Evaluating Performance of Citrus Mechanical Harvesting Systems
2000/01 Season

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Presentation to the Citrus Harvesting Research Council
Lakeland, FL
July 12, 2001

Table on page 2 summarizes, by variety and machine system, the sample periods and the number of individual blocks on which IFAS-SWFREC personnel collected data. Harvesting data were collected on blocks representing more than 4,000 acres and 1.7 million boxes of harvestedoranges.

Tables on pages 3-5 summarize performance statistics and block characteristics by harvest system. 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."

Table on page 6 specifically considers a TSC system and how improvements in **Recovery** percentages and **System Efficiencies** can enhance **Labor Productivity** and lower unit picking costs.

Table on page 7 outlines a process by which a grower can evaluate whether a mechanical harvest system would increase on-tree revenues.

Tables on page 8 present, for a specific set of cost assumptions, the maximum allowable non-harvest percentages by a mechanical system over a range of yields and delivered-in prices. In other words, for an any non-harvest percentage *less* than the table value for a yield and price combination, the grower's on-tree revenue increases relative to what he would have earned if the block had been harvested by hand.

A description of the relationships listed in the following tables and how they were derived is presented on page 9.

Scope of citrus mechanical harvesting project
2000/01 season

	Sample Periods	Blocks	Net Tree Acres	Net Weight Boxes
Total	**144**	**65**	**4,124**	**1,725,800**
Early/Mid		**38**		
Late		**27**		
TSC Coe-Collier				
Total	102	31	2,571	1,254,630
Early/Mid	83	24	2,103	1,105,351
Late	19	7	468	149,279
MB Stackhouse				
Total	11	11	317	124,376
Early/Mid	8	8	165	81,059
Late	3	3	152	43,317
MB FMC				
Total	2	2	20	4,525
Early/Mid	0	0	0	0
Late	2	2	20	4,525
CCSC Oxbo				
Total	26	18	1,212	340,470
Early/Mid	10	7	348	163,911
Late	16	11	864	176,559
CCSC Korvan				
Total	3	3	4	1,800
Early/Mid	0	0	0	0
Late	3	3	4	1,800

Performance statistics and block characteristics by machine system

1. TSC: Coe-Collier Harvesters

	Units	Early/Mids Average	Late Season Average
Number of trial periods	*#*	83	19
Average trial duration	*hrs*	1.9	1.7
Removal	*%*	94 %	89 %
Recovery (excluding preharvest drop)	*%*	87 %	78 %
Harvest %	*%*	99 %	99 %
Shake time	*sec*	13 (3-33)	7 (5-12)
Shake & move time	*sec*	31 (16-63)	26 (17-38)
Machine Speed (100% runtime)	*tree/hr*	107	137
Machine Productivity (100% runtime)	*boxes/hr*	318	246
System Efficiency (% runtime)	*%*	53 %	54 %
Labor Productivity (operators + goat drivers, no gleaners)	*boxes/hr*	53	39

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	*Tree/ac*	162	171
Tree age	*Years*	11	11
Avg. Block Yield	*Box/ac*	541	361
Avg. Tree Yield	*Box/tree*	3.55	2.12
Tree height	*ft*	14	14
Clear trunk height	*in*	16	16
Skirt height	*in*	25	25
Trunk circumference	*in*	19	19

2. MB: Stackhouse Harvester (no pick-up machine)

	Units	Early/Mids Average	Late Season Average
Number of trial periods	*#*	7	3
Average trial duration	*hrs*	6	3
Removal	*%*	95 %	88 %
Recovery (excluding preharvest drop)	*%*	97 %	100 %
Shake time	*sec*	46	12
Shake & move time	*sec*	90	65
Machine Speed (100% runtime)	*tree/hr*	62	na
Machine Productivity (100% runtime)	*boxes/hr*	410	na
System Efficiency (% runtime)	*%*	55 %	na
Size of Pick-up crew	*#*	12	na
Labor Productivity (pick-up crew)	*boxes/hr*	10 (6 – 18)	na

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	*Tree/ac*	75	103
Tree age	*Years*	48	
Avg. Tree Yield	*Box/tree*	7.35	5.17
Tree height	*ft*	20	20
Clear trunk height	*in*	14	14
Skirt height	*in*	na	na
Trunk circumference	*in*	40	40

3. CCSC: Oxbo Harvesters

	Units	Early/Mids Average	Late Season Average
Number of trial periods	*#*	10	16
Average trial duration	*hrs*	3.5	5.4
Removal	*%*	95 %	89 %
Recovery (excluding preharvest drop)	*%*	90 %	79 %
Harvest %	*%*	99 %	97 %
Travel Speed (min-max)	*mph*	.78 (.48 – 1.24)	1.74 (1.08 – 3.04)
Machine Speed (100% runtime)	*tree/hr*	226	604
Machine Productivity (100% runtime)	*boxes/hr*	623	741
System Efficiency (% runtime)	*%*	51 %	34 %
Crew Size (no gleaners)	*#*	4	6
Labor Productivity (operators + goat drivers)	*boxes/hr*	71	40

Block Characteristics	Units	Early/Mids Average	Late Season Average
Tree Density	*Tree/ac*	163	162
Tree age	*Years*	13	12
Avg. Block Yield	*Box/ac*	463	282
Avg. Tree Yield	*Box/tree*	3.06	1.75
Tree height	*ft*	15	15
Clear trunk height	*in*	14	14
Skirt height	*in*	23	23
Trunk circumference	*in*	20	20

Evaluating the impact of TSC's Recovery % and System Efficiency % on Labor Productivity and unit picking costs.

Assumptions:
1. System consists of three people – 2 operators and 1 goat driver.
2. Operators and goat drivers are paid $9.00 per hour.
3. Hand crew picks for $.70/box and can average 10 boxes/hr.

Recovery	Machine Productivity	System Efficiency	System Productivity	Labor Productivity	Unit Picking Costs
%	bx/hr	%	bx/hr	bx/hr	$/bx
85	300	50	150	50	$0.18
85	300	60	180	60	$0.15
85	300	70	210	70	$0.13
90	318	70	223	74	$0.12
95	335	70	235	78	$0.11

Example
Calculating on-tree revenue from a HAND harvest system and from a MACHINE harvest system.

Variables		Hand	Machine Yr-1	Machine Yr-2
Grove preparation costs	$/ac	0	$20	$15
Lost yield from skirting	%	0	5%	0
Damage to trees	$/ac	0	0	0
Repairs to irrigation	$/ac	0	$15	$15
Hauling costs	$/bx	$.50	$.50	$.50
Pick/Roadside	$/bx	$1.50	$1.00	$1.00
Fruit recovery	%	100%	90%	90%
Pre harvest tree yield	bx/ac	500	475	500
Delivered-in price	$/bx	$5.00	$5.00	$5.00

Harvested boxes	bx/ac	**500**	**428**	**450**
Delivered-in revenue	$/ac	$2,500	$2,140	$2,250
Deductions:				
-(Hauling cost)	$/ac	250	214	225
-(Pick/Roadside cost)	$/ac	750	428	450
-(Grove Prep costs)	$/ac	0	20	20
-(Irrigation repairs)	$/ac	0	15	15
"Net" on-tree revenue	$/ac	**$1,500** Hand	**$1,463** Machine Yr-1	**$1,545** Machine Yr-2

1. Economic Setting: $1.50 hand pick/roadside; $1.20 mechanical pick/roadside
(5.75 p.s. per box) $20/ac skirt cost; $10/ac post-harvest (irrigation) repairs
0% yield reduction from skirting
0% damage to trees from mechanical harvesting system

Maximum allowable non-harvest with mechanical system:

Yield (bx/ac)	Delivered-in price ($/bx)						
	$2.00 **($.35/ps)**	**$2.50** **($.43/ps)**	**$3.00** **($.52/ps)**	**$3.50** **($.61/ps)**	**$4.00** **($.70/ps)**	**$4.50** **($.78/ps)**	**$5.00** **($.87/ps)**
300	100%	29%	17%	12%	9%	7%	6%
400	100%	31%	18%	13%	10%	8%	7%
500	100%	32%	19%	14%	11%	9%	7%
600	100%	33%	20%	14%	11%	9%	8%

2. Economic Setting: $1.50 hand pick/roadside; $1.20 mechanical pick/roadside
$20/ac skirt cost; $10/ac post-harvest (irrigation) repairs
2% yield reduction from skirting
0% damage to trees from mechanical harvesting system

Maximum allowable non-harvest with mechanical system:

Yield (bx/ac)	Delivered-in price ($/bx)						
	$2.00	**$2.50**	**$3.00**	**$3.50**	**$4.00**	**$4.50**	**$5.00**
300	100%	27%	15%	10%	7%	5%	4%
400	100%	29%	17%	11%	8%	6%	5%
500	100%	31%	18%	12%	9%	7%	5%
600	100%	32%	18%	12%	9%	7%	6%

Explanation of terms and how they were calculated.

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)