PERFORMANCE AND ECONOMIC EVALUATION OF CITRUS HARVESTING SYSTEMS 1999/2000 SEASON

Final Report to the Florida Department of Citrus

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Background for Study

Since 1995, the Florida Department of Citrus (FDOC) has been funding research and development projects to create commercially viable mechanical harvesting systems. The FDOC's mechanical harvesting program has been building momentum. By the end of the 1999/2000 season, six harvesting systems [1] were under active review. The Citrus Harvesting Research Advisory Council anticipated that the 1999/2000 season would be a "break-out" year for mechanical harvesting systems, with harvested area expected to approach 10,000 acres. The number of commercial harvesters operating trunk-shake-catch systems increased from one to six and the canopy-area-shake system was being marketed aggressively by the Mongoose Company.

Prior to the 1999/2000 season, growers and fruit harvesters had little information from which to compare and judge the relative performance of the various harvesting systems. Only one system, the Fruit Harvesters International (FHI) trunk-shake-catch system, was operating on a commercial basis. FHI had been operating harvesting equipment for at least seven years, but performance statistics were not publicly available and subject to independent verification. The FDOC and the University of Florida tests were limited to small plot trials. The most extensive trial occurred during April 1999 when three trunk-shaker manufacturers (Coe, Compton, and FHI) operated their equipment simultaneously on adjacent 20-acre blocks in Highlands County at the Lykes-Ft. Basinger grove.

With limited recorded information and a growing number of harvesting systems evolving to commercial potential, the Citrus Harvesting Research Advisory Council requested that performance measures be developed so that growers and harvesting companies could begin to judge the effectiveness of specific mechanical harvesting systems under various grove conditions. Toward that end, the FDOC funded the University of Florida/IFAS to collect data and begin to develop commercial performance measures for mechanical harvesting systems. This report describes work done during the 1999/2000 season,

[1] Trunk-shake-catch (Coe-Collier Partnership, Compton, and Fruit Harvesters International), canopy -area-shake (Mongoose), single-drum continuous canopy shake-catch (Oxbo), double-drum continuous canopy shake-catch (Korvan), mono-boom trunk shaker (Orchard Rite/Stackhouse), and canopy-pull-catch (Crunkelton).

summarizes the data collected, and offers some preliminary analysis of how grove conditions affect harvesting performance.

Including the introductory section, there are six parts to this report. The next section outlines the study objectives and scope of work. The third section discusses research design and procedures. The fourth section describes the citrus blocks from which data were collected. The fifth section presents results, summarizing performance measures and implications of grove conditions. The sixth section outlines plans for continuation of work during the 2000/2001 harvest season.

Objectives and Scope of Work

If mechanical harvesting systems are to be commercially successful and replace hand crews as the dominant harvesting method, four conditions must be satisfied. First, mechanical systems will have to remove and recover a sufficient percentage of the crop. It is unlikely that a completely mechanical system will recover 100 percent of the available fruit, a goal achievable by a hand crew. A "sufficient" recovery using a mechanical system will be such that the economic value of the remaining fruit will be insignificant. Fruit prices, harvest costs of machine systems, and the labor costs of gleaning crews will dictate the acceptable threshold of "sufficient" recovery for a mechanical harvesting system. The second condition will be improvement of labor productivity to a point where the smaller available labor force can complete the harvest. In recent years, the concern among growers and harvesting companies has been increasing over whether an adequate number of workers will be available to harvest Florida's citrus crop. The industry has been relying on a harvesting work force that is predominately single male and foreign-born. These workers have few social anchors to Florida as they migrate into and out of the state during the citrus harvesting season. Further, a strong U.S. economy is attracting harvest workers to non-agricultural jobs with better year-round income potential. While concern over the availability of harvest labor may drive the initial adoption of mechanical harvesting systems, global competition from other citrus producing countries requires that the Florida citrus industry become more cost efficient. Consequently, the third condition of mechanical systems is that unit-harvesting costs be reduced enough to maintain a global competitive edge. The fourth condition is that mechanical harvesting systems do not damage bearing trees and shorten a tree's expected productive life. If mechanical harvesting shortens a tree's expected productive life, overall production costs increase.

Objectives of this study were to address the first two criteria discussed above – fruit removal / recovery percentages and gains in harvesting labor productivity. Specifically, this study sought to:

1) Collect data and develop harvesting performance measures, including labor and machine productivity, fruit removal and recovery percentages, and harvesting speed.
2) Analyze how grove conditions and tree architecture effect performance results.

Performance measures include rates of machine and labor productivity, harvest speed, and fruit removal and recovery percentages. Labor productivity measures must account not only for equipment operators, but also for ground crews gleaning non-harvested fruit and equipment support personnel such as mechanics. Comparisons of labor productivity rates between hand and machine crews will provide a basis on which to predict future demand for harvest labor. Machine productivity and harvest speeds are important to assess equipment capacities, overall equipment demand, and how capital costs will be spread over production units. Mechanical systems will change the speed at which citrus harvesting occurs, and most likely affect harvest schedules between a grower and a processing plant. Fruit recovery results are important in calculating overall unit costs of harvesting and determining the value of gleaning crews.

Florida citrus is being produced under a highly diverse set of grove conditions. From soil differences to tree densities to variety/rootstock combinations to management strategies, the parameters defining an individual block of trees are very specific. Consequently, how a mechanical harvesting system performs in one block may be significantly different from its performance in a second block with different production conditions. During the course of this study, data were collected on grove and harvester characteristics to begin to develop some relationships among grove characteristics and harvesting performance. Many experts, most notably Dr. Galen Brown (Administrator of the FDOC Harvesting Program), anticipate that a single harvesting system will not be adequate to handle the diverse conditions which exist within the Florida citrus industry. By identifying how grove conditions influence harvesting performance, a given system can be directed to the appropriate niche of grove conditions where its performance can be optimized.

It is also important to understand what this study did not address. Results presented in this report represent a cross-section of citrus blocks for a single year. Data from a single year can not anticipate long-term yield impacts. Other University of Florida researchers, notably Dr. Jodie Whitney, are conducting studies where the yields from a sample of mechanically harvested trees are being tracked over a number of years.

This study, also, did not address the cost of mechanical harvesting and performance differences among equipment manufacturers of similar harvesting systems. Estimating the cost of mechanical harvesting from data collected during 1999/00 would be premature, provide little value, and hinder future data collection efforts. For many of the harvesting companies, it was their first experience using mechanical harvesting systems to harvest citrus. Significant innovations occurred during the season as equipment operators learned how to adapt their machines to grove conditions and improve overall performance. More innovations are likely to occur for the 2000/01 season. As improvements are made, mechanical-harvesting costs should decline. Estimating a cost in advance of imminent innovation would be of marginal value to growers and to the industry at large. More importantly, a public pronouncement of harvesting costs would hamper the negotiating position of companies currently offering mechanical harvesting services, and thereby impede their opportunity to earn profits. Reducing the profit potential would not only discourage harvesting companies from sharing performance data with future IFAS studies, but would also discourage important investments into mechanical harvesting technology. As harvesting systems evolve and profits accrue to the business entrepreneurs, competition should drive harvesting costs downward. Competition will occur in two ways. First, more companies will organize to offer mechanical harvesting services. Second, all companies will lower harvesting costs to induce growers into providing more acreage to be mechanically harvested.

The intent of this study was to evaluate each harvesting system in specific grove situations, not to compare individual equipment manufactures or harvesting companies. For five out of the six systems under development during 1999/00, only one equipment manufacturer represented each system.[2] The trunk-shake-catch (TSC) system was the exception. Three commercial manufacturers operated TSC equipment during the 1999/00 season, Coe-Collier Citrus Harvesting LLP, Compton Enterprises, and Fruit Harvesters International. Given the innovations and design modifications made by all equipment manufacturers and operating crews, the data collected during 1999/2000 provides little information on performance differences among the three TSC manufacturers. As with harvesting costs, distinguishing performance differences (if any) among manufacturers of similar equipment will become evident only after the system processes have been refined.

Study Design and Procedures

Data in this study were organized around citrus blocks that were mechanically harvested. Each block was treated as a single observation or record. Performance measures were developed through a cross-sectional analysis of the study blocks. Data blocks in this report are referred to as either “IFAS Blocks” or “Supplemental Blocks” to distinguish whether or not IFAS personnel visited the block and collected data during harvesting.

For each IFAS Block, data records were assembled from three sources of information – grower records, harvester records, and IFAS field measurements. Attachments I, II, and III were the forms used to collect data from growers, harvesters, and field visits, respectively.

Grower records provided descriptive information about the block, including scion variety and rootstock combination, tree age, planting density, irrigation system, net tree acres, and an estimate of total bearing tree spaces within the block. Growers were also asked to provide a five-year yield history of the block and whether the block had been previously mechanically harvested. The most important data provided by the growers were daily weight tickets of harvested fruit during the 1999/2000 season.

Harvesting companies provided information about the labor and machine use. Important data included daily crew size and hours worked per day. The initial data collection plan included asking harvesters to keep a log of machine hours, noting when a given block was started and finished. Further, information was requested about daily hours of machine downtime. For some harvesting cooperators, keeping a daily log of machine

[2] Canopy -area-shake (Mongoose), single-drum continuous canopy shake-catch (Oxbo), double-drum continuous canopy shake-catch (Korvan), mono-boom-trunk-shaker (Orchard Rite – Stackhouse), and canopy-pull-catch (Crunkelton).

hours proved difficult. As an alternative to machine logs, payroll time sheets, which separated equipment operators from ground personnel, were used to estimate machine hours.

IFAS personnel visited as many blocks as time and scheduling constraints would allow during the harvest season. Data collected during those visits included tree measurements, block characteristics, speed of harvesting operations, and volume of available fruit not harvested by the mechanical systems. Samples of trees were measured to estimate tree characteristics including trunk circumference, clear-trunk, skirt (prior to harvest), and overall height. Within a sample of rows, total tree spaces, number of blanks, and young reset trees were counted to estimate the percentage of bearing trees. Times were recorded for various harvesting operations including shaking time, movement between trees, and transfer of fruit from storage bins to field goats.

The most time consuming activity on the IFAS Blocks was measuring fruit not recovered by the harvesting system. To collect this data, a sample of trees was marked prior to harvesting. Fruit on the ground, referred to as "pre-harvest ground fruit," was counted, weighed, and removed from the sample area. As the harvesting machines moved through the sample area, members of the harvesting ground crew were asked not to pick any of the ground or tree fruit that had not been captured by the machine. Once the machines had finished harvesting the sample area, IFAS personnel collected, counted, and weighed ground fruit. The number of damaged fruit was recorded and its pre-harvest weight was estimated from the remaining whole pieces of ground fruit. After the ground fruit was recorded, all fruit remaining in the sampled trees were gleaned, counted, and weighed. By separating non-harvested tree fruit from ground fruit, fruit removal percentages could be estimated independently of total recovery percentages.

Data was collected on Supplemental blocks that were harvested by a mechanical system but not observed by IFAS personnel. From these blocks, growers and harvesters provided the same type of data that was collected from the IFAS Blocks. Missing from the Supplemental Blocks were the IFAS data collected during harvesting, particularly fruit removal/recovery data.

General Description of Study Blocks

During the 1999/2000 season, data were collected from 84 blocks that were mechanically harvested. The general features of these blocks are summarized in Tables 1 and 2. Of the 84 total, 59 blocks (70 %) were IFAS Blocks. Harvesting systems were observed on five orange varieties, Hamlin (30 blocks), Parson Brown (3), Pineapples (5), standard Valencia (19), and Rodhe Red Valencia (2). Supplemental Blocks provided additional information on 25 blocks, including Hamlin (14), pineapple (2), and standard Valencia (9).

Data were collected on five mechanical harvesting systems – trunk-shake-catch (TSC), canopy area shake (CAS), single drum continuous canopy shake-catch (CCSC-1), double drum continuous canopy shake-catch (CCSC-2), and a mono-boom trunk shake (MBS).

A sixth harvesting system, the Crunkleton canopy-penetrater was not available for observation during the 1999/00 harvest season. A description and photos of each system can be found in the Citrus Harvesting Program Update Report (Brown, 2000).

The most complete data records came from blocks harvested by the TSC and the CAS systems, which were the two systems being marketed as commercial harvesting systems during the 1999/00 season. Two thirds of the study blocks, or 56 blocks, were harvested with trunk-shake-catch (TSC) systems. Sixteen blocks were harvested with the canopy-area-shake (CAS) system. The remaining 12 blocks were harvested by systems undergoing significant development, testing and design modifications. Machine and labor productivity data were not collected on these 12 blocks. Nine of these blocks were harvested by CCSC-1. A similar continuous traveling system, the CCSC-2, worked in portions of two blocks. A mono-boom trunk shaker (MBS) was used on several blocks during the season, but data was collected on only two blocks.

The Citrus Harvesting Program Update Report (Brown, 2000) estimated that 6,500 acres were mechanically harvested in Florida during the 1999/00 season. Data summarized in this project represents approximately 6,000 net tree acres, or more than 90 percent of the total mechanically harvested acreage. Mechanically harvested acreage is itemized by variety for IFAS and Supplemental Blocks, as well as for machine type, in Table 2. IFAS blocks represented 4,552 (78%) harvested acres and TSC systems accounted for 3,974 (66%) harvested acres. Harvested acreage was split fairly evenly between early-mid varieties (3,340 acres) and late season varieties (2,664 acres).

Descriptive statistics, including tree density, age, and yield, of the study blocks harvested by CAS and TSC systems are summarized in Table 3 by variety. Significant differences were found between blocks harvested with TSC systems and blocks harvested with the CAS system. Tree density in TSC blocks averaged 160 trees per acre, nearly twice (82 trees/acre) the tree density found in CAS blocks. Age of trees in CAS blocks averaged more than 40 years, nearly four times as old as trees harvested in TSC blocks (10 years of age). Early/mid trees harvested by the CAS system averaged 5.6 boxes per tree, 2.6 boxes per tree higher than early/mid trees harvested by TSC systems. However, production per acre from CAS blocks was lower than yields per acre in TSC blocks, 340 and 465 boxes per acre respectively. Beyond differences in simple averages between CAS and TSC blocks, the variability of the estimated average values (as measured by the standard deviation (stddev)) was higher among the CAS harvested blocks.

For blocks harvested with TSC systems, tree density and age were fairly similar between early/mid and late season varieties. As expected, early/mid yields, both on a per tree and per acre basis, were greater than yields from Valencia blocks (Table 3).

Performance Measures

TSC Systems

Table 4 summarizes fruit removal and recovery percentages, labor productivity, machine productivity, and harvest speed for all blocks harvested by trunk-shake-catch (TSC) systems. Separate performance measures were estimated for early/mid and late season blocks. An analysis of harvested blocks indicated that for each performance measure, a "majority" of blocks fell within a narrow range. The performance measures for the remaining blocks were significantly outside the range of the majority. Tables 5-8 present revised estimates of performance measures by removing blocks with extreme performance values. Tables 5-8 provide details of tree, grove, and harvester characteristics that correspond to the "majority" of blocks and to those blocks with extreme measures. In some cases, tree and harvester characteristics of blocks with extreme values provide insights into how grove conditions affect harvesting performance measures. In other cases, extreme values were probably a result of incomplete block data. Figures 1-24 plot selected tree and grove characteristics of individual blocks against a system's performance measure. The plots of individual blocks help indicate whether or not there is a systematic effect of a given grove characteristics on a particular performance measure.

A TSC system is comprised of two operations that work in parallel. On one side of a tree, a trunk shaker operates to remove fruit. At the same time and on the opposite side of the tree, a receiving unit catches the falling fruit and conveys it back to a trailing bin. Fruit from the bin is off-loaded to a field truck (goat), which in turn delivers the fruit to a road trailer. Fruit ***removal*** measures indicate the percentage of available fruit removed from the tree during the shaking action. Fruit ***recovery*** percentages represent the efficiency of catching the removed fruit and delivering it to the road trunk. For TSC systems, the fruit recovery percentage must be less than fruit removal percentage because some pieces of fruit will simply miss the catch frame or drop through the tree seal of the receiving unit. Clear trunk space and skirting are necessary for TSC systems to operate. More discussion of how these and other grove conditions affect TSC performance is discussed later in this report.

During the early/mid harvesting period, 95 percent of the blocks harvested by a TSC system achieved fruit removal percentages between 93 and 97 percent (Table 4). Average fruit removal was 95 percent. During the late season period, fruit removal percentages on most blocks ranged between 93 and 95 percent with an overall average of 94 percent. On average, the TSC system recovered and delivered to the hauling trailer 91% of available fruit in early/mid blocks. For most of the early/mid TSC blocks, fruit recovery ranged between 89 and 93 percent. Fruit recovery by TSC systems during Valencia harvest averaged 88 percent with a range of 85 to 91 percent for most of the late season blocks. The difference between 100% and the fruit recovery percentage is the volume of fruit available to gleaning crews.

Harvest ***labor productivity*** was measured for each block by dividing the total net weight boxes harvested by the total number of harvesting hours. Work by Polopolus et.al (1997) established that in blocks yielding between 400 and 500 boxes per acre average harvest productivity of hand crews is ten, 90-pound boxes per hour. This average rate only includes the hours of pickers during harvesting. They do not include the paid hours of goat drivers, crew leaders, and other supervisory personnel.

Labor productivity rates for TSC systems averaged 24 boxes per hour during early/mid season. For 95 percent of the blocks, labor productivity ranged between 21 and 27 boxes per hour, at least a 2-fold increase in productivity over hand crews. These estimates were based on data from 30 blocks and included ***all*** personnel hired to glean and collect fruit not recovered during the mechanical operation. In order to compare estimates of labor productivity between TSC systems and hand harvest crews, labor hours for goat drivers, crew leaders, and other supervisory personnel were not included. However, paid hours to TSC crews while machines were in transit to harvest sites and periods of inactivity due to mechanical break down and maintenance were included.

Labor productivity rates for TSC systems harvesting late season blocks are summarized for nine blocks in Table 4. It appears that productivity on late season blocks improved by 50 percent over early/mid blocks, from 24 to 36 boxes per hour. Further analysis, presented in Table 6b, suggests that this improvement is highly biased by the data from two blocks. Once the blocks with extremely high productivity values are removed, the overall average for labor productivity drops to between 23 and 25 boxes per hour.

Machine productivity measures the harvesting capacity of the harvesting equipment. Ideally, this estimate would be based on daily records of machine hours. Unfortunately, several harvesters did not record machine hours on a daily basis. In some cases, payroll records of equipment operators and field notes of equipment breakdowns were used to estimate machine hours. In other cases, even payroll information was not available to estimate machine hours.

For TSC systems, only 16 of the previous 30 early/mid season blocks had sufficient data to estimate machine productivity. Machine productivity was estimated for six of the nine late season blocks. On the early/mid season blocks, machine productivity of TSC systems averaged 192 boxes per hour with a range between 175 and 209 boxes per hour (Table 4). Machine productivity estimates were based on recovering only 91 percent of the available fruit. Consequently, the labor productivity of the core TSC system (2 equipment operators and 2 ground workers immediately trailing the harvesters) was between 40 and 45 boxes per labor hour.

Average machine productivity of TSC systems on late season blocks increased to 285 boxes per hour. This increase of nearly 50 percent is difficult to explain. On one hand, experience gained earlier in the year could have led to adjustments and innovations that improved harvesting efficiencies. On the other hand, Valencia production per tree is less than production from early/mid trees. For a given shake time, the total number of fruit pieces removed should be less. Two other reasons may explain the differences in machine productivity for TSC systems between early/mid and late season. First, the average estimate may not be reliable due to the limited number of blocks (only 6) comprising the late season estimate. Second, there may be a fundamental flaw in the data collected. As shown in Figures 13b-18b, the six late season blocks are evenly split between three blocks with machine productivity more than 270 boxes per hour and three blocks with machine productivity between 150 and 210 boxes per hour.

Harvest speed was closely linked to machine productivity. Harvest speed was estimated by dividing total number of harvested trees by the number of machine hours. The reciprocal, or inverse, of this number indicates the number of seconds spent harvesting each tree. Estimates of harvest speed include shake time and time spent moving equipment between trees and to different rows.

During the early/mid season, TSC systems required, on average, 53 seconds per tree to complete the shaking of one tree and reposition to another tree. This harvest speed translated to harvesting 68 trees per hour. Harvest speeds of TSC systems more than doubled during late season. TSC systems on late season blocks averaged only 20 seconds per tree, harvesting 177 trees per hour. However, as in the case of machine productivity, the reliability of these late season estimates is open to question because of the limited number of blocks and whether the correct data were collected.

Effect of grove and tree characteristics on TSC performance. Averages and ranges of performance measures provide some indication of how mechanical harvesting systems are evolving. However, growers need more specific information on how these systems will perform in their groves.

Insights as to how grove and harvester attributes affect system performance may be gleaned by comparing grove and harvester characteristics of blocks with extreme performance values against the same grove attributes found within the “majority” blocks. Tables 5-8 present revised estimates of average performance measures by identifying and separating blocks with extreme performance values. Blocks with extreme values for each performance measure were segregated from the remaining “majority” blocks and performance averages were recalculated for only the majority blocks. Average tree yield, tree density, and tree configuration are presented for the majority blocks. Performance estimates and grove characteristics for each “extreme” block are listed in adjacent columns. In addition, harvests dates and a harvester identification code are listed for the extreme blocks.

Fruit removal percentage averaged 96 percent for 22 blocks that fell within a range from 93 to 98 percent (Table 5a). Four blocks had lower removal percentages and one block achieved 99 percent removal. Among the blocks that experienced low fruit removal percentage, harvest dates tended to be early. Block ID numbers 46 and 34 were the first blocks harvested by Harvester #1 and 6, respectively. Harvester #1, in particular, experienced several personnel disruptions and equipment breakdowns early in the season. The block that experienced the highest fruit removal percentage (Block ID# 24, 99%) had higher clear trunk and skirt heights than the averages for the trees in the majority blocks.

Removal percentages on the majority of late season blocks were similar to those achieved on the early/mid blocks (Table 5b). Two late season blocks outside the majority achieved 98 percent removal (Block ID#s 46 and 47). A common link between these two blocks was the harvesting manufacturer, Fruit Harvesters International. However, both blocks were from the same grove, so it is unclear whether grove or equipment or operator skill was predominately responsible for the high removal percentages.

Tables 6a and 6b present labor productivity and grove conditions for early/mid blocks and late season blocks. Seven early/mid blocks were separated from the majority blocks. Six of the seven blocks achieved labor productivity less than the majority average of 27 boxes per hour. The most important similarity among these blocks was Harvester #6. Harvester #6, responsible for Block IDs 77, 35, 34, 33, and 78, employed the largest number of gleaners of any harvester operating TSC systems in 1999/00. Up to 10 people followed Harvester #6's TSC systems, collecting unharvested ground and tree fruit.

Two late season blocks (Block IDs 10 and 75) were estimated to have achieved labor productivity rates of 65 and 68 boxes per hour, significantly higher than the range of 19 to 32 boxes per hour of the remaining seven late season blocks. Grove and harvester characteristics do not suggest any reason why these blocks achieved such high rates of labor productivity. An inaccurate underestimate of labor hours could explain high productivity values. When the two extreme late season blocks are removed, the average labor productivity becomes 25 boxes per hour, very close to what was achieved during the early/mid season.

Machine productivity on twelve early/mid blocks averaged 193 boxes per hour (Table 7a). Four blocks (Block IDs 33, 24, 53, and 35) achieved between 15 and 43 percent higher productivity. Other than for tree density, which was generally higher on the "extreme" blocks (174/180 vs. 159 trees per acre), the data of tree/grove characteristics presented in Table 8a do not present any strong evidence to explain the differences in machine productivity on the latter four blocks. In all likelihood, machine hour data on the blocks with extreme values were not accurate.

Machine productivity on six late season blocks averaged nearly 50 percent higher than early/mid season blocks, 285 boxes per hour (Table 7b). However, as shown in Figures 13b-18b, the six late season blocks could be separated into two, three block groups, a high and low value group. The high block group averaged 301 boxes per hour. The low block group corresponded more closely with measures estimated on the early/mid blocks, averaging 174 boxes per hour. Among the high block group there is a question as to whether machine hours were estimated accurately. If total hours were underestimated, the estimated performance measure of machine productivity would be overstated.

On twelve early/mid season blocks, harvest speeds averaged 66 trees per hour, or 55 seconds per tree (Table 9a). One block (ID# 49) harvested at a slower speed, 44 trees per hour (81 seconds/tree). Three blocks (ID#s 45, 33, and 35) harvested at faster speeds. Two general trends are identified from the exceptions. First, harvesting speeds increased during the season, which can be explained by improvements of equipment operators and overall coordination within a given harvesting team. Second, harvesting speed was inversely correlated with tree yield. The higher the tree yields the slower the harvest speed.

Harvest speeds on three late season blocks averaged 116 trees per hour (31 seconds per tree). Lower tree yields and increased experience of the harvesting crews may explain the improvements in harvesting speed on late season blocks. Harvest speeds on two blocks (ID#s 10 and 18) were estimated to be 203 and 328 trees per hour (18 and 11 seconds per tree), respectively. These estimates are not realistic, being significantly faster than any timed samples observed during the late season. Rather, these estimates of harvest speeds suggest inaccurate data. In all likelihood, the estimate for total machine hours was underestimated.

Figures 1-24 provide more details on how differences in grove characteristics may affect harvesting performance of TSC systems. In the figures, individual block characteristics of tree yield, tree density, clear trunk height, trunk circumference, skirt height, and tree height are plotted against harvest system performance measures. Figures 1-6 plot the selected grove and tree characteristics against fruit removal percentages. Figures 7-12 plot the same set of grove and tree factors against labor productivity measures. Likewise, Figures 13-18 and 17-24 demonstrate the effect of grove and tree characteristics on machine productivity and harvest speed. For each set of graphs, early/mid season blocks are separated from late season blocks.

For the particular grove characteristic being considered, individual blocks are plotted from lowest to highest value. For example, Figure 1a plots fruit removal percentages against clear trunk heights that range from 11.3 inches to 17.9 inches. If clear trunk height has an effect on fruit removal, then one would expect to observe a “trendline” through the data. Such a trendline through the scatter points would be upward, downward, or horizontal. An upward slope would suggest that higher clear trunk heights increase fruit removal percentages. Likewise, a downward slope would suggest that an increase in clear trunk height adversely affect the fruit removal percentage. A horizontal trendline would suggest that clear trunk height has no effect on fruit removal percentage. It is important to realize that trendline conclusions are limited to the range of data collected.

All blocks with performance measures are plotted, including blocks with extreme values. Blocks with extreme performance values are highlighted in the figures with a star. In general, it is hard to discern any clear trends and definitive guidelines from the figures.
If one ignores blocks with extreme values, the following preliminary observations for TSC systems are drawn from the figures.

Fruit Removal

1. Removal percentages on early/mid blocks were consistently above 95% when clear trunk height was greater than 14 inches (Figure 1a). Not including blocks with extreme values, four out of six blocks with less than 14 inches of clear trunk height

had fruit removal percentages less than 95 percent. Conversely, 15 out of 17 blocks with more than 14 inches of clear trunk height had fruit removal greater than 95 percent.
2. 14 out of 17 early/mid blocks with skirt heights greater than 34 inches (Figure 3a) achieved at least 95 percent removal. Two of the three blocks with less than 95 percent removal were identified in Table 5a as being harvested by a crew experiencing equipment and logistical difficulties (Harvester #1).
3. Variability of removal percentages decreased in blocks with tree densities of more than 150 trees per acre (Figure 5).
4. Over the ranges specified in the figures, trunk circumference, tree height, and tree yield did not exhibit much systematic effect on removal percentages (Figures 2, 4, and 6).

Labor Productivity
1. Labor productivity on early/mid blocks did not fall below 20 boxes per hour when skirt heights were more than 34 inches (Figure 9a).
2. Blocks from which tree yields were greater than 2.7 boxes per tree achieved productivity rates of at least 20 boxes per hour (Figure 12).
3. Over the ranges specified in the figures, clear trunk height (Fig. 7), trunk circumference (Fig. 8), tree height (Fig. 10), and tree densities (Fig. 11) seem to have little effect on labor productivity rates.

Machine Productivity
1. Machine productivity on late season blocks was split between three blocks with rates between 275 and 325 boxes per hour and three blocks with rates between 150 and 200 (Figure 13b).
2. Over the ranges specified in the figures, no discernable effects on machine productivity were observed from the selected grove characteristics (Fig. 13-18).

Harvest Speed
1. Harvest speed tends to decrease as tree yields increase (Figure 24).
2. Over the ranges specified in the figures, other tree characteristics do exert an effect on harvest speed.

A trend line through the data points of many of the graphs would be horizontal, reflecting no observable influence by a grove variable on a given performance measure. For example, tree heights between 10 and 19 feet do not appear to influence labor productivity results of TSC systems (Figure 10a and 10b). For other relationships, the graphs offer conflicting insight as to what may be occurring. For instance, Figure 11 indicates that five blocks with tree density of 174 had labor productivity measures of near 10 boxes per hour. However, six blocks with tree density of 180 achieved labor productivity measures of at least 20 boxes per hour.

Three reasons suggest why many of the figures do not provide clear insights into how grove conditions influence harvesting performance. First, there may be no effect to be observed. For instance, why should tree density affect fruit removal? Second, the range over which data was collected may not be great enough to show clear trends. Clear trunk height ranges between 11 inches and 18 inches. Perhaps clearer patterns would emerge if performance measures from blocks with less than 10 inches were compared to performance measures from blocks with greater than 20 inches of clear trunk height. Finally, several factors may be combining in ways that are difficult to isolate, without developing very strict experimental protocols and multiple regression analysis.

CAS System

The CAS system, operated by the Mongoose Harvesting Company during 1999/2000, did not require trees to be skirted. This flexibility was due to the fact that the CAS system did not mechanically catch fruit. Instead, the CAS system shook fruit out of the tree and utilized a hand crew to recover fruit off the ground and any fruit remaining in the tree. Consequently, fruit recovery for the CAS system during the 1999/2000 season had a different meaning than fruit recovery percentages estimated on TSC blocks. By utilizing a hand crew to pick-up fruit, the CAS system always recovered 100% of the available fruit.

CAS equipment worked backward down the row, harvesting one-half of a tree on either side of a row middle. Generally, the tines of the shaker head were positioned and inserted into the tree canopy four times to cover the area of one tree side.

The CAS system worked in blocks that were different from blocks that were harvested by TSC systems. Mature trees of CAS blocks were more than 40 years old. Yields were between 5 and 8 boxes per tree, but tree density was between 75 and 90 trees per net acre (Table 3 and 9).

On seven blocks of early/mid oranges, the mechanical fruit removal component of the CAS system averaged 67% (Table 9). Managers of the CAS system claimed that the system could achieve higher removal percentages, but in order to accommodate the preferences of the ground crew who wanted standing time while collecting fruit, some fruit was purposely left low in the tree. Despite initial claims to the contrary, fruit removal by the CAS system did not eliminate the need for harvesting ladders. On all the IFAS blocks where the CAS system was observed, the ground pick-up crew used ladders to harvest fruit from the tops of trees.

Managers of the CAS system said that a harvesting team consisted of eight ground personnel for each equipment operator. Therefore, if two machines were working in tandem on a block, 16 people would be working to pick up and glean remaining fruit. Unfortunately, reliable labor and machine hour data was not available to estimate labor productivity, machine productivity, and harvest speeds. Earlier productivity and harvest speed estimates that were reported to the FDOC Harvesting Advisory Council could not be supported with independent observations.

CCSC-1

A single drum continuous-canopy-shake-catch (CCSC-1) system worked in several blocks on a single grove during the 199/00 season. The system utilized a pair of harvesters working parallel down a hedged tree line. Drums, rotating horizontally and vertically, knocked fruit on to a catch frame. The fruit was conveyed to trailing bin trucks, which delivered fruit to the road trailers. The system demanded four equipment operators, drivers for the two harvesters and accompanying bin trucks. The CCSC-1 harvester was not responsible for hiring additional people to glean unharvested fruit and/or pick-up any post-harvest ground fruit. The CCSC-1 system spent much of the 1999/2000 season making various design modifications. In particular, time was spent modifying the tree seal to improve fruit catch along the tree line.

Fruit removal and recovery data were collected on three separate occasions. On the third trial, the CCSC-1 system removed 97 percent of the fruit from the tree, and with its mechanical catch system delivered 88 percent of the available fruit to the field trunk (Table 9). Much of the fruit loss during the catch phase occurred at the tree line, suggesting that once a better tree seal is developed, recovery percentage will improve.

Harvesting results of the CCSC-1 system were on blocks that were not optimally suited for the harvester. Tree densities were only 116 trees per acre, and despite being fully mature trees, average yield on the sampled trees were less than three boxes per tree. Further, trees at the CCSC-1 site were not skirted and many trees were taller (15-17 feet) than the system’s harvesting drum (12 feet) (Table 9).

Data on machine and labor hours by harvest block of the CCSC-1 system were incomplete. Consequently, formal estimates of machine and labor productivity are not presented in this report. However, field observations and notes suggest that the potential gains in labor productivity are significant with the CCSC-1 system. In-row traveling speeds of the CCSC-1 ranged between one mile per hour to 1.25 miles per hour, which translate to harvest speeds of more than 7 trees per minute in a grove with 15 x 25 feet tree spacing (116 trees per net acre). A limiting factor to harvest speed, however, was the capacity of the bin truck and the need to stop harvesting while the bin truck off-loaded fruit to the road trailer. The “Big Jack” fruit bin was used as the receiving unit for the CCSC-1 system and collected approximately 150 field boxes before dumping fruit into road trailers. Given the grove conditions at the harvesting site and accounting for dumping time of the bin truck, the CCSC-1 system could harvest 50 trees every 15 minutes, or 200 trees per hour. Assuming yields of three boxes per tree and 88 percent of the available fruit delivered to the road trailer, the potential machine productivity was more than 500 boxes per hour. At that level of machine productivity, labor productivity for the four equipment operators would be more than 125 boxes per hour, at least a 10 fold increase in the labor productivity of hand crews.

MBS

The mono-boom trunk shaker (MBS) was similar to the CAS system in that fruit was shaken to the ground and collected by a hand crew. The shaking action of a MBS could occur either at the main trunk or on a major limb. While trees did not have to be skirted, visibility was important to attach the shaking arm to the trunk or major limb. The MBS system worked backward down the row, shaking trees on either side of the row. At the one site where a MBS system was observed, fruit removal was 96 percent. Since a hand crew simultaneously picked up and gleaned remaining fruit in the tree, overall recovery was 100 percent. Insufficient data prevented estimating labor and machine productivity for the MBS system during the 1999/2000 season.

Plan of Work for the 2000/01 Season

The FDOC Harvesting Council has funded a second year of data collection to evaluate harvesting performance of mechanical systems. Data collection efforts will continue on blocks harvested by TSC systems with the goal of refining how grove and tree characteristics effect harvesting performance. More effort will be directed to CAS, MBS, and CCSC (both single and double drum) systems as acreage harvested by these systems is expected to increase.

Data collection procedures will be modified to improve the quality of data collected. Procedures developed during the 1999/00 season to describe grove and tree characteristics, as well as evaluating fruit removal and recovery percentages, were satisfactory and will be continued in the 2000/01 season. Better data on labor and machine hours are needed to improve evaluations of productivity and harvest speed measures. In part, this improvement will be achieved because harvesters have more experience and will be in a better position to share these data. Further, IFAS personnel will be devoting more time per site visit to develop independent measures of labor productivity, machine productivity, and harvest speed.

Table 1. Number of 1999/2000 data blocks by variety and machine type. Equipment manufacturers are noted in parentheses.

	Hamlin	**Parson Brown**	**Pineapple**	**Valencia (Std)**	**Rodhe Valencia**	**Total**
			Number of Blocks			
Observed by IFAS	30	3	5	19	2	59
Supplemental blocks	14	0	2	9	0	25
Trunk-shake-catch (Coe-Collier Partnership LLP, Compton Enterprises, Fruit Harvesters International)	31	3	5	15	2	56
Canopy-area-shake (Mongoose)	13	0	0	3	0	16
Monoboom (Orchard Rite - Stackhouse)	0	0	0	2	0	2
Cont. Trav. Canopy shake-catch						
Single drum: (Oxbo)	0	0	2	7	0	9
Double drum: (Korvan)	0	0	0	1	0	1
Total Block x Variety	44	3	7	28	2	84

Table 2. Acreage of 1999/2000 data blocks by variety and machine type. Equipment manufacturers are noted in parentheses.

	Hamlin	Parson Brown	Pineapple	Valencia (Std)	Rodhe Valencia	Total
			Net Tree Acreage			
IFAS blocks	1,820	260	550	1,808	114	4,552
Supplemental blocks	560	0	150	742	0	1,452
Total Acreage x Variety	***2,380***	***260***	***700***	***2,550***	***114***	***6,004***
Trunk-shake-catch (Coe-Collier Partnership LLP Compton Enterprises Fruit Harvesters International)	1,920	260	480	1,200	114	3,974
Canopy-area-shake (Mongoose)	460	0	0	100	0	560
Monoboom (Orchard Rite - Stackhouse)	0	0	0	100	0	100
Cont. Trav. Canopy shake-catch						
Single drum: (Oxbo)	0	0	220	1,100	0	1,320
double drum: (Korvan)	0	0	0	50	0	50
Total Acreage x Variety	***2,380***	***260***	***700***	***2,550***	***114***	***6,004***

Table 3. Average tree density, age, and yield for the 1999/2000 data blocks by variety and machine type. Standard deviation (stddev) and sample size (number) given in parentheses.

	Units	**Canopy-area-shake** (Mongoose) ***Early/mids***	**Trunk-shake-catch** ***Early/mids***	**Trunk-shake-catch** ***Valencia***
Tree Density				
Average	tree/ac	82	159	165
(stddev, number)		(28, 12)	(18, 39)	(3, 15)
Tree Age				
Average	years	41	11	10
(stddev, number)		(14 ,9)	(4, 39)	(3, 15)
Acre Yield				
Average	box/ac	340	465	327
(stddev, number)		(139, 9)	(121, 38)	(86, 12)
Tree Yield				
Average	box/tree	5.6	3.0	2.1
(stddev, number)		(4.3, 8)	(0.9, 38)	(0.6, 12)

Table 4. Summary of performance measures of TSC system by variety for the 1999/2000 data blocks. Average performance value calculated for all blocks, range of 95% of blocks, and number of blocks from which data were used.

	Units	Trunk-shake-catch *Early/mids*	Trunk-shake-catch *Valencia*
Fruit Removal			
Average	%	95%	94%
95% interval		93-97%	93-95%
number of blocks		27	10
Fruit Recovery			
Average	%	91%	88%
95% interval		89-93%	85-91%
number of blocks		27	10
Labor Productivity			
Average	box/hr	24	36
95% interval		21-27	21-51
number of blocks		30	9
Machine Productivity			
Average	box/hr	192	285
95% interval		175-209	184-306
number of blocks		16	6
Harvest (machine) Speed [z]	sec/tree	53	20
Average	tree/hr	68	177
95% interval		62-74	88-266
number of blocks		16	6

[z] Speed represents time harvesting one tree plus moving to second tree.

Table 5a. Fruit removal percentages from mechanically harvested ***early/mid*** blocks, tree characteristics, and details of blocks with removal percentages outside the majority range.

			IFAS Blocks				
Block ID	***Majority of blocks***		***46***	***58***	***45***	***34***	***24***
Avg Removal	***96%***	%	**83%**	**88%**	**90%**	**91%**	**99%**
Range	*93-98%*	%					
Number of blocks	*22*	#					
Yield- tree	*2.99*	bx/tree	4.58	2.55	3.19	2.68	3.22
Tree age	*11*	yrs	14	12	13	10	7
Tree density	*159*	trees/ac	145	145	145	174	180
Clear trunk	*14.9*	in.	13.1	15.4	13.5	15.6	17.9
Trunk circum.	*18.4*	in.	19.4	21.5	17.7	14.6	16.8
Skirt height	*33.8*	in.	35.2	38	34	32	36.4
Tree height	*13*	ft.	14	15	15	12	13
Harvest dates		mo/day	11/23-1/17	1/21-2/3	1/25-2/17	1/18-2/4	1/8-2/1
Trees sampled		#	18	15	24	12	12
Harvester		code	1	1	5	6	4

Table 5b. Fruit removal percentages from mechanically harvested ***late season*** blocks, tree characteristics, and details of blocks with removal percentages outside the majority range.

			IFAS Blocks		
Block ID	***Majority of blocks***		***54***	***48***	***47***
Avg Removal	***94%***	%	**91%**	**98%**	**98%**
Range	*92-96%*	%			
Number of blocks	*7*	#			
Yield- tree	*2.18*	bx/tree	2.06	1.62	2.56
Tree age	*10*	yrs	13	11	11
Tree density	*169*	trees/ac	151	145	180
Clear trunk	*14.9*	in.	19.2	16.2	14.6
Trunk circum.	*16.7*	in.	23.6	24.3	19.9
Skirt height	*34.6*	in.	36	44	36
Tree height	*13*	ft.	19	19	15
Harvest dates		mo/day	4/18-5/12	3/20-4/4	3/6-3/19
Trees sampled		#	15	6	18
Harvester		code	4	7	7

Table 6a. Labor productivity rates from mechanically harvested ***early/mid*** blocks, tree characteristics, and details of blocks with labor productivity outside the majority range.

			Suppl	IFAS	IFAS	IFAS	Suppl	IFAS	IFAS
Block ID	***Majority of blocks***		***77***	***35***	***34***	***33***	***78***	***52***	***44***
Avg Labor Productivity	***27***	**Bx/hr**	**8**	**10**	**10**	**12**	**12**	**15**	**44**
Range	*19-36*	Bx/hr							
Number of blocks	*23*	#							
Yield- tree	*3.17*	bx/tree	2.20	2.55	2.68	2.36	2.54	2.04	1.62
Yield- acre	*481*	Bx/acre	380	435	465	408	439	229	278
Tree age	*11*	yrs	10	10	10	10	10	14	13
Tree density	*159*	trees/ac	174	174	174	174	174	151	151
Clear trunk	*15.1*	in.		13.4	15.6	13.8		15.9	12.6
Trunk circum.	*18.6*	in.		15.5	14.6	12.6		19.3	21.8
Skirt height	*33.7*	in.		32	32	29		29	36
Tree height	*13*	ft.		12	12	10		16	14
Harvest dates		mo/day	12/1-12/20	2/5-2/14	1/18-2/4	1/6-1/18	12/20-1/5	2/9-2/13	12/15-1/6
Trees sampled		#	0	11	12	12	0	6	18
Harvester		code	6	6	6	6	6	5	4

Table 6b. Labor productivity rates from mechanically harvested ***late season*** blocks, tree characteristics, and details of blocks with labor productivity outside the majority range.

			IFAS	Suppl
Block ID	***Majority of blocks***		***10***	***75***
Avg Labor Productivity	***25***	**%**	**65**	**68**
Range	*19-32*	%		
Number of blocks	*7*	#		
Yield- tree	*2.37*	Bx/tree	1.66	1.44
Yield- acre	*366*	Bx/acre	295	238
Tree age	*11*	yrs	8	13
Tree density	*165*	Trees/ac	180	165
Clear trunk	*15.7*	in.	14.6	
Trunk circum.	*18.5*	in.	15.6	
Skirt height	*35.9*	in.	33.1	
Tree height	*14*	ft.	12	
Harvest dates		Mo/day	3/16-3/17	3/28-4/1
Trees sampled		#	18	0
Harvester		code	4	5

Table 7a. Machine productivity (bx/hr) from mechanically harvested ***early/mid*** blocks, tree characteristics, and details of blocks with machine productivity outside the majority range.

			IFAS Blocks			
Block ID	***Majority of blocks***		***33***	***24***	***53***	***35***
Avg Production	***193***	Bx/hr	**222**	**229**	**250**	**276**
Range	*152-220*	Bx/hr				
Number of blocks	*12*	#				
Yield- tree	*2.95*	Bx/tree	2.36	3.22	4.81	2.55
Yield- acre	*446*	Bx/acre	408	578	689	435
Tree age	*10*	Yrs	10	7	11	10
Tree density	*159*	Trees/ac	174	180	151	174
Clear trunk	*15.2*	In.	13.8	17.9	16.4	13.4
Trunk circum.	*18*	In.	12.6	16.8	20.4	15.5
Skirt height	*36*	In.	36	36.4	36.2	32
Tree height	*13.3*	ft.	13.3	12.5	13	12
Harvest dates		mo/day	1/6-1/18	1/18-2/1	1/22-2/4	2/5-2/14
Trees sampled		#	12	12	12	11
Harvester		Code	6	4	5	6

Table 7b. Machine productivity (bx/hr) from mechanically harvested ***late season*** blocks, tree characteristics, and details of blocks with machine productivity outside the majority range.

Block ID	***All blocks***		High Blocks	Low Blocks
Avg Production	***237***	Bx/hr	301	174
Range	*144-336*	%	278-336	144-210
Number of blocks	*6*	#	3	3
Yield- tree	*2.25*	bx/tree	2.42	2.08
Yield- acre	*350*	bx/acre	358	343
Tree age	*10.5*	yrs	11	10
Tree density	*165*	trees/ac	161	170
Clear trunk	*15.7*	in.	14.1	16.7
Trunk circum.	*18*	in.	18.7	17.3
Skirt height	*33.2*	in.	34.3	32
Tree height	*14.5*	ft.	14.1	14.8

Table 8a. Harvesting speeds (trees/hr) from mechanically harvested ***early/mid*** blocks, tree characteristics, and details of blocks with harvesting speeds outside the majority range.

			IFAS Blocks			
Block ID	***Majority of blocks***		***49***	***45***	***33***	***35***
Avg Speed	***66***	Trees/hr	**44**	**85**	**94**	**108**
Range	*52-79*	Trees/hr				
Number of blocks	*12*	#				
Yield- tree	*3.04*	Bx/tree	4.03	3.19	2.36	2.55
Yield- acre	*472*	Bx/acre	589	449	408	435
Tree age	*9.5*	yrs	13	13	10	10
Tree density	*162*	trees/ac	151	145	174	174
Clear trunk		in.				
Trunk circum.	*17.8*	in.	19.8	17.7	12.6	15.5
Skirt height	*36*	in.	36	34	29	32
Tree height	*12.8*	ft.	14	15	10	12
Harvest dates		mo/day	12/29-2/17	1/25-2/17	1/6-1/18	2/5-2/14
Trees sampled		#	24	24	12	11
Harvester		code	5	5	6	6

Table 8b. Harvesting speeds (trees/hr) from mechanically harvested ***late season*** blocks, tree characteristics, and details of blocks with harvesting speeds outside the majority range.

			IFAS Blocks		
Block ID	***Majority of blocks***		***55***	***10***	***18***
Avg Speed	***116.5***	Trees/hr	**53**	**203**	**328**
Range	*100-141*	Trees/hr			
Number of blocks	*3*	#			
Yield- tree	*1.93*	bx/tree	3.12	1.66	2.92
Yield- acre	*315*	bx/acre	472	295	388
Tree age	*8*	yrs	14	8	18
Tree density	*170*	trees/ac	151	180	151
Clear trunk	*15.3*	in.	17.2	14.6	15.3
Trunk circum.	*17.1*	in.	18.3	15.6	22.9
Skirt height	*36*	in.	26.2	33.1	31.9
Tree height	*14.5*	ft.	18.5	11.5	16.6
Harvest dates		mo/day	4/3-4/26	3/16-3/17	4/18-4/21
Trees sampled		#	6	18	18
Harvester		code	4	4	4

Table 9. Fruit removal and recovery percentages and grove conditions on blocks that were mechanically harvested by a single drum Continuous-Canopy-Shake-Catch (CCSC-1) system, a mono-boom truck shaker (MBS) system, and the Canopy Area Shake (CAS).

	units	***CCSC-1***	***CCSC-1***	***CCSC-1***	***MBS*** [1]	***CAS***
Fruit removal	%	**88**	**95**	**97**	**96**	**67**
Fruit recovery	**%**	**79**	**87**	**88**	**100**	**100**
Scion variety	--	Valencia	Valencia	Valencia	Valencia	Early/mid
Sample date	mo/day	3/31	4/7	4/12	4/25	
Sampled trees	#	3	9	5	3	7 blocks
Yield – tree	box/tree	3.8	2.4	2.6	7.0	8.4
Tree age	years	33	37	37	na	45
Tree density	trees/net acre	116	116	116	100	75
Clear trunk	in.	11	13	13	13	12
Trunk circum	in.	24	18	18	27	36
Skirt height	in.	0	0	0	0	0
Tree height	ft	16	15	15	17	18

[1] The MBS system was similar to the Canopy Area Shake system in that it shook fruit to the ground for hand pick-up.

Attachment 1. Data sheet provided to grower request information on block being mechanically harvested.

Grower/Block Data Sheet 1999/2000 Season

Grower/Contact Person Telephone

Grove Name: ____

Block Name: ____

Net Tree Acres: ______________________________________

Variety: ____

Rootstock: ____

Planting Date: ____________________Mo/Yr

Percent of block reset: ________ %

Percent of trees less than 4 years of age: ________ %

Tree Spacing: (a) in-row _________(feet) (b) b/w rows__________(feet)

Tree Density: __________________(tree/ac) = 43560) (a * b)

Bed configuration: none 1-row 2-row 3-row 4-row

Trunk height:_______(inches) Trunk circm:_____(inches) Tree height:______(feet)

Hedged: G **Yes** G **No** **Topped:** G **Yes** G **No** **Skirted:** G **Yes** G **No**

If yes ______inches at drip above soil.

Cost of hedging / topping / skirting: _____ $/ac

Estimate of fruit loss first year after grove shaping work: _____ Bx/ac

Irrigation system: G **drip** G **microjet** G **seep** G **overhead** G **flood** G **none**

Historical production: Total weight boxes harvested from the block

1998/99 ____________________ G mechanical G hand

1997/98____________________ G mechanical G hand

1996/97 ____________________ G mechanical G hand

1995/96 ____________________ G mechanical G hand

1994/95 ____________________ G mechanical G hand

Comments: (note any damage to trees or irrigation equipment from harvesting)

Attachment 2. Data sheet for harvester, requesting information about labor and machine hours on blocks mechanically harvested.

Harvester Data Sheet 1999/2000 Season

Harvest contact:______________________ **Telephone: __________________________**
Grove Name:____________________________ **Block Name:_______________________________**
Machine Type: __________________________ **Machine Manufacturer:______________________**
Description of machine crew personnel:____
Machine operator=s name(s): ____

Date:	month/day	month/day	month/day
Begin hr/End hr for crew Lunch break ___________			
Crew Size	# workers		
Crew hours paid	# hours		
Harvesting hours	# hours		
Down time (reason)	**# hours (reason)**		
Trailer No and boxes	___Trl# ___ #field bx ___ Wt ___Trl# ___ #field bx ___ Wt ___Trl# ___ #field bx ___ Wt		
Total Harvested weight	# pounds		
Total weight boxes (/90 lbs)	# boxes		
Cull weight boxes	# boxes		
Net weight boxes	# boxes		
Total trees unharvested (missed, dead, small)	# trees		
Total trees harvested	# trees		
Trees/harvest hour	# trees		
Total boxes/harvest hour	# boxes		
Total boxes/labor hour	# boxes		
Total boxes/acre	# boxes		

Comments:

Number of trees gleaned	# trees		
Total tree weight	# pounds		
Total ground weight	# pounds		
Average weight per tree	# pounds		
Estimate of lost fruit (Box/tree):	# boxes		

Attachment 3. Data sheet completed by IFAS personnel when visiting a block being harvested.

Data collected directly by IFAS crew:

1. **Estimate the percentage of reset trees and non-bearing trees within block.**

2. **Observe bed configuration, irrigation system, and tree shaping program.**

3. **Measure tree spacing and estimate tree density. Measure, for a sample of trees, trunk height, tree height, trunk circumference, and skirt height at the soil drip line.**

4. **Observe machine type, crew size and individual duties. Time speed of harvesting, including shake time, travel time, and unload time to the goat.**

5. **For a sample of trees, glean unharvested fruit.**
   a. **Weight per tree of ground fruit**
   b. **Weight per tree of fruit dropped on ground by mechanical harvester**
   c. **Weight per tree of fruit remaining in the tree.**

6. **Record comments of grower and/or harvester describing unusual situations within block.**