	20	21

**Table 3. Average performance statistics of TSC -FMC and harvest block characteristics, 2002/03 season**

		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Number of trial periods</b>	<i>#</i>	5	3
<b>Average trial duration</b>	<i>Hrs</i>	3.5	5.0
<b>Removal</b>	<i>%</i>	92%	84%
<b>Recovery</b> (excluding preharvest drop)	<i>%</i>	75%	64%
<b>Shake time</b>	<i>Sec</i>	10	7
<b>System Efficiency</b> (% runtime)	<i>%</i>	50%	47%
<b>Machine Speed</b> (100% runtime)	<i>tree/hr</i>	104	135
<b>Machine Productivity</b> (100% runtime)	<i>boxes/hr</i>	317	77
<b>Crew Size</b>	<i>#</i>	3	3
<b>Labor Productivity</b> (operators + goat drivers, no gleaners)	<i>boxes/hr</i>	53	11

<b>Block Characteristics</b>		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Tree Density</b>	<i>Tree/ac</i>	165	165
<b>Tree age</b>	<i>Years</i>	12	12
<b>Avg. Block Yield</b>	<i>Box/ac</i>	600	Na
<b>Avg. Tree Yield (Block)</b>	<i>Box/tree</i>	3.6	Na
<b>Avg. Tree Yield (Sample)</b>		3.7	0.9
<b>Tree height</b>	<i>Ft</i>	14	18
<b>Clear trunk height</b>	<i>In</i>	18	19
<b>Skirt height</b>	<i>In</i>	18	19
<b>Trunk circumference</b>	<i>In</i>	19	27

**Table 4. Average performance statistics of CCSC-Oxbo and harvested block characteristics, 2002/03 season**

		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Number of trial periods</b>	<i>#</i>	5	23
<b>Average trial duration</b>	<i>hrs</i>	3.25	4.0
<b>Removal</b>	<i>%</i>	96%	95%
<b>Recovery</b> (excluding preharvest drop)	<i>%</i>	91%	90%
<b>Travel Speed</b>	<i>mph</i>	0.7	1.0
<b>Machine Speed</b> (100% runtime)	<i>tree/hr</i>	313	474
<b>Machine Productivity</b> (100% runtime)	<i>boxes/hr</i>	802	751
<b>System Efficiency</b> (% runtime)	<i>%</i>	66%	67%
<b>Crew Size</b> (no gleaners)	<i>#</i>	5-6	6
<b>Labor Productivity</b> (operators + goat drivers)	<i>boxes/hr</i>	110	83

<b>Block Characteristics</b>		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Tree Density</b>	<i>Tree/ac</i>	160	156
<b>Tree age</b>	<i>Years</i>	15	13
<b>Avg. Block Yield</b>	<i>Box/ac</i>	415	334
<b>Avg. Tree Yield (Block)</b>	<i>Box/tree</i>	2.9	2.4
<b>Avg. Tree Yield (Sample)</b>		2.9	2.3
<b>Tree height</b>	<i>ft</i>	14	14
<b>Clear trunk height</b>	<i>in</i>	15	18
<b>Skirt height</b>	<i>in</i>	13	16
<b>Trunk circumference</b>	<i>in</i>	20	21

**Table 5. Average performance statistics of CCSC-Korvan and harvested block characteristics, 2002/03 season**

		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Number of trial periods</b>	<i>#</i>	5	3
<b>Average trial duration</b>	<i>hrs</i>	3.5	4.0
<b>Removal</b>	<i>%</i>	96%	97%
<b>Recovery</b> (excluding preharvest drop)	<i>%</i>	91%	92%
<b>Travel Speed</b>	<i>mph</i>	0.7	1.1
<b>Machine Speed</b> (100% runtime)	<i>tree/hr</i>	290	535
<b>Machine Productivity</b> (100% runtime)	<i>boxes/hr</i>	921	594
<b>System Efficiency</b> (% runtime)	<i>%</i>	38%	44%
<b>Crew Size</b> (no gleaners)	<i>#</i>	5	6
<b>Labor Productivity</b> (operators + goat drivers)	<i>boxes/hr</i>	65	42

<b>Block Characteristics</b>		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Tree Density</b>	<i>Tree/ac</i>	135	163
<b>Tree age</b>	<i>Years</i>	20	14
<b>Avg. Block Yield</b>	<i>Box/ac</i>	272	234
<b>Avg. Tree Yield (Block)</b>	<i>Box/tree</i>	2.0	1.3
<b>Avg. Tree Yield (Sample)</b>		4.3	1.6
<b>Tree height</b>	<i>ft</i>	14	15
<b>Clear trunk height</b>	<i>in</i>	15	20
<b>Skirt height</b>	<i>in</i>	6	9
<b>Trunk circumference</b>	<i>in</i>	23	21



**Table 6. Average performance statistics of Pull-along-Oxbo and harvested block characteristics, 2002/03 season**

		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Number of trial periods</b>	<i>#</i>	9	4
<b>Average trial duration</b>	<i>hrs</i>	2.75	4.0
<b>Removal</b>	<i>%</i>	89%	95%
<b>Recovery</b> (excluding preharvest drop)	<i>%</i>	99%	99%
<b>Machine Speed</b> (100% runtime)	<i>tree/hr</i>	217	255
<b>Size of Pick-up crew</b>	<i>#</i>	23	18
<b>Labor Productivity</b> (pick-up crew)	<i>boxes/hr</i>	13	21

<b>Block Characteristics</b>		<b>Early/Mids</b>	<b>Late Season</b>
	<b>Units</b>	<b>Average</b>	<b>Average</b>
<b>Tree Density</b>	<i>Tree/ac</i>	90	145
<b>Tree age</b>	<i>Years</i>	37	20
<b>Avg. Tree Yield (Block)</b>	<i>Box/ac</i>	335	292
<b>Avg. Tree Yield (Block)</b>	<i>Box/tree</i>	4.3	1.9
<b>Avg. Tree Yield (Sample)</b>	<i>Box/tree</i>	5.1	3.3
<b>Tree height</b>	<i>ft</i>	15	14
<b>Clear trunk height</b>	<i>in</i>	18	15
<b>Skirt height</b>	<i>in</i>	5	4
<b>Trunk circumference</b>	<i>in</i>	31	26

**Table 7. Average performance statistics of TSC on early-mid oranges from 2000/01 to 2002/03**

		<b>2000-01</b>	<b>2001-02</b>	<b>2002-03</b>
<b>Yield</b>	<b>Bx/acre</b>	<b>561</b>	<b>512</b>	<b>492</b>
<b>Removal</b>	<b>%</b>	<b>95</b>	<b>95</b>	<b>94</b>
<b>Recovery</b>	<b>%</b>	<b>87</b>	<b>89</b>	<b>87</b>
<b>Harvest speed</b>	<b>Tree/hr</b>	<b>107</b>	<b>174</b>	<b>187</b>
<b>Runtime</b>	<b>%</b>	<b>53</b>	<b>67</b>	<b>54</b>
<b>Productivity</b>	<b>Bx/man-hr</b>	<b>53</b>	<b>98</b>	<b>82</b>

**Table 8. Average performance statistics of CCSC on early-mid oranges from 2000/01 to 2002/03**

		<b>2000-01</b>	<b>2001-02</b>	<b>2002-03</b>
<b>Yield</b>	<b>Bx/acre</b>	<b>463</b>	<b>429</b>	<b>415</b>
<b>Removal</b>	<b>%</b>	<b>95</b>	<b>95</b>	<b>96</b>
<b>Recovery</b>	<b>%</b>	<b>90</b>	<b>90</b>	<b>91</b>
<b>Harvest speed</b>	<b>Tree/hr</b>	<b>235</b>	<b>288</b>	<b>313</b>
<b>Runtime</b>	<b>%</b>	<b>51</b>	<b>67</b>	<b>66</b>
<b>Productivity</b>	<b>Bx/man-hr</b>	<b>70</b>	<b>98</b>	<b>110</b>