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Field Evaluation of a Citrus Fruit Pick-up Machine

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Abstract. *Citrus groves encompass 0.75 million acres of Florida's land and produced 292 million boxes of fruit in 2004. A citrus fruit pick-up machine developed by OXBO International Corp. was tested for its performance and productivity. The machine was evaluated for its picking rate, picking efficiency, field capacity, impact on surface microbial loads, and its efficiency for removing undesirable fruit and trash. The performance test was conducted under different ranges of forward speed and grove conditions. For picking rate of 256-432 lb/min, the picking efficiency varied between 80 to 97 percent for different grove conditions. The average field capacity was about 0.35 ac/hr. The results of study on the microbial load on the surface of citrus fruit indicated no significant differences between fruit harvested from the tree, fruit picked up from the ground by hand, and the fruit picked up by a pick-up machine.*

Keywords. Citrus, Mechanical harvesting, Performance evaluation, Microbial load.

Introduction

Florida had 0.75 million ac (0.304 million ha) of citrus groves in 2004 and produced 292 million boxes (90 lb) of fruit. Harvesting has been a labor intensive operation and labor shortage is a major issue for the citrus industry. The cost of harvesting Florida citrus now exceeds the total cost of production. This fact has focused industry attention on mechanical harvesting technologies that can reduce costs associated with harvesting. Although a mechanical harvesting and abscission program was conducted from the 1960s to the 1980s, very few mechanical harvesting systems were commercially adopted and no abscission material was registered for use (CREC, 2005; Whitney, 1995). Mechanical harvesting systems for citrus have recently found their way into Florida's citrus groves. Several machines have been developed for removal of citrus fruit from the trees (Coppock, 1969) and different pick-up machines have been developed since 1970. Many different concepts for picking up the fruit have been investigated. A pick-up machine was developed and tested to pick up oranges from a windrow tree shaker, windrowing rake and pick-up harvesting system by Marshall and Hedden (1970). The average ground speed was 0.4 km/h (0.26 mph) with 185 kg/min (408 lb/min) picking rate. Churchill and Hedden (1983) developed a self-propelled rake pick-up machine with a rod draper chain and a double belt trash eliminator system in order to pick up the fruit. Fruit was loaded directly into a high-lift truck with an average picking rate of 490 kg/min at 0.46 km/h (0.29 mph). The picking efficiency was 92 percent. Churchill and Hedden (1974) also evaluated trash removal devices for mechanically harvested oranges and reported that the belt type system was highly successful.

Two types of mechanical harvesters are commonly used in modern citrus groves; continuous canopy shake and trunk shake systems. Trunk shake-catch systems have been used commercially to a limited extent to mechanically harvest Florida oranges for processing. Abscission chemicals were used to reduce the detachment force of oranges and have been tested to find a 10 to 15 percentage increase in the fruit removal efficiency of the shakers with a 50 to 80 percent reduction in orange detachment forces (Whitney et al., 2000). Two continuous canopy shake harvesting systems are being used to harvest citrus fruit destined for delivery to juice processing plants. One, commonly referred to as a shake and catch system, is a self-propelled unit that shakes the tree canopy causing the fruit to fall from the tree and onto a catch frame. The second system is a tractor-drawn unit that simply shakes fruit to the ground, requiring the fruit to be picked up by a hand crew or pick-up machine. A canopy shake and catch system is best suited for groves with uniform canopy sizes whereas tractor-drawn pull type canopy shakers can work efficiently in non-uniform tree canopy size groves (Futch and Roka, 2005).

OXBO International Corp. (OXBO), Clear Lake, Wisc., has recently developed a citrus fruit pick-up machine that uses an innovative mechanism to pick detached fruit from the ground. The detachment of fruit from trees during recent hurricanes in Florida has also encouraged the growers to consider pick-up machines for picking up fruit.

Objective

The purpose of this study was to evaluate the overall performance of a prototype fruit pick-up machine developed by OXBO. The specific objectives of this field test were:

- To evaluate picking rate, picking efficiency and field capacity under different grove conditions.
- To find its efficiency for removing undesirable damaged fruit and trash.
- To evaluate the external microbial load of ground fruit picked up by this machine.

Materials and Method

The OXBO Pick-up Machine

The schematic of the pick-up machine is shown in figure 1 and the photographic view is in figure 2. Two sweepers that are installed on the long arm in front of the pick-up assembly are used to sweep oranges from under the tree canopy. Cutters cut branches that are between the trees or swept out from under the trees into small pieces so they don't lodge in the pick-up head. The pick-up head assembly uses lollipop-type fingers to pick up the oranges from the ground and rotate them about 75 degrees. Strippers then strip the oranges from the pick-up wheel into an auger. The auger conveys the oranges stripped from the heads into the feeder house conveyor. The conveyor which uses the rod over belt design throws away small debris to the ground. Cleaning brushes "float" the large sticks/branches to the side so they can be guided out of the product stream. The draper conveyor carries material that will not roll - off the machine. Pinch rolls receive oranges from the draper conveyor and clean stems from them as well as small particles and debris. A split remover is added during the field testing phase and is a large pair of pinch rolls used to take out the split fruits which are collected on a rubber sheet and can be seen in figure 3.

The machine has undergone operational modifications during the testing phase in the field. Although the picking principle remains the same, the picking assembly has been changed to incorporate the issues of an undulating field such as ditches, depressions, etc. The latest prototype of the machine is shown in figure 4. The picking assembly is composed of eleven segments and each segment can move up and down to adapt to the ground conditions. Each segment has four discs of 8.375 in diameter, which hold the picking tines (5.5 in long) numbering 45 on each disc. The picking tines are commonly known as lollipops because each tine has a rubber ball on top of it. The front sweep has been changed for more flexibility such that it can cover a maximum area. A belt with iron rods is provided to deflect trash such as bottles, cans, or larges branches. A closer view of the picking assembly with the deflecting belt can be seen in figure 5. The width of the picking assembly is 7.25 ft. The evaluation results are from this prototype.

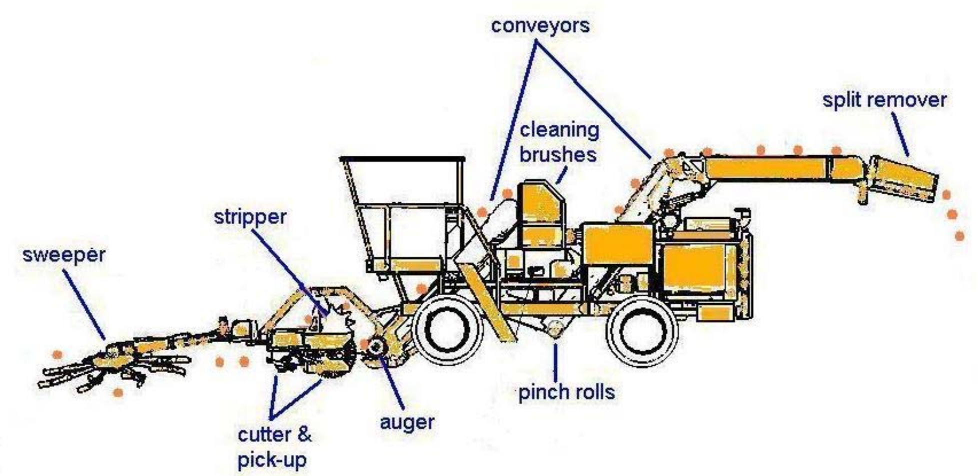

Figure 1: Schematic of the pick-up machine

Figure 2: The OXBO pick-up Machine

Figure 3: The split remover is added during the field testing phase

Performance Test and Procedure

The performance test was proposed for picking rate and efficiency, trash pick up, field capacity and efficiency, optimum forward speed, fruit damage and microbial load. Because the pick-up machine is still in the developmental process, it was not tested for field efficiency as it needs data over longer periods of time. Two field tests were conducted at two different groves with different grove conditions.

The first performance test was carried out at Lykes Grove, Lake Wales, Fla., which is a ridge grove. The row-to-row spacing varied from 25 to 30 ft, with Astatula soil type. Nine months before the tests, sludge was applied on the herbicide band (5 ft each side of the tree) in field test area. The test plots were 50 ft and 75 ft between two rows of trees. The fruit was gathered by the pick-up machine and was loaded on the goat truck which was weighed by a scale before and after picking up the fruit. The load-meter scales were calibrated against a known mass. The fruit which was not collected by the pick-up machine was collected manually from the area weighed by a shipping scale. The unpicked fruit was collected only from the area of machine width as the sweeper was not working for this test. The experimental design was completely randomized and the test was replicated five times.

Figure 4: The modified OXBO pick-up machine

The second test was conducted in a Silver Strand bed and swale grove in Immokalee, Fla. The row-to-row distance is about 24 ft. This test was a part of late harvest abscission chemical test for mechanical harvesting. The grove has bed and swale and the test was conducted separately in both the ground conditions. The experimental design was completed in a completely randomized block with bed and swale as blocks. There were twenty replications for swale and twenty two replications for bed.

Picking Rate and Efficiency

The picking rate is described as the amount of fruit collected in a unit time and is expressed in lb/min or kg/hour. It would depend on the topography of the harvesting area, the amount of fruits on the ground and the forward speed of the picking machine. The picking efficiency of the machine indicates its capability of picking fruit in a specified area in the field. This can be calculated as the ratio between the amount of fruit picked and the amount of fruit harvested.

The theoretical picking capacity can be calculated from the size of the picking assembly. There are eleven segments in the picking assembly and each segment can hold 135 oranges and more if they "double-up". The circumference of a segment is 43.6 in. If there are enough fruits on the ground to be picked up by the machine, all the groves in the picking assembly shown in figure 5 are filled and the machine is moving at a speed of 0.6 ft/s, the machine can pick maximum of 245 oranges per second. Considering 0.54 lb/fruit, the theoretical maximum picking rate can be calculated as around 7,950 lb/min if assuming each segment picks only 135 oranges. If each sub-segment picks more than one orange “double-up”, this number in theory could be doubled.

Field capacity and efficiency

The theoretical field capacity of the machine is a product of width of the picking assembly and forward speed. It is the area covered by the machine in unit time without considering the time wasted for turning or non-useful work. The effective field capacity of the machine indicates the actual area covered in a given time. It is calculated as the area covered by the machine in total time. The field efficiency is the ratio between the effective and theoretical field capacity of the machine. It indicates the time lost in the field and the failure of utilizing the full width of the machine.

Figure 5: Closer view of the picking assembly and trash throwing belt

Trash pick up

Trash in the form of plastic sheets, irrigation hoses, plastic bottles, aluminum cans, and glass bottles were randomly placed on the ground to observe how much and what forms were picked up by the machine.

Optimum forward speed

Optimum forward speed is important for picking rate (PR), picking efficiency (PE) and removing unwanted materials. The speed would depend on the amount and distribution of fruit on the ground along with the topography of the space between tree rows. The optimum forward speed would be variable depending on the grove conditions, fruit yield and the operator.

Fruit Damage

The damaged fruit for this study was defined as any fruit with deep cut or crushed fruit where internal structure of the fruit is exposed, enhancing the chance of contamination. This include fruits damaged by harvesting machines, rotten fruits fell earlier on the ground and any fruit damaged by the pickup machine during the pick up process. The pick up machine has a system of removing the damaged fruit. The damaged fruits are pulled down by the action of two rollers used as the split remover and collected on a rubber sheet. The split remover is placed at the end of the conveyor of the pickup machine. The weight of the damaged fruit is recorded for each replication and is then related to the total fruit picked up in that segment.

Microbial Load

The microbial load on the surface of the fruit as they were picked up from the ground with the pick-up machine was evaluated and compared against hand picked fruits. Seventy-five fruits per trial were collected, with 25 wholesome, non-defective fruit randomly selected from each of the three sample groups. Sample groups were identified as follows: Control (hand picked from tree in sanitary manner), MH/hand PU (mechanically-harvested from tree, then picked up by hand in a sanitary manner), and MH/machine PU (mechanically-harvested from the tree, then sampled from the collection hopper after being mechanically picked up). In addition, the fruit was tested for presence of *E. coli* and *Salmonella* according to the procedure described by Parish et al. (2001). The VIP *Salmonella* test kit (BioControl, Bellevue, Wash.) was used as specified by the manufacturer for the *Salmonella* assay, while the E*Colite™ test kit (Charm Sciences, Lawrence, Mass.) was used to detect the presence of generic *E. coli*. Appropriate negative and positive controls were processed to ensure performance of test kits and numbers of positive composite samples were reported. This part of the study is described in more detail by Goodrich et al. (2006).

Statistical analysis

Evaluating quantitative test data in terms of their respective means, where tests are greater than two, can be completed by using ANOVA. This procedure is actually concerned with the level of means of the samples and is useful in engineering evaluations. The data received from all the replications are analyzed to see if they fit the model.

Results and Discussion

The evaluation data for the first preliminary test was collected for five replications. The picking rate, picking efficiency, damaged percentage, and field capacity was calculated from the data and presented together in table 1.

The data from the performance evaluation test were analyzed using the SAS program “proc glm” and found that there was no significant difference between each replicate The machine could on an average pick 354 lb/min with a picking efficiency of 97 percent. Though picking rate may not be an appropriate machine characteristic as it also depends on the amount of fruits on the ground, combined with picking efficiency it is good measure to evaluate the pick-up machine. The fruit damaged was minimal with about 0.53 percent. The field capacity was calculated to be 0.35 acres per hour considering only the picking width.

None of the trash except a glass bottle was picked up by the machine. Plastic bottles and aluminum cans were thrown away by the belt with iron rods. The plastic sheets and irrigation hoses were not picked up as they were quite flat.

Table 1: Field evaluation test results of the pick-up machine from preliminary test.

Rep. No.	Picking rate (lb/min)	Forward speed mph	Picking Eff. (%)	Damaged (%)	Field Capacity (ac/hr)
1	416.2	0.38	98.60	0.71	0.333
2	256.1	0.42	96.51	0.88	0.365
3	421.3	0.48	97.66	0.30	0.421
4	243.2	0.33	96.55	0.49	0.291
5	432.7	0.38	96.54	0.28	0.332
Average	353.9	0.40	97.17	0.53	0.348

The pick-up machine was also tested in a grove with bed and swale. It is very hard to pick up fruit in swale due to its topography and presence of grass and other materials. The results from this test are shown in table 2. The experiment was designed with bed and swale as two blocks and was completely randomized block. In each block, the data were collected at random.

Table 2: Evaluation results from the test on Sliver Strand Grove

	Bed			Swale		
	Picking rate (lb/min)	Picking efficiency (%)	Damaged fruits	Picking rate (lb/min)	Picking efficiency (%)	Damaged fruits
Average	213.55	91.36	8.70	207.25	80.49	9.38
Std dev	81.97	4.98	5.88	103.58	14.18	4.93
Max	400.98	98.78	28.48	426.32	97.24	20.56
Min	98.45	78.59	3.02	78.46	47.57	3.31

The SAS program proc glm was used to analyze the data and it was found that the picking efficiency in each block was not significantly difference from each other and can be accepted as the representative data for that test condition, but the percentage of damaged fruit in each block was significantly different. This was also evident from the physical data set as it varies from 3 to 21 percent of the fruits. The picking efficiency in the bed was as high as 98.8 percent with an average of 91.4 percent whereas it was as high as 97.2 percent with an average of 80.5 percent in swale. The percentage of damaged fruit was as low as 3 percent with average of 8.7 percent in bed whereas it was as low as 3.3 percent with average of 9.4 percent in swale. As evident from the results, the machine was more efficient while operating on the flat bed. In this test, the trash throwing belt was removed due to technical problems and most of the trash was picked up by the machine.

Microbial Load

The results of the study of the microbial load on the surface of the fruit indicated that there were no significant differences between the three different groups. *E.coli and Salmonella* were not detected on the surface of the fruit from any of the three groups. Table 3 summarizes the results for the presence/absence of *E. coli* and *Salmonella.*

Table 3: Summary of fruit surface indicator and pathogenic organisms

Control	MH/hand PU	MH/machine PU
	Results of *E. coli* tests	
0/20*	0/20	0/20
	Results of *Salmonella* tests	
0/20	0/20	0/20

* (number of positive tests)/ (number of total tests)

Conclusion

The combination of a tractor driven canopy shaker with a pick-up machine provides an alternative choice for citrus growers in terms of selecting a mechanical harvesting system that fits their needs. A pick-up machine can be adopted by the growers if it can efficiently pick-up the fruit from the ground at a lower cost comparing with manual pick up. It should also be able to separate the trash and moldy fruit from the good fruit. In addition, the processing plant requires that microbial and pathogen load on the surface of the fruit be comparable with the hand-picked fruit. A new pick-up machine developed by Oxbo Corp. was evaluated in two different types of groves. The average picking rate was 354 lb/min in ridge, 214 lb/min in bed and 207 lb/min in swale. The picking efficiencies was about 97 percent on the ridges and it was as low as 80 percent on the swale. About 0.53 percent of the fruit was damaged in the ridge but approximately 9 percent of fruit was damaged in the swale. The preliminarily results showed that fruit picked up by the pick-up machine has the same level of microbial load compared to hand picked fruit. In spite of preliminarily satisfactory results, more tests are needed in different grove types and different ranges of fruit loads to completely evaluate the performance of this machine which is continuing to be developed and hopefully improved.

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References

Churchill, D. B. and S. L. Hedden. 1974. Evaluation of trash removal devices for mechanically harvested oranges. Proceedings of the Florida State Horticultural Society, Miami, Fla., November 5-7.

Churchill, D. B. and S. L. Hedden. 1983. A double-sided rake-pickup Machine for Citrus. Transaction of ASAE, Vol. 26 (4): p 1034-1036.

Citrus Research and Education Center (CREC). 2005. The citrus abscission program. URL: http://www.crec.ifas.ufl.edu/abscission/ Last viewed on November, 2005.

Coppock, G. E. 1969. Review of citrus harvest mechanization. RMC Report no. 16:777-805, ASAE, St. Joseph, Mich. 49085

Futch, S. H. and F.M. Roka. 2005. Continuous canopy shake mechanical harvesting systems. Publication number HS1006, Horticultural Sciences Department, Florida Cooperative Extension Service, IFAS, University of Florida, Gainesville, Fla.

Goodrich, R. M., R. Ehsani and L. Friedrich. 2006. Effect of ground fruit pick-up systems on the microbial quality of citrus fruit surfaces. Paper no. 32, Proc. Fla. State Hort. Soc. 2006.

Marshall, D. E. and S. L. Hedden. 1970. Design and performance of an experimental citrus fruit pick-up Machine. Transaction of ASAE, Vol. 13 (3): p 406-408.

Parish, M. E., R. M. Goodrich, J. A. Narciso, and L. M. Friedrich. 2001. Microflorae of orange surfaces and juice from fruit in processing facilities: preliminary results. Proc. Fla. State Hort. Soc. 114:174-176.

Whitney, J. D., U. Hartmond, W. J. Kender, J. K. Burns and M. Salyani. 2000. Orange removal with trunk shakers and abscission chemicals. Applied Engineering in Agriculture 16(4): 367-371.

Whitney, J. D. 1995. A review of citrus harvesting in Florida. Trans. Citrus Engineering Conference, Florida Section, ASME 41: 33-59.