



## Development and evaluation of pick positioner for fruit harvesting and tree pruning

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Many types of fruits are grown in diverse agro-climatic zones of India. According to the Indian Horticultural Database of the National Horticulture Board (under the Union Ministry of Agriculture), production of fruits in the country in 2010-11 was 74877.5 million tonnes, from an area of 6.1 million hectares (Anon 2012). Fruit growers are facing two significant problems, i.e. adequate labor supply and lesser shelf-life of fruits. Mainly fruits are harvested by conventional methods like hand picking after climbing on trees or by using ladders. In these type of harvesting operations, labour productivity is very low with high drudgery along with lesser safety during harvesting. The availability of labor also gets scarcer each year and the supply of hand fruit pickers continues to shrink.

Tree fruit harvesting is the process of detachment, collection, and handling of the fruit. Picking is the detachment of the fruit from the tree (Coppock and Jutras 1960). The workers pick from a multitude of positions in the tree, to get all the fruits. The workers dump the fruits 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 using ladders.

In conventional tree fruit harvesting, a considerable portion of a worker's efforts are spent in climbing up and down the ladders, carrying the fruits to the crates, dumping the fruits, 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 (1953) 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. Rest of the time was spent in mounting the ladder etc. Kolhe (2009) developed a tractor mounted hydraulic lifter for fruit harvesting, pruning and spraying by integration of Agricultural and Mechanical Engineering concepts, manufacturing processes, material properties and tree characteristics. The principles of hydraulic circuit were used and accordingly turn table, harvesting arm, harvesting bucket and tractor mounting assembly was designed and developed.

Peterson *et al.* (1997) developed a mechanical harvest aid to position two pickers to remove apples from a narrow inclined trellis. Design concept maximized the pickers' time spent locating and detaching fruit, and minimized time spent handling fruit and controlling the unit. In medium to high yields, picker productivity was increased by 36 to 44% over conventional hand harvesting. Fruit quality from the harvest aid was nearly as good as that from conventional hand harvesting. Ground and tree losses were low for both harvesting techniques. All mechanical and electrical systems functioned reliably. Peterson (2005) developed a mechanical harvest aid for narrow inclined trellises that allowed pickers free movement in order to optimize their picking time. The harvest aid featured auto-steer, continuous ground speed, a fruit sorting section, and automated bin filling. Field tests demonstrated the potential to improve worker productivity up to 22% and effectively removed culls in the orchard. Fruit damage was unacceptable and require refinements in the fruit handling components. Baeten *et al.* (2007) described the construction and functionality of an Autonomous Fruit Picking Machine (AFPM) for robotic apple harvesting. The results of the AFPM were very promising. The proposed concepts guarantee adequate control of the autonomous fruit harvesting operation globally and of the fruit picking cycle particularly. The aim was to reduce the picking cycle period from an average of 9 to about 5 seconds (or less). The productivity of the AFPM will be close to the work load of about 6 workers, which makes the machine economically viable.

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Whitney *et al.* (1996) analysed harvesting data collected during the 1993–1994 season for four pairs of pickers in orange trees with fruit yields from 30 to 76 tonnes/ha, fruit weight from 160 to 235 g and tree heights from 3.7 to 5.5 m. Each picker used a conventional ladder and bag. The average harvesting rate per picker was found to range from 241 to 376 kg/h and it was found that harvesting increased by 40.8 kg/h for an approximate increase of either 20 tonnes/ha in yield or 50 g in fruit weight, or a 2m decrease in tree height. Sumner and Hedden (1980) developed a tractor drawn rake to gather fruit into a windrow at the tree drip line or at the centre of the row ready for pick-up. Towed by a 37.3 kW tractor, it had an average fruit recovery of 99% at raking speeds of 0.8–1.6 km/h in an average fruit load of 22 kg/m of windrow. Seamount and Opitz (1973) examined the overall efficiency and the various picking activities involved in the use of an ‘Auto picker’ compared to the use of ‘ladder and bag’ picking. The results showed that the time required to pick a box of fruit using a ladder was 8.07 minutes and using the ‘Auto picker’ was 6.46 minutes. Hence, the two-man positioning machine was found to increase the productivity and picking efficiency of each picker.

Mechanization of fruit picking and tree pruning aims to accelerate the harvesting operations process by using a system that emulates the human picker for decision making and picking. Conceptually, such a system would provide the same or better quality produce, at a much faster rate, would work more hours/day. Labor productivity could be increased with a mechanically powered positioner. The mechanically powered positioner would position the worker, during picking or pruning and eliminate the time lost due to worker movement. Therefore, a tractor mounted pick positioner was developed and evaluated for the tree pruning and fruit picking operations.

A tractor front mounted pick positioner was developed and evaluated at Punjab Agricultural University, Ludhiana. The pick positioner is having a movable platform, persons can stand on the platform and can be lifted to the total height of 9.6 m (32') for harvesting of fruits and pruning of trees. The platform can be moved in vertical plane only and the horizontal movement of platform can be achieved by changing the position of tractor. A vertical bar was mounted on the rear axle of the tractor. A rectangular shaped main bar and platform was attached with vertical bar. A double acting, tractor powered, hydraulic cylinder was installed between the main bar and vertical bar. The specifications of pick positioner are presented in Table 1. The hydraulic cylinder is connected to the tractor hydraulic system to operate the platform. A support from the front axle was also given to the vertical bar. Two men are required to operate the machine (one man is needed to operate the tractor and another man for operations). The front portion of the pick positioner act as a cantilever and hangs over the tractor. A supporting frame was developed to reduce the excessive vibrations and smooth

Table 1 Specifications of pick positioner machine

Item	Specifications
Tractor power	35-40 HP
Rpm of hydraulic motor	2000 RPM
Oil tank capacity	47 l
Transportation box	
(Length × Width × Depth)	1250 × 1000 × 750 mm
Vertical bar length and cross section	2750 & 100 × 50 mm
Middle Link length and cross section	3860 & 80 × 40 mm
Upper link length and cross section	1750 & 80 × 40 mm
Supporting frame length and width	1390 & 680 mm
Weight of the Machine	470 kg

transportation of the machine. The supporting frame mounted on front of the tractor. It supports hanging portion of the pick positioner and reduces vibrations. The total length and width of the supporting frame are 1390 mm and 680 mm respectively.

The weight of pick positioner is about 470 kg. Further, a worker has to stand on the platform; thus affects the centre of gravity of tractor and, hence, stability. Reactions of front and rear wheel were taken to calculate the centre of gravity of the machine. Field evaluation of tractor operated pick positioner was performed for fruit pickings and pruning of trees.

In hydraulic flow system hydraulic fluid pass through the filters, pump, distributor, hydraulic cylinder from the oil tank of the tractor. The fluid from the oil tank flow to oil pump through magnet and oil filter. The oil pump further transferred the fluid to oil distributor which passes the fluid to the hydraulic cylinder which causes the upward and downward movement of the pick positioner machine. The overflow of fluid can be adjusted through the overflow pipe attached with the hydraulic cylinder.

General Linear Model (GLM) procedure was used for statistical analysis with the help of SAS 9.3 software. The p values were calculated for comparison of picking and pruning operation performed by using pick positioner and manually.

The designed machine was evaluated for safety and capacity point of view. The center of gravity of the machine was determined for safety point of view. The field capacity of machine was evaluated for picking of fruit and pruning of trees.

#### Determination of Center of Gravity

A man of about 70 kg weight with a dead weight of 30 kg (to simulate harvested fruit weight) was put on the platform. The reaction on front tyre ( $R_f$ ) and rear tyre ( $R_r$ ) of tractor were taken by a weighing balance without pick positioner and with pick positioner to calculate centre of gravity. The reactions were presented in Table 2. On the basis of these reactions the centre of gravity (CG) was calculated. The wheel base of tractor was 200.0 cm. The centre of gravity of tractor alone was 67.9 cm from rear axle, whereas the CG of

Table 2 Front and rear reaction of tractor with pick positioner

Reactions, kg	R <sub>f</sub>	R <sub>r</sub>	Total wt	CG, cm (From rear axle)
Wt of tractor	720	1 400	2 120	67.9
Wt of tractor and machine	1 200	1 390	2 590	92.6
Wt of tractor Down and machine position	1 320	1 370	2 690	98.1
with man Up position	1 227	1 463	2 690	91.2

tractor with pick positioner was 92.6 cm from rear axle. The CG of tractor shifts form 67.9 cm to maximum of 98.1 cm from rear axle in downward position. Since the use of pick positioner for the pruning and harvesting operations is performed at the stationery position of the tractor, and shifting of CG is towards the centre of the wheel base, so the system is safe along the longitudinal direction. Again the pick positioner is symmetrical about the centre line so it is safe along the lateral direction.

*Evaluation of Pick Positioner for Fruit Harvesting*

Tractor mounted pick positioner was used for fruit/seed

Table 3 Picking capacity during amla fruit picking

Subject's	Replications	Using pick positioner	Conventional picking
		Capacity (kg/h)	Capacity(kg/h)
S1	R1	120	24
	R2	125	35
	R3	103	39
S2	R1	133	33
	R2	113	31
	R3	128	41
S3	R1	135	29
	R2	126	38
	R3	118	42
	Mean	122.3	34.7
	SD	10.1	6.0
	CV	8.2	17.2

S1S2S3- subject SD- standard deviation, CV- coefficient of variation R1 R2 R3 – replication

picking. Mahagony, mango and amla fruits were picked from tree with the help of tractor mounted pick positioner. When, pick positioner was evaluated for amla harvesting and its comparison with manual harvesting (without pick positioner). Three subjects were selected for the experiments. The workers were asked to pick the fruits for 30 minutes duration for which fruit picking capacity were recorded (Table 3). The average amla fruit picking capacity of three different subjects using pick positioner was found to be 122.3 kg/h having CV 8.2 whereas in case of conventional picking the average picking capacity of amla fruit for three different subjects was 34.7 kg/h having CV 17.2. The overall results revealed that picking capacity for amla fruit by pick positioner was significantly higher (P = 0.0001), i.e. 3.5 times than conventional method.

The average field capacity using the pick positioner was found to be 2.73, 18 and 122 kg/h for mahagony, mango and amla fruits respectively (Table 4). It was also observed during the operation that bruising of mango fruit occur when fruit was picked with hand (without pick positioner). It was found that the collection of mahagony fruit was not possible without pick positioner being located at the end of branches. Mango fruits harvested were 8 kg/h by using ladder and harvested manually against 18 kg/h fruits picked by using pick positioner. The labour requirement for picking by using machine for harvesting of amla and mango fruits (Assuming yield of amla and mango fruits 1.5 and 2.0 q/tree with 180 and 105 trees/ha) were 55.32 and 291.26 man-days/ha (Table 5), as compared to labor required 194.52 and 656.26 man-days/ha in case of conventional method respectively. The saving in labour was found to be 71.55 and 55.62 % for amla and mango fruit picking.

*Evaluation of pick positioner for tree pruning*

Tractor mounted pick positioner was also used for pruning of various trees such as ashoka (*Longofolia*), ashoka, kachnara, palmeria, mahagony, balemkheira, jamun, talli, peepal, shahtoot, bhail, alostonia, dake, amaltass, gulmohr, safeda, neem, kachnar, silver oak, mango at the various location of the university but the evaluation data for the five trees namely ashoka, ashoka (logofolia), jamun, alostonia, and mahagony were measured during the tractor mounted pick positioner operation as shown in Table 6. It was found that the labour requirement was 2.5, 2.2, 1.51, 1.40, and 1.3

Table 4 Average picking capacity for amla, mango and mahagony fruit picking

Fruit	Height of crop (m)	Field capacity (kg/man-h) with pick positioner				Field capacity (kg/man-h) without pick positioner	p-value
		R1	R2	R3	Average		
Mahagony	6.0 – 7.62	3.2	3	2	2.73	Not Possible without pick positioner	
Mango	7.6-9.3	15	20	19	18	08	0.0099
Amla	5.0-8.0	116	125	126	122	34.7	0.0001

Table 5 Labour required (man-days/ha) for harvesting by using pick positioner machine and by conventional method

Crop	Man-days/ha (Conventional method)	Man-days/ha (Pick Positioner)	Saving (%)
Amla	194.52	55.32	71.55
Mango	656.26	291.26	55.62
Mahagony			

observed that picking capacity for amla fruit by using pick positioner was significantly higher ( $P = 0.0001$ ) than picking by conventional method. The average picking capacity using the pick positioner was found to be 2.73 and 18 kg/h for mahagony and mango fruits respectively as compared to the picking capacity 8 kg/h in case of mango fruit during conventional method whereas for mahagony fruits, picking was not possible by conventional method. The labour

Table 6 Tree pruning performance of tractor operated pick positioner

Tree	No. of trees pruned	Total labour requirement (man-h)	Average labour requirement using Pick positioner (man-h/tree)	Labour requirement using conventional methods (man-h/tree)	p – value
Ashoka ( <i>Saraca asoca</i> )	8	20	2.5	15 (06-24)* (Avg. labour saving 80-90%)	
Ashoka ( <i>Longofolia</i> )	6	13	2.2		
Jamun ( <i>Syzygium Cumini</i> )	14	21	1.51		
Alostonia ( <i>satpatia</i> )	10	14	1.40		
Mahagony ( <i>Sweitenia mahagani</i> )	11	14	1.3		
Average	-	-	2.0	15	0.0120

\*Normal pruning to pruning of thick stems

man-h/tree for Ashoka, Ashoka (*logofolia*), Jamun, Alostonia, and Mahagony trees respectively. On the other hand in case of conventional method (By using ladder or by climbing on the tree) of tree pruning, on an average labour requirement was found to be 15 man-h/tree ranging from 6 man-h/tree for simple tree pruning to 24 man-h/tree in case of pruning/cutting of thick stems. It was also observed that fuel consumption during the machine operation varied from 2.0-2.5 l/h when tractor engine was stopped after positioning the platform at required height to 5.0-5.5 l/h when tractor engine was always running during harvesting/pruning. The overall results revealed that labour requirement for tree pruning by pick positioner, i.e. 2 man-h/tree was significantly ( $P = 0.0120$ ) lesser than conventional method i.e 15 man-h/tree.

### CONCLUSION

A tractor mounted pick positioner was developed and evaluated, which has a movable platform, persons can stand on the platform and can be lifted to the total height of 9.6 m (32') for harvesting of fruits and tree pruning. The weight of pick positioner is about 470 kg and it act as a cantilever on tractor. The centre of gravity of tractor alone was 67.9 cm from rear axle. The CG of tractor shifted form 67.9 cm to maximum of 98.1 cm from rear axle during down position of pick positioner. The average amla picking capacity of three different subjects using pick positioner was found to be 122.3 kg/h having CV 8.2, whereas in case of conventional amla picking the average picking capacity of three different subjects was 34.7 kg/h with 6.0 SD having CV 17.2. It was

requirement (man-h/tree) was 2.5, 2.2, 1.51, 1.40, and 1.3 man-h/tree for ashoka, ashoka (*Logofolia*), jamun, alostonia, and mahagony trees respectively. On the other hand in case of conventional method of tree pruning, an average labour requirement was found to be 15 man-h/tree ranging from 6 man-h/tree in simple tree pruning and 24 man-h/tree in case of pruning of thick stems. The overall results revealed that labour requirement for tree pruning by pick positioner i.e. 2 man-h/tree was significantly lesser ( $p = 0.0120$ ) than conventional method, i.e. 15 man-h/tree. The fuel consumption during the machine operation varied from 2.0-2.5 l/h when tractor engine was stopped after positioning the platform at required height to 5.0-5.5 l/h when tractor engine was always running during harvesting/pruning.

The developed pick positioner can also be used for other miscellaneous rural/village level activities. Total number of operational hours of tractor owned by a farmer also improves by using the machine for harvesting/pruning and other miscellaneous activities because of use of machine in the whole year.

### SUMMARY

A tractor mounted pick positioner was developed and evaluated, which has a movable platform, persons can stand on the platform and can be lifted to the total height of 9.6 m (32') for fruit harvesting and tree pruning. The weight of pick positioner is about 470 kg and it act as a cantilever on tractor. The centre of gravity of tractor alone was 67.9 cm from rear axle, whereas the CG of tractor with pick positioner

was shifted to 92.6 cm from rear axle. The CG of tractor shifts from 67.9 cm to maximum of 98.1 cm from rear axle in downward position of pick positioner. For amla harvesting, the average picking capacity of three different subjects using pick positioner was found to be 122.3 kg/h having CV 8.2 whereas in case of conventional picking the average picking capacity of three different subjects was 34.7 kg/h having CV 17.2. The results revealed that picking capacity for amla fruit by pick positioner was significantly higher ( $p = 0.0001$ ) than conventional method. The average field capacity using the pick positioner was found to be 2.73 and 18 kg/h for mahagony and mango fruits respectively. The labour requirement was 2.5, 2.2, 1.51, 1.40, and 1.3 man-h/tree for ashoka, ashoka (longofolia), jamun, alostonia, and mahagony trees respectively, whereas in case of conventional method of tree pruning, an average labour requirement was found to be 06 man-h/tree in simple tree pruning and 24 man-h/tree in case of pruning of thick stems. The fuel consumption during the machine operation varied from 2.0-2.5 l/h when tractor engine was stopped after positioning the platform at required height to 5.0-5.5 l/h when tractor engine was always running during harvesting/pruning. The overall results revealed that labour requirement for tree pruning by pick positioner was significantly ( $P = 0.0120$ ) lesser than conventional method.

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