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Performance evaluation of a tractor mounted groundnut pod collecting machine

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■ **ABSTRACT :** The performance of a tractor mounted groundnut pod collector was evaluated at different levels of machine speed (1.0-1.5, 1.5-2.0 and 2.0-2.5 km/h) and sieve oscillations (200, 250 and 300 rpm) at a constant penetration depth of 10 cm. The performance of the machine was found to be better at 1.5-2.0 km/h forward speed and 250 rpm sieve oscillations, respectively, looking to minimum losses and maximum pod collection efficiency. Pod collection efficiency was found maximum (93.75%) at 1.5-2.0 km/h and 250 rpm. The theoretical field capacity of groundnut pod collector was found as 0.22 ha/h while effective field capacity was 0.18 ha/h and field efficiency was 81.81 per cent. On comparison with manual pod collection method, there was 88.42 per cent reduction in time while 48.10 per cent reduction in pod collection cost was observed.

■ **KEY WORDS :** Performance, Groundnuts, Tractor mounted, Pod collection, Cost economics

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Groundnut (*Archis hypogaea*. L) or peanut is one of the most important cash crops of our country and it plays a major role in bridging the vegetable oil deficit in the country. Groundnuts in India are available throughout the year due to a two-crop cycle harvested in March and October. In India the six major groundnut-growing states are Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Rajasthan and Tamil Nadu account for about 90 per cent of the total groundnut area of the country. Andhra Pradesh and Gujarat contribute more than 55 per cent of the total area and production of groundnut. Among the major groundnut growing states, Gujarat is the most important one accounting for 36 per cent of the total area (Anonymous, 2014).

Groundnut cultivation requires various field operations such as seedbed preparation, sowing, fertilizer application, interculturing, harvesting, threshing and pod collection from soil. In harvesting of groundnut, human, animal and mechanical power is used. Farmers have been using animal and tractor power with different types of simple and improved blade harrows and now-a-days, tractor drawn digger-shaker has been used in harvesting of groundnut. The digger continually uproot the plants, cut the roots, pull the plants by their vines, shake and clean them while being elevated and finally drop on the ground to build a windrow. The uprooting operation causes groundnuts losses and usually the pods are left in the ground. The losses may be upto 10– 30 per cent depending upon the conditions. These have to be manually picked up by laborers. Traditionally, the left-over pods are picked manually either in sitting or bending posture which is very tedious, time consuming and costly also. Therefore, this machine was developed to dug out, separate pods from soil and collects the left out pods mechanically.

■ METHODOLOGY

Description of the groundnut pod collector:

The principal components of the tractor mounted groundnut pod collector are main frame, digging blade, soil throwing roller, soil extension plate, sieve shaking unit, depth control wheel, transportation wheel and power transmission assembly. The soil cutting blade is made of 1200 x 100 mm thick spring steel blade having thickness of 12 mm. It was welded to the front portion of the soil conveying plate. The plate (39×120 × 0.2 cm) was welded with main frame at a 35° angle with horizontal for conveying the soil mass. Soil mass was lifted up to total height of 30 cm from the bottom of the cut of soil mass. It is fitted just behind the digging blade. It was observed that the soil cut by the bottom blade started collecting at the end which hindered the further upward movement of soil therefore, the roller consisting two flaps and made of MS flat (116 × 7.5 cm) were welded longitudinally at the periphery of the pair of disks of 30 cm diameter. The roller was rotated at 140 rpm and soil along with pods was thrown to the sieve shaking unit. A sieve shaking unit consisting of set of two sieves, was provided in the rear to get the clods and soil separated from the pods. The shape of openings of both the sieves was oblong and size of openings of upper sieve was 50 × 20 mm while that of lower sieve was 60 × 8 mm. Removal of clods bigger than the size of groundnut pods was done through the upper sieve and pods were collected on the lower sieve. For collection, an opening (a collecting trough) was provided on rear part of the lower sieve. The fabricated view of the machine is shown in Fig. A.

Fig. A : Developed groundnut pod collector

The performance parameters *viz.*, depth of operation, width of operation, speed of operation, draft and power requirement, actual field capacity, theoretical filed capacity, digging efficiency, fuel consumption and per cent pod loss (harvesting losses) were recorded using IS Test code, IS: 11235 – 1985.

Plot design and layout:

The field experiments were laid out in strip-plot design with four replications of each treatment. The whole cropped area of 47 m × 46.2 m was divided into four equal parts, each of 47 m × 10.8 m to conduct the field study into four replications. The area of each replication was again divided into three equal sections to get three levels of tractor forward speeds. This area of 47 × 1.2 m was divided length-wise into three sections, each of 15 m length so as to get three levels of sieve oscillations. Thus, in three rows three levels of sieve oscillation could be achieved. Hence, for three level of forward speed and three levels of sieve oscillation, total 9 plots (3×3) for one replication and 36 plots (9 × 4) for four replications were prepared out of the cropped area to conduct the field study.

Experimental design:

During field evaluation of the machine strip plot design was followed in the study. The experimental data collected from all dependent parameters was analyzed statistically with Microsoft Excel (2007) using ANOVA procedure. The analysis of variance was performed and the critical difference at 5 per cent and 1 per cent level of significance was calculated for testing the significance of difference between different treatments.

Experimental procedure:

Prior to the operation of the machine, the sieve oscillation was set at 200 rpm and the machine was run for 15 m length. For next 15 m run, the sieve oscillation was kept at 250 rpm and for the last segment of 15 m the oscillation was changed to 300 rpm. Variation in sieve oscillation was achieved by changing the belt of stepped pulley on sub-main shaft of the machine. For these three oscillations the forward speed was kept in the range of 1.0 km/h -1.5 km/h. For remaining two forward speeds *i.e.* 1.5 km/h – 2.0 km/h and 2.0 km/h – 2.5 km/h the same procedure was followed. The variation in forward speed of operation was obtained by adjusting the throttle

Table A : Specifications of developed groundnut pod collector

Sr. No.	Particulars	Specifications
1.	Name of the equipment	Tractor operated groundnut pod collector
2.	**Type of hitch and its detail**	
	Linkage	3 – Point
	Power source	Tractor PTO
3.	**Overall dimensions**	
	Length, mm	1800
	Width, mm	1320
	Height, mm	1220
	Weight, kg	435
4.	**Main frame**	
	Material of fabrication	Mild Steel (L – section size: 65 mm x 65 mm x 6 mm)
	Length, mm	1800
	Width, mm	1320
	Height, mm	632
5.	**Digging blade**	
	Material of fabrication	Spring steel
	Dimensions, mm	1200 x 100 x 12
	Method of fixing	Bolted with soil mass conveying plate
	Inclination/Rake angle	35°, also adjusted by tractor's top link
6.	**Soil mass conveying plate**	
	Material of construction	Mild Steel
	Dimensions, mm	400 x 1200 x 6
	Method of fixing	Bolted with main frame at 35° from horizontal by means of angle iron (65 x 65 x 6mm)
7.	**Soil throwing roller**	
	Outer diameter of the shaft, mm	50
	Length of the shaft, mm	1160
	No. of outer circular disc	3
	Thickness of the disc, mm	6
	Dimensions of blade, mm	1160 x 75 x 6
	Material of blade	MS flat
8.	**Sieve shaking unit**	
	Material of construction	Frame (C – channel size: 62 mm x 62 mm x 6 mm)
	Sieve box dimensions, cm	120 × 110
	Number of sieves	2
	Material of sieves	Galvanized iron
	Thickness	24 Gauge
	Hole type	Elongated/ Oblong
	Upper sieve hole dimension, mm	50 × 20
	Lower sieve hole dimension, mm	60 × 8
	Slope, °	4°
9.	**Depth control wheel**	
	Number of wheels	2
	Material	Mild steel
	Diameter, mm	200
10.	**Pneumatic wheel**	
	Number of wheels	2
	Material	Rubber
	Ply rating	3.50 × 8, 4

of the tractor.

After completion of the picking operation by the machine from the individual plots of 1.2 m x 15 m size, groundnut pod collection efficiency and losses were determined.

The losses were calculated with the help of following formulae.

The following formula was used in the computations:

– Total quantity of pods **a = b +c + d**

where,

a = Total quantity of pods collected from the sample area and from machine.

b = Quantity of damaged pods collected from the sample area.

c = Quantity of left out pods.

d= Quantity of undug pods.

– Percentage of damaged pods loss **= b / a x 100**

– Percentage of left-out pods loss **= c / a x 100**

– Percentage of undug pods loss = d / a x 100

– Total percentage of pods loss = **Percentage of damaged pods loss + Percentage of left-out pods loss + Percentage of undug pods loss**

– Pod collection efficiency

$$= \frac{\text{Pods collected by machine from sample area}}{\text{Total quantity of pods from sample area and machine}} \times 100$$

Theoretical field capacity:

The theoretical field capacity is the rate of field coverage that would be obtained if the implement operates continuously without interruption. It is calculated by the formula (Kepner *et al.*, 2005)

$$\text{TFC} = \frac{\text{W x S}}{10}$$

where,

TFC= Theoretical field capacity, ha/h

W= Width of cut, m

S= Forward speed, km/h.

Effective field capacity:

This is the actual rate of field coverage based on field time. It is calculated by the formula,

$$\text{EFC} = \frac{\text{W x L}}{\text{T x 10000}}$$

where,

EFC= Effective field capacity, ha/h

W= Width of cut, m

L= Length of strip, m

T=Time taken, h.

Field efficiency:

Field efficiency is the ratio of effective field capacity to the theoretical field capacity expressed as percentage.

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \text{x100}$$

Economics of tractor operated groundnut pod collector:

The economics of the mechanical pod collection method in terms of time and cost of operation was observed and compared with the manual method of groundnut pod collection. Straight line method was used for cost analysis for estimating the cost of operation of groundnut pod collector. In case of mechanical equipment, the fixed and variable costs were taken into consideration to estimate the cost of operations. In manual pod collection method, the groundnut pods were picked up manually and collected in bags from the sample area.

■ RESULTS AND DISCUSSION

The developed groundnut pod collector was tested for its working performance at Agronomy and Instructional farm of the Junagadh Agricultural University, Junagadh. During the field testing of the same, the observations were recorded as illustrated in Tables 1 and 2.

Table 1 : Preliminary observations during harvesting operation

Sr. No.	Particular	Observation
1.	Name of the crop	Groundnut
2.	Variety of crop	Semi-spreading (GG-20)
3.	Type of soil	Medium black soil
4.	Area of groundnut grown	1.95 ha
5.	Date of sowing	11/06/2016
6.	Plant geometry	R – R: 60 cm
7.	Width of beds	200 cm
8.	Width of bunds	30 cm
9.	Date of harvesting	28/10/2016
10.	Crop duration	140 days
11.	Curing period	11 days
12.	Soil moisture content	10.38 %
13.	Soil bulk density	1.22 g/cc
14.	Area of operation	1.05 m^2

Table 2 : Performance of groundnut pod collector		
Sr. No.	Parameters	Value
1.	Speed of operation, km/h	1.83
2.	Net pull, kg	383
3.	Draft, kgf	383
4.	Drawbar horsepower requirement, hp	2.59
5.	Fuel consumption, l/h	3.81
6.	Theoretical field capacity, ha/h	0.22
7.	Effective field capacity, ha/h	0.18
8.	Field efficiency, %	81.81
9.	Time required to cover a hectare, h/ha	5.55

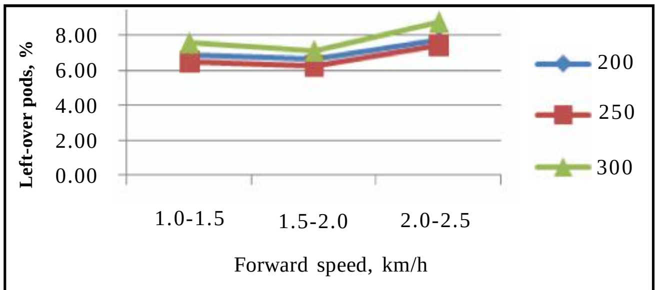

Fig. 1 : Effect of forward speed on left-over pods

Groundnut pod losses and collection efficiency:

Left-over pod loss:

After the collection of pods by machine from the area of 15 m x 1.2 m, the left over pods on the surface were collected and percentage of left-over pods from the sample area was calculated. The results of left-over pods were analyzed statistically to see the effect of forward speed and sieve oscillations. The results are shown in Table 3.

Effect of forward speed and sieve oscillations on left-over pod loss:

A perusal of data presented revealed that the effect of forward speed on left-over pods was found highly significant as shown in Fig. 1. From the figure, it is clear that as forward speed was increased from 1.0 km/h to 1.5 km/h, the percentage of left-over pods decreased from 6.98 per cent to 6.67 per cent but when speed was increased from 1.5 km/h to 2.0 km/h, the percentage of left-over pods increased to 7.96 per cent. The reason for more losses at high forward speed may be due to high speed the dugout soil along with the pods was not taken up by the blade and left on the field. The minimum percentage (6.67 %) of left pods was found at medium forward speed *i.e.* at 1.5-2.0 km/h. Maximum percentage (7.96 %) of left pods was found at higher speed *i.e.* at 2.0-2.5 km/h. Similar findings were reported by Afshin *et al.* (2014) for groundnut harvester.

Effect of sieve oscillations on left-over pods was found significant as shown in Fig. 2. The average left-over pods were 7.07 per cent, 6.73 per cent and 7.82 per cent at 200 rpm, 250 rpm and 300 rpm, respectively as shown in Table 3. Minimum left-over pods (6.73 %) were obtained at 250 rpm. Maximum left-over pods (7.82%) were observed at 300 rpm. When the sieve oscillation was 250 rpm, the left-over pods was 6.73 per cent and this increased to 7.82 per cent when the sieve oscillations frequency increased to 300 rpm. The

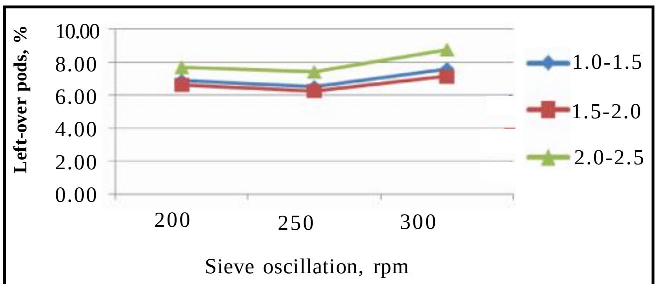

Fig. 2 : Effect of sieve oscillations on left-over pods

Table 3: ANOVA showing the effect of sieve oscillations (S) and forward speed (F) and their interaction on left-over pod loss									
Source	df	SS	Mss	Calf	Tab F	Test	S.E.±	C.D. (P=0.05)	CV
REPL	3	0.01	0.01	0.02	4.76	NS			
F	2	10.88	5.44	34.53	5.14	**	0.12	0.39	5.51
S	2	7.48	3.74	9.83	5.14	*	0.18	0.62	8.57
F X S	4	0.35	0.09	0.55	3.26	NS	0.20	NS	4.56
Error	12	1.92	0.16						
Total	35	23.87							

* and ** indicate significance of values at P=0.05 and 0.01, respectively NS =Non-significant

increase in left-over pods with increasing sieve oscillations may be due to less resident time of the materials to be separated on the sieve and the increase agitations allows more materials to pass through the sieve holes. Similar results were reported by Simonyan *et al.* (2006) and Werby (2013). The interaction effect of different sieve oscillations at different forward speeds on left-over pods was found non-significant

Damaged pod loss:

The results of damaged pods were analyzed statistically to see the effect of forward speed and sieve oscillations. The results are shown in Table 4.

Effect of forward speed and sieve oscillations on damaged pod loss :

It is evident from the Table 4 and Fig. 3 that the effect of forward speed on damaged pods was found significant at 1 per cent level of significance. Minimum damaged pod percentage (0.98 %) was found at medium forward speed (1.5-2.0 km/h) whereas maximum damage to pods (1.32 %) occurred at high speed (2.0-2.5 km/h). Similar findings were reported by Ibrahim *et al.* (2008) for multipurpose digger. The effect of sieve oscillations on damaged pod loss was found significant (Table 4). The percentage of damaged pods losses increased at higher sieve oscillations (Fig. 4). The increasing trend was observed in damaged pod percentage with increase in the sieve oscillations. The minimum damaged pod loss (1.03 %) was found at 200 rpm and maximum (1.26 %) at 300 rpm. It was observed that by increasing sieve oscillations above 250 rpm, there was too much vibrations developed in the sieve shaking unit, due to which the pods were damaged at higher oscillations. The combined effect of different sieve oscillations at different forward speeds on damaged pods was found significant.

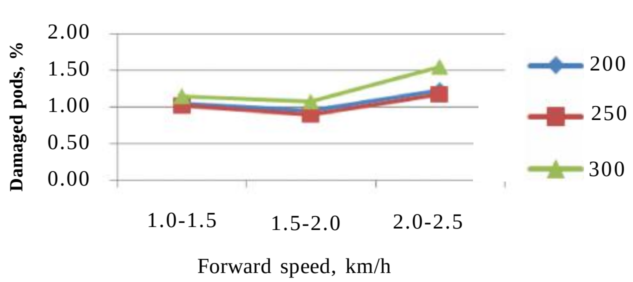

Fig. 3 : Effect of forward speed on damaged pod loss

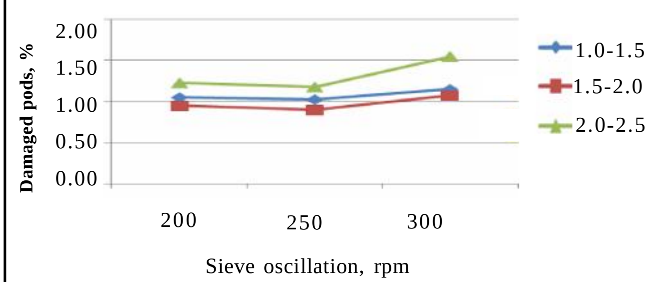

Fig. 4 : Effect of sieve oscillations on damaged pods loss

Pod collection efficiency:

The results of pod collection efficiency were analyzed statistically to see the effect of forward speed and sieve oscillations. The results in the form of ANOVA are shown in Table 5.

Effect of forward speed and sieve oscillations on pod collection efficiency:

The effect of forward speed on the pod collection efficiency was found significant at 1 per cent level of significance (Table 5 and Fig. 5). The data presented revealed that at different forward speeds, F2 (1.5-2.0

Table 4 : ANOVA showing the effect of different sieve oscillations (S) and forward speed (F) and their interaction effects on damaged pod loss

Source	df	SS	Mss	Calf	Tab F	Test	S.E.±	C.D. (P=0.05)	CV
Repl	3	0.01	0.01	0.17	4.76	NS			
F	2	0.74	0.37	25.15	5.14	**	0.04	0.21	10.81
S	2	0.34	0.17	6.25	5.14	*	0.05	0.17	14.77
F X S	4	0.09	0.02	4.65	3.26	*	0.03	0.11	6.12
Error	12	0.06	0.01						
Total	35	1.48							

* and ** indicate significance of values at P=0.05 and 0.01, respectively NS =Non-significant

km/h) showed maximum pod collection efficiency of 93.33% and minimum pod collection efficiency (92.04 %) was obtained at F3 (2.0-2.5 km/h) forward speed. The reason for lower pod collection efficiency at higher forward speed was less collection of pods by machine. It may also be due to sliding of pods along with the soil. The results were in tune with those of Afshin *et al.* (2014) and Ibrahim *et al.* (2008). The effect of sieve oscillations on pod collection efficiency was found significant at 5 per cent level of significance (Table 5 and Fig. 6). The percentage of pod collection efficiency increased with increase in sieve oscillations. The minimum pod collection efficiency *i.e.* 92.18 per cent was found at 300 rpm and maximum (93.28%) pod collection efficiency was recorded at 250 rpm. It was observed that by increasing sieve oscillations above 250 rpm, too much vibrations observed in the machine, due to which the pods were damaged at higher oscillations. The decrease in the pod collection efficiency with increasing sieve oscillations may be due to less resident time of the pods on the sieve and the increase agitations allows more materials to pass through the sieve holes. Harrison and Blecha (1983) described that the transport of particles along oscillating sieves, which is a function of sieve oscillation frequency, affects the efficiency of the process and affects metering of particulate substances along the sieve. The results were in tune with those of Hanna *et al.* (2010); Werby (2013) and Voicu *et al.* (2011). The interaction of different sieve oscillations at different forward speeds on pod collection efficiency was found non-significant.

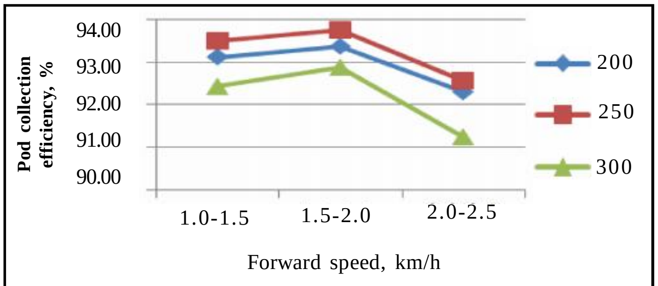

Fig. 5 : Effect of forward speed on pod collection efficiency

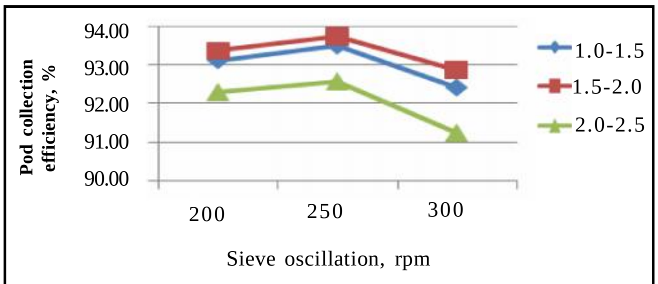

Fig. 6 : Effect of sieve oscillations on pod collection efficiency

From the results presented and discussion made above, it can be said that machine should be operated at medium forward speed (1.5-2.0 km/h) and sieve oscillations of 250 rpm to collect maximum left out groundnut pods.

Economics of groundnut pod collection:

The cost associated with existing practice (manual pod collection) of groundnut pod was compared with the cost of operation of developed tractor drawn groundnut pod collector.

Manual pod collection:

The observations regarding the manual operation of groundnut pod collection were taken. Three replications were taken to get the appropriate value and average value was calculated. In this method, the groundnut pods were collected manually. Before manually pod picking from the field, the undug pods were

Table 5 : ANOVA showing the effect of different sieve oscillations (S) and forward speed (F) and their interaction effects on pod collection efficiency

Source	df	SS	Mss	Calf	Tab F	Test	S.E.±	C.D. (P=0.05)	CV
Repl	3	0.01	0.01	0.02	4.76	NS			
F	2	10.88	5.44	34.53	5.14	**	0.12	0.39	0.44
S	2	7.48	3.74	9.83	5.14	*	0.18	0.62	0.67
F X S	4	0.35	0.09	10.05	0.548611	NS	0.20	NS	0.43
Error	12	1.92	0.16						
Total	35	23.87							

* and ** indicate significance of values at P=0.05 and 0.01, respectively NS =Non-significant

exposed by using tractor drawn cultivator. So, the cost of operation of tractor drawn cultivator was also included in this method. This cost was taken on custom hiring basis, as this practice is generally adopted by farmers. The custom hiring charges were considered for tractor drawn cultivator Rs. 250 per ha, including tractor driver charges and fuel consumption. The time required to expose the undug pods by using tractor drawn cultivator was considered as 3 hours per hectare. The total time required and cost of operation were 250 man-h/ha and Rs. 7000/- per ha for the manual pod collecting method, respectively.

Mechanical pod collection:

The developed groundnut pod collector was useful to dig the groundnut pods and separate them from soil and can be collected in bags. It was observed that a labour was required to collect the pods from machine after each strip. During the field trial, the time required for mechanical pod collecting per unit area of the crop was observed and the time required per hectare was determined. In addition to that, the labour time required to collect the mechanically collected pods per unit area was also considered. It was found that total time required and cost of operation were 28.96 man-h/ha and Rs. 3633.05/- per ha for the mechanical pod collecting method, respectively.

Economical comparison of groundnut pod collecting methods:

The economical comparison between manual and mechanical pod collection method of groundnut crop is shown in Table 6.

On the peak harvesting season the availability of labour fall short and it may take excessively long time in manual pod picking per hectare of a given area. The developed groundnut pod collector required 5.55 hours for digging of 1.0 ha area. The cost of pod collection with the groundnut pod collector was calculated to be Rs. 3633.05/ha. It is evident from the Table 6 that in the mechanical pod collection method there was 88.42 per cent time decreased over the manual pod collection of groundnut while 48.10 per cent reduction in pod collection cost. The payback period of the machine was calculated 6.46 years with B-C ratio of 1.55.

As the developed groundnut pod collector had shown the reduction in time and cost as comparable to manual method, it is found economically feasible. It would also eliminate drudgery in manual pod collection and alleviate problems of labour non- availability.

Conclusion:

– The optimum forward speed and sieve oscillations were found as 1.5-2.0 km/h and 250 rpm, respectively, looking to minimum losses and maximum pod collection efficiency.

– The average depth of cut was observed as 10 cm while width of cut was measured 120 cm. The draft requirement to operate the groundnut pod collector was measured 383 kg at 1.83 km/h forward speed of operation and power requirement was determined as 2.59 hp with the fuel consumption 3.81 l/h.

– The theoretical field capacity of groundnut pod collector was found as 0.22 ha/h while effective field capacity was 0.18 ha/h and field efficiency was 81.81 per cent.

– The time required for manual pod collection was 250 man-h/ha while in the case of mechanical cum manual pod collection, it was found as 28.96 man-h/ha *i.e.* there was 88.42 per cent saving in time over manual pod collection method.

– The manual pod collection cost was Rs. 7000.00/ - per ha, while mechanical cum manual pod collection cost was found as Rs. 3633.50/- per ha *i.e.* 48.10 per cent saving in cost over manual pod collection method. Thus, a farmer can save Rs. 3366.50 /- per ha.

Table 6 : Economical comparison of mechanical pod collection with manual pod collection of groundnut crop

Sr. No.	Particular	Mechanical pod collection	Manual pod collection	Increase/ decrease over manual pod collection (%)
		X	Y	$\frac{X-Y}{Y} x100$
1.	Total time required, man-h/ha	28.96	250.00	- 88.42 %
2.	Total pod collection cost, Rs./ha	3633.05	7000.00	- 48.10%
3.	Payback period, years	6.46	-	-
4.	B : C ratio	1.55	-	-

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