DEVELOPMENT OF A TREE FRUIT HARVESTING AID

(Suggested Short Title)

Thorburn

DEVELOPMENT OF A CONTINUOUSLY MOVING THREE-LEVEL MAN POSITIONING TREE FRUIT HARVESTING AID.

by
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M. Sc. AGRICULTURAL ENGINEERING

ABSTRACT

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DEVELOPMENT OF A CONTINUOUSLY MOVING THREE-LEVEL MAN-POSITIONING TREE FRUIT HARVESTING AID

A mechanical aid was developed to improve labor productivity in tree fruit harvesting. The design of this machine was compatible with current orchard practice in eastern Ontario.

The mechanical aid was a 3-man independent-positioning device. It was evaluated through a time and motion study in a commercial apple orchard.

An economic analysis was performed to determine the allowable capital investment in mechanical aids of this kind.

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I. INTRODUCTION

Labor productivity (13) in tree fruit harvesting is comparatively low (33). Reliable data on harvesting rates for eastern Ontario were not available prior to the inception of this study. However, quoted figures in the range of 3 bushels per man hour (8) were approximately 1/3 of that reported by Marshall (26) for Massachusetts, and by Gaston et al. (12) for Michigan.

The study by Levin et al. (24), indicated that labor productivity could be increased by subdividing the tasks involved, in the conventional method of tree fruit harvesting. They found that by assigning a worker specific regions in the trees to be harvested, it was possible to increase the labor productivity by 7.5% over that obtained by picking throughout the tree.

Task subdivision or work simplication is one way to increase productivity and lower costs in industry (15). The International Labor Office has reported examples of substantial increases in productivity in the manufacturing industries (16).

Increases in labor productivity are also possible through improvements in materials handling. The four principles of good materials handling as reported by the

Anglo-American Council on productivity (14) are:

1. eliminate manual handling whenever possible
2. avoid rehandling
3. use equipment that sets a uniform work pace
4. palletize and use unit loads.

Tree fruit harvesting machines could be developed that incorporate the principles of good materials handling and work simplification, to achieve increased labor productivity in tree fruit harvesting. A mechanical aid that would relieve the workers of positioning themselves in the trees, and convey the picked fruit to a collection point more rapidly than with the conventional method (buckets and ladders), could theoretically increase the labor productivity.

This study is concerned with the development of a mechanical aid to be used in harvesting fresh market apples. Fresh fruit is defined as that fruit intended for direct human consumption, without any processing (34). The conventional method of harvesting in eastern Ontario was used as a basis for determining the increase in labor productivity, associated with the use of the mechanical aid.

II. OBJECTIVES

The objectives of this study were:

1. to develop a mechanical aid which would increase labor productivity in the harvest of fresh market apples.

2. to evaluate the mechanical harvesting aid in a commercial eastern Ontario apple orchard.

3. to determine the allowable capital investment in mechanical tree fruit harvesting aids of this kind, justified by the achieved increases in labor productivity.

III. REVIEW OF LITERATURE

Tree fruit harvesting is the process of detachment, collection, and handling of the fruit (34). Picking is the detatchment of the fruit from the tree (10). Presently, fresh market fruit is harvested by hand using buckets and ladders. This is known as the conventional method of harvesting. The workers pick from a multitude of positions in the tree, to get all the fruit. The workers dump the fruit from the picking buckets, into the crates laid alongside the tree rows. When the bottom region of the tree is being harvested, the workers pick from a standing position on the ground, instead of from ladders.

In conventional tree fruit harvesting a considerable portion of a worker's efforts are spent in climbing up and down ladders, carrying the fruit to the crates, dumping the fruit, and moving the ladders. In addition, the workers pick with one hand since they must hold onto the ladder, thus reducing their potential picking capacity. Gaston and Levin (12) found that approximately 73% of a worker's time was spent in picking, while about 19% of the time was spent in moving fruit to a collecting point, dumping it into the crate, and returning to a new picking position. About 3% of the time was spent in positioning air blast (20), and vibrating tines (32). In all cases the fruit harvested with these machines was unacceptable for the fresh market, because of bruising. Therefore, ways of increasing the hand picking rates were sought.

Labor productivity could be increased with a mechanically powered positioner, and conveyor system. The mechanically powered positioner would position the worker while he picked, and eliminate the time lost due to worker movement. A conveyor could move the fruit from the pickers position in the tree, to the temporary storage area. However, it is not possible to have a mechanical conveyor system function, unless the picker is positioned to use it. Therefore, if the worker is positioned within reach of the conveyor, he can spend more time picking. Marshall (27) found that there was no increase in the picking rates with mechanical aids not having a conveyor system. Picking rate increases of up to 95% were obtained with a positioner-conveyor system(11).

The number and spacing of man positioner-conveyors on a mechanical aid, are important to its productivity. Levin and Gaston (24) studied the effects of assigning 3 teams of workers to a tree, each man with a given height region to be harvested. The workers at the lowest level stood on the ground, those at the center picked from 7-foot stepladders, and the ones at the top picked from 22-foot ladders. They found that with this work simplification, the average picking rate was increased 7.5%.

Levin and Gaston's (24) work showed that the most important criteria for determining the number and location of positioner-conveyors, is the worker's vertical reach and tree height. However, a seated worker is more secure on a positioner than is one standing on a platform, and should have a higher labor productivity (18). Since most trees in eastern Ontario are between 13 to 16 feet high, and a man's comfortable vertical reach is 4 1/2 feet (29), it is possible to have high picker productivity by covering the entire range with 3 seated workers, one above the other.

The mechanical aids of Marshall (26), and McMechan (28), moved forward intermittently. They stopped at one tree while the workers picked, and then moved on to the next tree. Marshall found that 25.9% of a worker's time was spent waiting for the worker at the other level. McMechan noted that with a single level mechanical aid, the faster workers had to wait for the slower ones to finish picking. This rate variability problem has been overcome on production lines by introducing continuous motion (19). Therefore, similar benefits could be realized, if a mechanical aid moved forward continuously.

IV. DESIGN OF THE MECHANICAL AID

On the basis of prior research and on knowledge of the orchard conditions in eastern Ontario, a 3-man positioner-conveyor mechanical aid with seats located at the 30-, 84-, and 138-inch levels above the ground was constructed. Because all of the tree characteristics and the picking rates were not known, adjustability was incorporated into the basic design of the machine. One example of adjustability was the forward speed control of the entire machine. This was achieved through a variable speed hydrostatic drive.

Positioner Design

The following criteria were established in regard to the positioner design:

1. A lateral extensible range of 10 feet was required to be able to harvest one side of a tree, 20 feet in diameter.
2. The machine had to accomodate trees set on row spacings as narrow as 28 feet. Therefore, with the positioners retracted, the machine width had to be less than 8 feet.
3. Workers would be in a seated position when picking. To avoid a sense of insecurity in

the workers, lap belts would be used.

4. The distance traversed by the picker's hand in conveying the fruit from the tree to the conveyor, would be a practical minimum, leaving the maximum amount of time for picking.
5. The positioners should extend and retract at a velocity sufficient to reduce wasted time, but not so fast that the picker feels insecure.
6. Each positioner would have two degrees of freedom for movement. They would consist of:
   a) forward movement by the mechanical aid
   b) lateral extension into the tree.

   A third degree of movement in the vertical direction, though sometimes desirable would be difficult and expensive to incorporate into the design.
7. The positioner should not damage the tree branches.
8. The worker's seats would be designed to swivel, so that each person could pick from the horizontal angle most comfortable to him.
9. Each picker would be able to extend or retract his own positioner independent of the others.

In addition pickers would use their feet to control the lateral movement of their positioners. This leaves the hands free to pick while movement was taking place.

The accordian type (multiple scissors) positioner can satisfy the requirements. It is hown in Figure 1.

Each picker would have a vertical picking range of 4 1/2 feet. This value was derived from the findings of Molitorisz and Perry (29), and some preliminary observations. The bottom worker picked from the 24-inch level to the 78-inch level, the center one from the 78-inch level to the 132-inch level, and the top one from the 132-inch level to the 186-inch level. The pickers were seated at the 30-, 84-, and 138-inch levels. The pickers could gain an extra horizontal reach of 3 feet by bending forward. This facilitated picking of trees up to 26 feet in diameter. The positioners were designed to accomodate pickers weighing up to 230 pounds.

The three horizontal positioners were mounted on a self-propelled hydrostatically-driven carrier frame as shown in Figure 2. The seats and foot rests pivoted about a vertical axis on the outer end of the positioner. The swivelling seat enabled a worker to proceed to areas of high fruit density, without having to wait for the machine

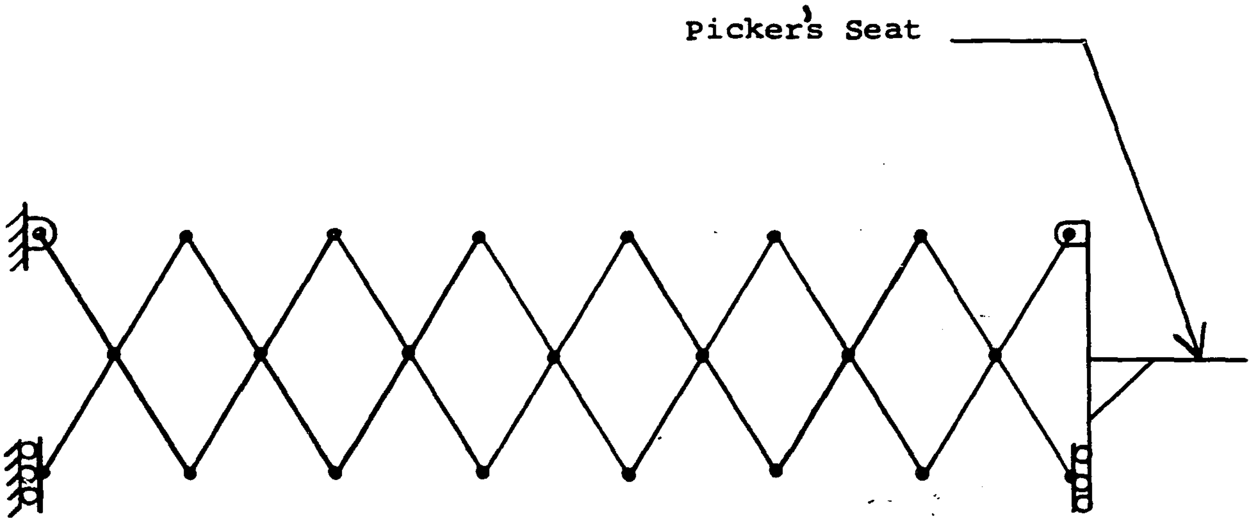

Figure 1.
Schematic Drawing of Accordion Type Positioner
Partially Extended

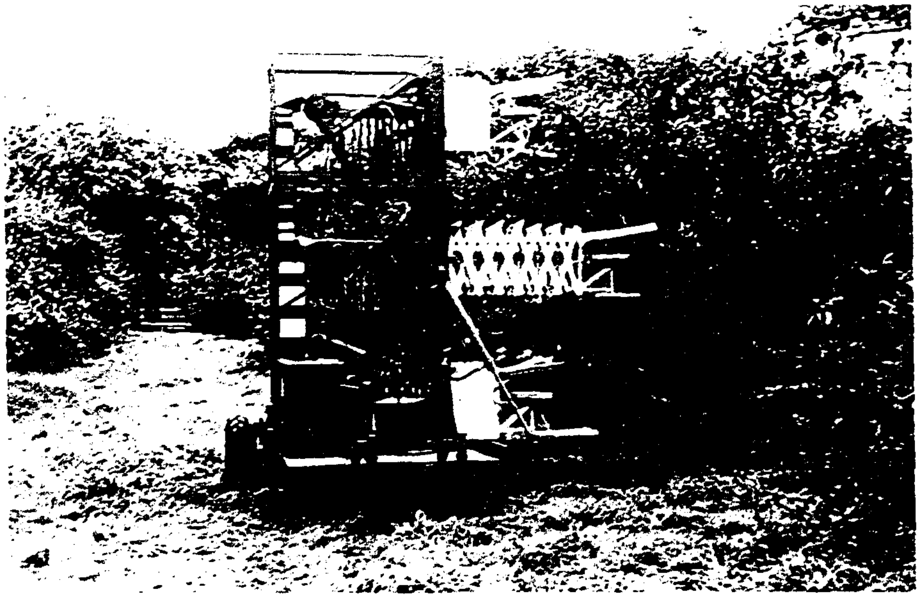

Figure 2
Rear View of Mechanical Tree Fruit Harvesting Aid, Showing the Center Positioner Partially Extended

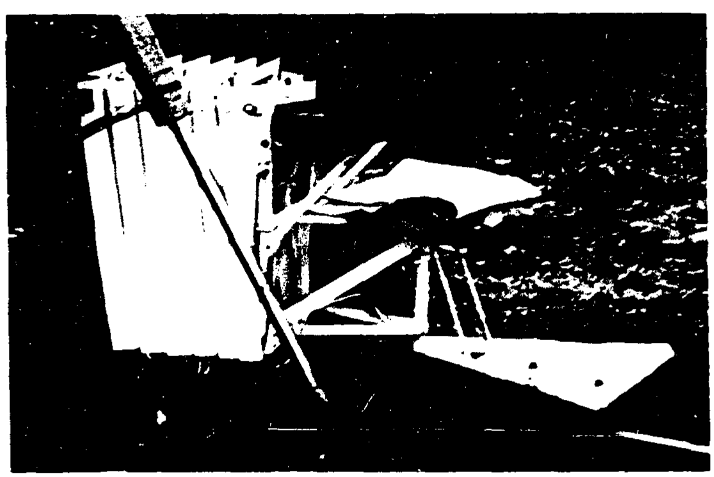

Figure 3
Bottom Level Seat with Positioner in the Retracted Mode

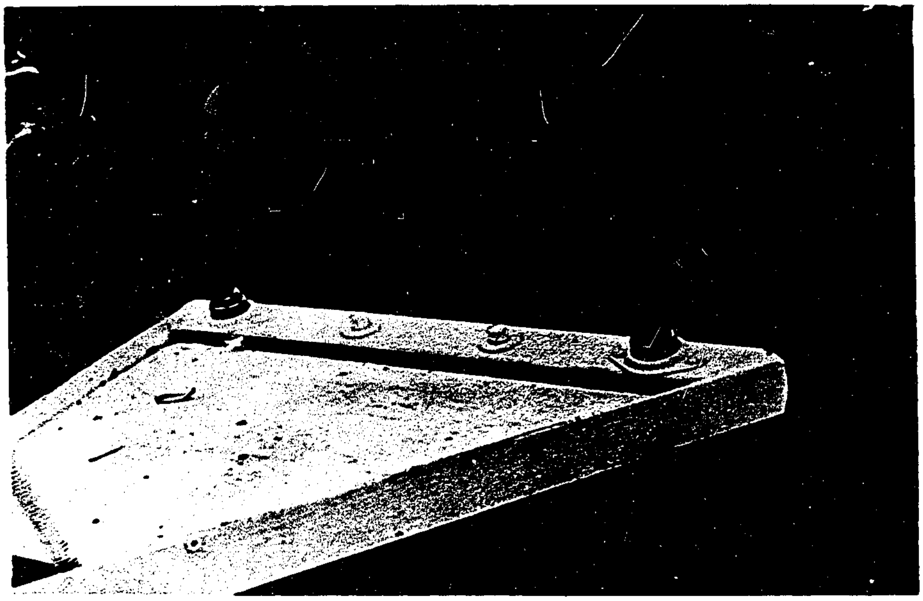

Figure 4
Workers Footrest Showing Positioner
Actuation Switches

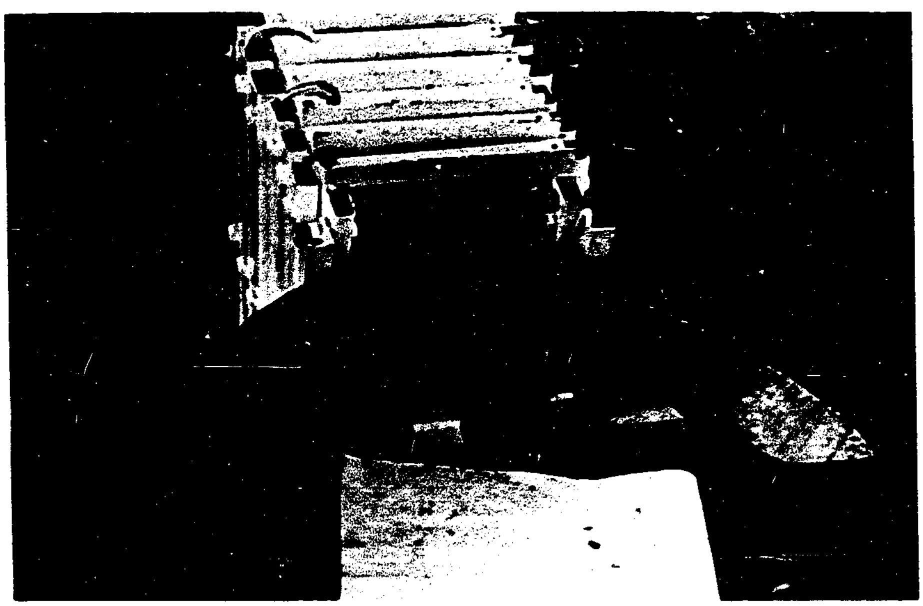

Figure 5
Final Design of the Conveyor
Feed Ramps

Conveyor Design

The following criteria were established with regard to the conveyor design:

1. The conveyor system would move the fruit from the picker's hands to a central sorting area.
2. The system would function for all positioner locations from fully retracted to fully extended.
3. Fruit bruising would not occur on the conveyors.

Once the fruit rolled down the plywood feed ramps it moved onto the conveyor. This is illustrated in Figure 6.

The positioners' conveyors were 6 5/8 inches wide by 1/8 inch thick cotton belt, with 1 3/4-inch diameter holes spaced every 6 inches. The holes allowed under-sized apples to fall through and prevented the remaining apples from rolling along the belt. The apples were kept from falling off the belts by having 1 inch square polyurethane foam strips glued, to each edge of, and across the belts. The 3 conveyor belts each travelled at 110 feet per minute. This speed was faster than the positioner's rate of retraction and therefore, no slack in the positioners' conveyor belts could result when the positioners were

Figure 6
Conveyor Adapted to Accordion Type
Positioner

Figure 7
Transition Between Positioner-Conveyor
and Vertical Fruit Conveyor

being retracted.

The positioners' conveyor belts were kept at constant tension for every degree of extension. This was accomplished by a positioner-actuated bell crank mechanism connected to a bank of tightener pulleys. The bell crank and linkage were designed so that the motion of the positioner, and the tightener pulleys were always synchronized at a certain ratio. The linkage was spring loaded to prevent any misalignment. The positioners' conveyors were driven by 3 hydraulic motors in series. Other methods of driving them would have been equally satisfactory.

When the apples reached the end of the positioners' conveyor belts, they were lifted out of the hole they were indexed in by a flat faced pulley. The apples were then dumped into the entrance of the padded vertical conveyor. This apparatus is illustrated in Figure 7. From there the fruit from the top and center positioners, dropped down through the baffle conveyor as shown in Figure 8.

The fruit fell slowly through the vertical conveyor since it dropped only 5 inches before changing directions by 120 degrees; the polyurethane foam blocks absorbing the kinetic energy. The polyurethane foam baffles were developed with the aid of closed circuit television and a videotape system. This equipment recorded the fruits' velocity and trajectory for various baffle angles. The selected trajectory prevented any free fall, and the rate of descent was further reduced by the friction of the fruit rolling against the baffles.

The vertical conveyor discharged the fruit onto the horizontal sorting belt. The fruit from the bottom positioner's conveyor was moved up, and discharged onto the sorting belt by polyurethane foam covered belts, similar to those described by Berlage and Yost (2). The rubber sorting belt had polyurethane bars glued across it to prevent the apples from falling off. The spacing of these bars permitted the apples to rotate through one revolution, and allowed the graders to see all sides of the individual fruit. The maximum distance of fall from the vertical conveyor to the sorting belt was 4 inches. Since the sorting belt was made from soft rubber, bruising could not occur here (3). The sorting belt travelled at 110 feet per minute. The conveyor system is illustrated in Figure 9.

Figure 9
Vertical Fruit Conveyor and Grading
Conveyor

Power Train Design

The self-propelled carrier was powered by a small diesel engine. The engine drove two variable displacement, axial piston hydraulic pumps. The pumps in turn, powered two axial piston motors. These two hydraulic motors were coupled to the drive wheels. The hydrostatic drive system gave the mechanical aid a speed range between 1 foot per minute and 3 miles per hour. The mechanical aid was operated at speeds between 1 1/2 and 2 1/2 feet per minute when picking.

Steering was accomplished by introducing a relative velocity between the drive wheels. Either wheel could be operated in forward or reverse independently, by changing the oil flow direction to the hydraulic drive motors. The rear wheels were free to caster. The whole system is similar to that described by Case (6). This type of steering was chosen because it was adaptable to testing various steering methods.

The mechanical aid required a team of 5 workers. Three picked from the positioners while one grader, and a driver-grader were located on the platform. The driver-grader spent most of his time grading because, driving the mechanical aid required much less attention than normal.

mechanical aid before any data were collected. The workers positions on the mechanical aid were changed daily, with no worker picking from any specific positioner more than twice in the trials.

The mechanical aid was evaluated in a McIntosh apple orchard owned by Robertson Apple Farms at Iroquois, Ontario. The trees were set 20 feet in rows, and 40 feet between rows. Tree heights ranged from 13 to 16 feet, and the lowest branches were approximately 2 feet above the ground. Most of the trees were over 20 years old. Some trees were pruned in the form of a cone while others had long scaffold branches. The orchard was on level terrain overlooking the St. Lawrence River.

The mechanical aid moved along one side of the row until it was beside the first tree. The outrigger wheel was put down to stabilize the mechanical aid; the workers extended themselves into the trees and started to pick. The workers extended and retracted their positioners as they worked past a tree. Sometimes, the workers fully extended their positioners while working along the widest part of the tree because, they had to go to the center of the tree to pick the hard to reach fruit. However, most of the apples were concentrated in the periphery of the trees.

The grower measured the fruit quality on both the apples harvested with the mechanical aid, and those harvested by the conventional method. The grower also recorded the labor productivity of the same pickers, harvesting by the conventional method.

Time logs and picking rate data were not taken simultaneously. The picking rates were measured first. Three persons were assigned to count the fruit picked by the individual workers, while the fourth person recorded this data as well as the data concerning the mechanical aid's forward velocity. This procedure is illustrated in Figure 10.

The time and motion study was executed in compliance with the accepted standards of work sampling (30). The absolute picking rate trials were taken for consecutive 5-minute intervals, sometimes lasting almost 2 hours. The 5-minute picking rates were then projected to an hourly basis. Both male and female pickers participated in these trials.

On the other hand, the time log of the workers activities was conducted using male workers only. It consisted of a record of the worker's activities while they were seated on the positioners. These were taken over random intervals of time. One observer was assigned the task of observing and recording one worker's activities

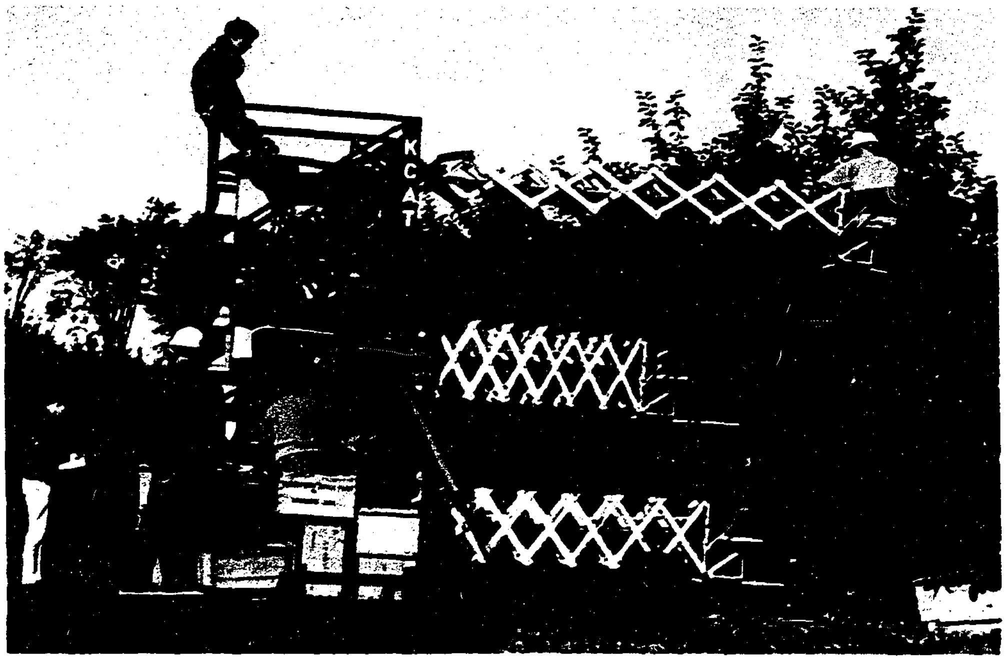

Figure 10
Operational View of Mechanical
Aid Showing Data Being Taken

VI. RESULTS AND DISCUSSION

The operational performance of the mechanical picking aid was evaluated in light of the previously outlined objectives. Picking rates with the mechanical aid were taken under normal operating conditions in a commercial orchard. Grading rates were not considered.

Picking Rate Study

The picking rates that were obtained in the time and motion study appear in Table 1. Several interesting facts are evident from this table. First, the persons on the center positioner picked apples faster than did those on the top or bottom positioners. Since the positioners moved forward at the same rate, and the workers picked for the same time intervals, more fruit was present between the 78-inch and 132-inch levels, than in either the top or bottom picking regions.

Female pickers on the top positioner picked 16.4 bushels per hour compared to 9.8 for the male picker. Similar results were obtained on the center and bottom positioners. Statistically, the value for the female worker on the bottom positioner is not a good sample because, only 1 trial was involved.

Projecting the 5-minute picking rates to an hourly basis was a good estimate of the actual results. The average machine harvesting rate, using 3 pickers was 31.0 bushels per hour, compared to the projected hourly rate of 31.8

Positioner Location	Picker	Average Picking Rate (5 minute period) Apples	Bushels[a/]	Number of Samples	Five Minute Rate Projected to 1 hour (bushels)	Average Hourly Picking Rate
Top	Female	196	1.37	7	16.4	
	Male	118	.82	73	9.8	
Middle	Female	222	1.55	8	18.5	
	Male	128.5	.89	79	10.7	
Bottom	Female	140	1.32	1	15.9	
	Male	120	.83	79	10.0	
Total	Female	538	4.24	16	50.8	
	Male	366.5	2.54	231	30.5	
	Both			247	31.8	31.0

[a/] Average number of apples per bushel = 144

Table 1.
Harvesting Rate Performance

bushels. This difference represents small sampling errors, and indicates that 5 minute test periods are good indicators, for predicting the hourly output of the mechanical aid.

The grower found that each worker picked only 3.1 bushels per hour, by the conventional method in 10 hours of trials. This value is very low compared to those reported for Michigan (12) and for Massachusetts (27).

Time and Motion Study

The results of the time and motion study appear in Table 2. The bottom picker picked 84.0% of the time, while those at the center and top picked, 79.4% and 72.4% of the time respectively. These values are higher than those obtained by Marshall (26). This was partially due to the workers being able to position themselves.while picking, and also to the elimination of the time spent in carrying the fruit.

Continuous forward motion also maximized the picking time percentage. This motion accelerated the slow pickers since the driver set the mechanical aid's forward speed as fast as possible, without having the slow picker leave an excessive amount of fruit. It was usually possible to maintain this pace because of the competition between the pickers. The competition was stimulated because picking with the mechanical aid was less strenuous.

The top worker had the highest percentage of unproductive time. This was due to waiting for the center picker, who had more fruit to pick. This situation is illustrated in Figure 11.

Workers on the bottom positioner spent the greatest percentage of time picking, but they had the lowest picking rate. The apples were harder to pick from the bottom

Positioner Location	Time Picking %	Time not Picking %	Total Time (minutes)	Total Dist. Ext Moved (feet)	Total Moves	Avg. Dist. per Move (feet)	Avg. Time Between Moves (minutes)
Top	72.4	27.6	130.6	458	124	3.7	1.16
Middle	79.4	20.6	115.9	305	111	2.75	1.04
Bottom	84	16	35.4	79	19	4.1	1.86

Table 2

Time and Motion Study Results

Figure 11
Top Picker Waiting for Man at
Center Position to Finish Picking

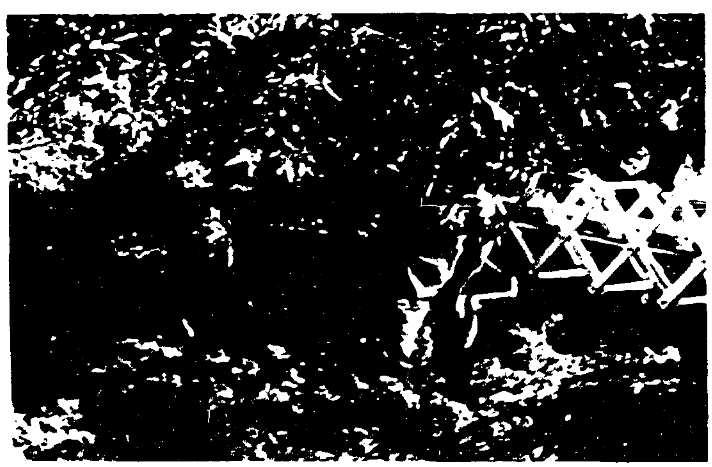

Figure 12
Bottom Worker Picking from the Ground

positioner because branches with fewer fruit were present in this area. In addition the bottom workers often stood on the ground to pick, and at the same time used the positioner as a mobile dumping station. This is shown in Figure 12.

The record of positioner movement produced some interesting results. The average time between moves was greatest for the bottom positioner; the distance per move was also greatest. It's total usage in terms of distance moved per unit time however, was the least, because the workers stood on the ground and picked a larger area before moving the positioner. This tendency of the pickers to use the bottom positioner as a portable dumping station indicates that the bottom positioner is not necessary.

The pickers at the center level repositioned themselves most frequently. However, their movements were shortest, averaging 2.75 feet per move. Molitorisz and Perry (29) found that a person's forward horizontal reach was 3.25 feet. This indicated that the pickers on the center positioner did not make full use of their reach. Tree branches were thick in this region, and moving the positioner more than 2.75 feet at any one time, would have caused an entanglement with the branches.

Conversely the branches near the top of the tree were fewer in number, and there were more voids. The top pickers moved their positioner 3.7 feet per move. The extra reach was obtained by rotating the seat 90 degrees, and picking sideways from there.

Bruising Study

The grower found that 93% of the apples harvested with the mechanical aid were within the Extra Fancy grade's bruising tolerance, while only 79% of the apples harvested by the conventional method met this standard. This indicates that less fruit damage is to be expected with the mechanical aid.

operated controls were available. These controls are inexpensive.

The following terms are used in the analysis:

C = harvesting cost for the conventional method (\$/bu.)

K = harvesting cost for the mechanical aid (\$/bu.)

H = annual usage of the mechanical aid (hr./yr.)

L = life expectancy of the mechanical aid (hr.)

M = initial cost of the mechanical aid (\$)

r = average total picking rate for 3 workers using the conventional method (bu./hr.)

R = average total picking rate for 3 workers on the mechanical aid (bu./hr.)

x = total hourly wage for 3 pickers (\$/hr.)

The harvesting costs in dollars per bushel appear below. The procedure is that used in Bainer et al. (1).

A) In conventional harvesting:

$$\text{Labor cost } C = \frac{x}{r}$$

B) For harvesting with a self-propelled mechanical aid requiring 3 pickers:

a) Depreciation is the initial cost M minus the salvage or resale value (considered negligible here) divided by the estimated life on a straight line basis.

b) Interest is charged at 6% of the average investment per year on a straight line basis. Average investment equals the initial cost M plus the resale value (negligible) divided by 2.

c) Total annual cost of taxes, insurance, and shelter are 1.5% of the initial cost M.

d) Oil, grease, and filters are 15% of the fuel cost.

e) **Fuel** costs $0.25 per Imperial gallon.

f) Fuel consumption is approximately 1.2 Imperial gallons per hour (actual consumption of the reported mechanical aid's engine).

g) Repair costs are 60% of the initial cost M, that is, a repair rate similar to that of a self-propelled combine.

h) The life expectancy L = 2000 hours. This is based on the pattern for a self-propelled combine.

Costs per bushel

1) Overhead

i) Depreciation $= \frac{M-0}{LR} = \frac{M}{LR}$

ii) Interest $= \frac{.06(M+0)}{2LR} = \frac{.03M}{LR}$

iii) Taxes, Insurance Shelter $= \frac{.15M}{LR}$

Total Overhead $= \frac{1.03M}{LR} + \frac{.15M}{HR}$

2) Operating Costs

i) Fuel, Oil, Lubrication $= \frac{1.15(\text{Fuel Consumption})\text{Fuel Cost})}{R}$

$$= \frac{(1.15)(1.2)(.25)}{R} = \frac{.35}{R}$$

ii) Repairs $= \frac{.60M}{LR} = \frac{.6M}{LR}$

iii) Labor $= \frac{x}{r} = \frac{x}{r}$

Total harvesting cost per bushel $= K$

Where $K = \frac{M}{LR} + \frac{.15M}{HR} + \frac{.03M}{LR} + \frac{.35}{R} + \frac{.6M}{LR} + \frac{x}{R}$

and substituting for L

$$K = \frac{1}{R}(.000815M + \frac{.1M}{H} + .35 + x)$$

To determine the break even initial cost M, the cost equations for both methods of harvesting are set equal to each other, viz,

$$\frac{x}{r} = \frac{1}{R}(.000815M + \frac{.1M}{H} + .35 + x)$$

and solving for M yields,

$$M = \frac{x\left(\frac{R}{r}\right) - .35 - x}{.000815 + \frac{.1}{H}}$$

Where $\frac{R}{r}$ is the ratio expressing the labor productivity using the mechanical aid, as compared to the labor productivity of the conventional method.

It is possible to plot the above equation for the breakeven cost using various values of H, $\frac{R}{r}$, and x. From this plot the breakeven initial cost M could be found. This is shown in Figure 13.

VII. CONCLUSIONS

1. Substantial increases in labor productivity were realized with the mechanical tree fruit harvesting aid developed during this study. There was an average increase of 328% in productivity for male workers using the mechanical aid, as compared with the same workers harvesting without the mechanical aid. These increases are based on the comparatively low harvesting rates, obtained with the conventional method in this study.

2. A 3-man positioner mechanical aid restricts the activities of each picker relative to his fellow workers. The increases in labor productivity, in part, were due to the cooperative attitude of the orchard manager and the pickers. In actual practice, wage incentives based on group effort, may be necessary to achieve similar results. Experience in industry (17) and with other multi-man harvesting units (11), indicates the desirability of group incentive plans.

3. Highest picking rates were achieved by workers at the center level. The design developed here, did not permit spillage time from one level to be utilized at another level. Therefore the operator

of the mechanical harvesting aid should place the most efficient pickers in the area of highest fruit density.

4. Female workers picked 66% more apples per hour than males with the mechanical aid. The reduction of heavy lifting with the mechanical aid, may provide a more efficient labor source that would not otherwise be available.

5. The mechanical aid developed in this study was capable of operating within the conditions peculiar to the orchards of eastern Ontario.

VIII. RECOMMENDATIONS FOR FURTHER RESEARCH

1. Since the workers tended to use the bottom positioner-conveyor as a dumping station, a study should be made to determine if the bottom positioner is economically justified.

2. A study of daily productivity should be made to indicate the advisability of incorporating automatic sorting and bin filling equipment, into the mechanical aid's basic design.

3. Further development of the hedge row tree system would reduce the tree width, and the amount of positioner extensibility.

4. Various wage schemes including group incentive plans should be experimented with to see what effect they have on production. At times during the trials it appeared that a fixed hourly wage did not provide enough incentive.

5. Long term research should be directed towards bruise free, completely mechanized, harvesting of tree fruit.

IX. SUMMARY

A mechanical aid for tree fruit harvesting was developed. Three workers one above the other, were seated on horizontal positioner-conveyors while picking fruit from the tree.

The mechanical aid was tested in an apple orchard. The absolute picking rates for both men and women were measured. A time log was kept of each pickers activity and each positioner-conveyor's movement.

Over the entire tree men picked on the average 328% faster with the mechanical aid than with buckets and ladders.

Workers spent from 72.4 to 84% of their time picking fruit when the mechanical aid was used.

A generalized cost analysis was made to determine the approximate break even capital investment in a mechanical aid, as compared to the cost of picking by the conventional method.

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APPENDICES

APPENDIX A

DATA ON PICKER PRODUCTIVITY

Table A 1

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
15:20-15:25	97	114	158
15:25-15:30	132	168	79
15:30-15:35	100	129	47
15:35-15:40	85	132	111
15:40-15:45	70	115	54
15:45-15:50	71	129	50
15:50-15:55	138	121	69
15:55-16:00	62	85	98
16:00-16:05	95	110	135
16:05-16:10	126	88	75
16:10-16:15	92	93	105
16:15-16:20	20	95	128
16:20-16:25	142	149	73
16:25-16:30	200	99	116

Date: October 2, 1968

Tree Spacing and Height: 20 feet x 40 feet, 15-16 feet high

Pruning: Poor

Apples per Bushel: 175 average

Forward Velocity: 1.85 feet per minute, average

Workers Sex: Male

Table A 2

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
13:25-13:30	89	148	194
13:30-13:35	93	63	94
13:35-13:40	184	134	183
13:40-13:45	196	144	170
13:45-13:50	90	153	158
13:50-13:55	109	118	201
13:55-14:00	133	138	170
14:00-14:05	117	95	127
14:05-14:10	53	233	132
14:10-14:15	95	150	101
14:15-14:20	175	157	75
14:20-14:25	210	154	122
14:25-14:30	239	172	138
14:30-14:35	119	110	116
14:35-14:40	34	168	108
14:40-14:45	187	171	101
14:45-14:50	-	154	84
14:50-14:55	125	147	120
14:55-15:00	120	86	118
15:00-15:05	177	120	120

Date: October 4, 1968

Tree Spacing and Height: 20 feet x 40 feet, 15-16 feet high

Pruning: Fair

Apples per Bushel: 145 average

Forward Velocity: 1.76 feet per minute, average

Worker Sex: Male

Table A 3

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
15:10-15:15	136	97	103
15:15-15:20	-	124	148
15:20-15:25	115	160	139
15:25-15:30	163	58	122
15:30-15:35	140	168	180
15:35-15:40	150	179	114
15:40-15:45	124	153	142

Date: October 4, 1968

Tree Spacing and Height: 20 feet x 40 feet, 15-16 feet high

Pruning: Fair

Apples per Bushel: 145 average

Forward Velocity: 1.76 feet per minute, average

Worker Sex: Male

Table A 4

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
14:15-14:20	138	174	74
14:20-14:25	133	138	101
14:25-14:30	80	142	80
14:30-14:35	115	210	82
14:35-14:40	56	151	87
14:40-14:45	125	126	161
14:45-14:50	122	173	112
14:50-14:55	120	120	106
14:55-15:00	150	117	74
15:00-15:05	139	146	108
15:05-15:10	123	187	103
15:10-15:15	130	90	64
15:15-15:20	100	114	32
15:20-15:25	80	162	-

Date: October 4, 1968

Tree Spacing and Height: 20 feet x 40 feet, 13-15 feet high

Pruning: Poor

Apples per Bushel: 146 average

Forward Velocity: 2.5 feet per minute, average

Worker Sex: Male

Table A 5

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
13:45-13:50	120	120	101
13:50-13:55	135	111	65
13:55-14:00	140	87	146
14:00-14:05	70	152	253
14:05-14:10	140	138	132
14:10-14:15	155	124	279
14:15-14:20	200	99	192
14:20-14.25	50	123	257
14:25-14:30	106	154	160
14:30-14:35	87	117	172
14:35-14:40	90	80	101
14:40-14:45	146	121	16
14:45-14:50	185	96	100
14:50-14:55	35	110	222
14:55-15:00	135	181	338
15:00-15:05	165	-	102
15:05-15:10	55	113	-
15:10-15:15	-	101	104
15:15-15:20	83	100	-
15:20-15:25	62	132	-
15:25-15:30	143	101	133
15:30-15:35	-	104	187

Date: October 11, 1963

Tree Spacing and Height: 20 feet x 40 feet, 13-16 feet high

Pruning: Good

Apples per Bushel: 145 average

Forward Velocity: 1.87 feet per minute average

Pickers: Male

Table A 6

PICKER PRODUCTIVITY

Time Interval	Number of Apples Picked		
	Top Picker	Center Picker	Bottom Picker
14:15-14:20	175	170	154
14:20-14:25	166	230	163
14:25-14:30	-	179	137
14:30-14:35	204	259	71
14:35-14:40	204	201	118
14:40-14:45	174	263	73
14:45-14:50	252	191	108
14:50-14:55	197	292	117 *

Date: October 12, 1968

Tree Spacing and Height: 20 feet x 40 feet, 13-15 feet high

Pruning: Good

Apples per Bushel: 141 average

Forward Velocity: 2.00 feet per minute, average

Pickers: Those on the top and center positioner-conveyors were female. Both male and female workers were employed on the bottom positioner-conveyor. The result denoted by an asterik was the only data obtained with a female located on the bottom positioner conveyor.

APPENDIX B

MOTION AND TIME DATA FOR PICKING

Table B 2

MOTION DATA FOR CENTER PICKER

Time Interval (minutes)	Time Picking (minutes)	Number of Moves	Distance Moved (feet)
6.58	5.41	9	16
5.92	4.08	8	18
10.41	8.75	10	26
7.91	7.25	6	16
9.41	7.91	6	16
9.58	5.75	5	10
11.50	5.75	8	35.5
4.58	4.08	5	22.5
6.58	6.41	3	14
4.67	4.67	8	21
9.17	6.67	8	27
4.58	4.58	7	19
5.00	5.00	8	21
6.00	5.66	10	29
11.17	7.66	8	14
2.50	2.50	2	4

Date: October 12, 1968.

Table B 3

MOTION DATA FOR BOTTOM PICKER

Time Interval (minutes)	Time Picking (minutes)	Number of Moves	Distance Moved (feet)
15.17	8.25	3	12
14.67	12.75	6	24
5.33	5.33	2	7

Date: October 12, 1968.