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Research Article

PERFORMANCE EVALUATION OF PRECISION GROUNDNUT DIGGER-INVERTER

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Abstract

Conventional groundnut digger blades are labor-intensive, time-consuming, and have high yield losses (up to 30%). The objective of this study was to adopt a precision groundnut harvesting technology in the country to reduce groundnut harvesting losses and to compare its performance with the conventional digger blade. Agricultural Engineering Institute, NARC, PARC imported a precision groundnut digger-inverter from the USA. This machine was tested at farmer's fields and its performance was compared with the conventional digger. Data from both machines were collected for total digging losses, viz exposed pod losses, unexposed pod losses, damaged pod losses, and undug pod losses from different locations in the *Pothohar* region of Punjab, Pakistan. Results revealed that total pod losses using an imported precision digger shaker harvesting machine were 4.76%, whereas the total losses of a conventional digger were 28.26%. The operational cost using a conventional digger was Rs. 4,400/a, which was reduced to Rs. 2,350/a using a precision digger-inverter. The net benefit in terms of recoverable losses was Rs. 14,050 per acre. It is concluded that a significant amount of losses is reduced and farmer profit increases by adopting precision groundnut digger-inverter. There is a need to upscale this technology in the country's groundnut growing areas to reduce harvesting losses.

Keywords: Digger inverter, Digger blade, Groundnut, Yield losses.

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1. INTRODUCTION

Groundnut (Arachis hypogaea L.), also called as peanut, is a major Kharif crop of rain-fed (Barani or Pothwar) areas of the Punjab province of Pakistan. It is also cultivated in some irrigated areas of south Punjab, Khyber Pakhtunkhwa, and Sindh provinces. However, about 90% of groundnut is grown in rain-fed areas of the North Punjab (Pothwar). A well-drained, coarse-textured, and sandy loam soil is suitable for groundnut production. Groundnut is a cash crop and is a major source of income in barani areas. The groundnut is mainly grown for table purposes but it can also be grown as an oil seed crop because it contains more than 50% oil content. The groundnut kernel is rich in both oil (43-55%) and protein (25-28%) (Saeed et al., 2009). In Pakistan, groundnut is grown on 102.9 thousand hectares with a total yield of 94.5 thousand tonnes. The average yield is 0.919 t/ha (FAOSTAT, 2019).

In Pakistan, the groundnut is mostly cultivated in fallow lands from early March to the end of April to conserve soil moisture from winter rains. It can also be grown in May and June after wheat harvest if adequate moisture is available. The crop maturity period is 130-160 days depending on variety and weather conditions. The current practice that is being used for groundnut sowing is the broadcast method, kera & pora method and some progressive farmers have modified drills of wheat. The recommended row-to-row distance is 30-45 cm and plant-to-plant is 10-15 cm with a seed depth of 4-6 cm (Agribusiness Pakistan, 2017)

In Pakistan, harvesting of groundnut is finished with a conventional digging blade in two steps. The first step is to slice the soil and soften the roots using a blade, the second step is pulling the crop manually and inverting it to allow dry in the field. After drying collected the crop from the field and threshed with a stationary thresher. About 95% of farmers used digging blades to harvest the groundnut when 75% of pods are matured. This groundnut digging blade was designed and developed by the Agricultural Engineering Institute (AEI) formerly called as Farm Machinery Institute (FMI) in 1983 and introduced first time in Pakistan (FMI, 1983). The problem with this harvester was that it was just a digger and did not invert the dug crop. After digging the crop with a blade, labour is required for picking, shaking, and inverting the crop and leaving it in the field for drying. Almost 4-5 persons are involved in inverting the crop in 2-3 hours per acre. In the case of manual harvesting, a considerable amount of groundnut pods is lost due to insufficient soil moisture or post-maturity of the crop (Padmanathan et al., 2007).

Picking, shaking, and inverting the crop is a very labor-intensive and time-consuming operation, also high cost paid due to non-availability/shortage of labor. Furthermore, financial losses occur due to ineffective digging because a significant number of pods remain in the soil with blades. Also shattering losses occur due to manual picking, shaking, and inverting the crop. About 30 to 40% of pod losses occurred due to conventional blade and manual inverting. Some local agricultural machinery manufacturers modified the potato digger for groundnut harvesting but the problem was that losses were high and inversion of crop not properly. Currently, this digger blade is considered very helpful and has been used by groundnut farmers as there were no alternate machines available in the country. Therefore, an efficient groundnut digger-inverter is the demand of groundnut farmers to overcome the labor shortage and reduce losses. The mechanical harvesting of peanuts has the advantage of reducing the cost and labor requirements (Ademiluyi et al., 2011).

To reduce yield losses caused by incorrect digging angles, the top link length should be adjusted according to soil texture. Traditionally, the top link is set for the heaviest soil texture in the field, but this can cause the digger to go too deep in lighter soils. Proper depth adjustment means the blades cut the taproot about an inch below the pods. Digging too deep can cause soil to build up on the blades, pushing plants forward before the taproot is cut. A study at the Edisto Research and Education Center showed a recovery savings of 312.5 kg/ha (279 lb/ac) when using the correct digger setting for lighter soils (Warner et al., 2015).

AMRI (2005) recommends initial speeds of 4.0 to 4.8 kph (2.5 to 3 mph), while KMC suggests ground speeds of 4.8 to 5.6 kph (3 to 3.5 mph). Bader (2012) advises digging speeds of 5.6 to 8.0 kph (3.5 to 5 mph), and Vennela et al. (2018) note that ground speeds over 6.4 kph (4 mph) can cause significant pod losses. KMC also mentions that digging too quickly can cause bunching, and digging too slowly can pull vines apart, leading to pod loss. A study by Asghar et al. (2014) found that each plow had an optimal speed to minimize digging losses. Digging too shallowly results in below-ground losses as pods below the tap root cut level are missed, while digging too deeply increases detachment due to reduced soil loosening, causing greater soil resistance during lifting.

Ademiluyi et al. (2011) tested a tractor-drawn groundnut digger/shaker under three soil moisture levels. They found that soil moisture significantly affects the digging efficiency of the implement, with an optimal range of 12 to 15%. This study aims to assess the performance of a 2-row groundnut digger-inverter with variable depth and forward speed for potential commercialization, comparing it to the conventional blade. Timely operation is crucial in groundnut production, and harvesting at the wrong time with the digger/shaker can result in low digging efficiency. Additionally, the forward speed and conveyor slope angle significantly influence the machine's performance.

Agricultural Engineering Institute addressed this issue and introduced a tractor-mounted groundnut digger-inverter to reduce the losses and to solve the problem of labor shortage. On-demand of farmers one unit of 2-row KMC groundnut digger-inverter procured from USA. This machine performed four functions simultaneously, i.e., digging, conveying, mud removing, and inverting the crop in rows. The objective of this study is to evaluate the performance of a 2-row groundnut digger-inverter variable depth and forward speed for its commercialization and compare the performance with the conventional blade.

2. Materials and Methods

The study was carried out at the Natioal Agricultural Research Center, Islamabad. The plot area was 1ha for the main study. The maturity of the crop was 160 days after sowing. The Pothowar variety was sown with the walking-type precision planter with a row spacing of 45 cm and plant spacing of 15 cm. The moisture content was 18.4% VWC (Volumetric water content). To compare the harvesting losses in conventional digger blade and 2-row KMC digger-inverter the studied factors for evaluation of both harvesters were three levels of forward speed (2, 3, and 4 km/h). For this purpose, the field was divided into two experimental plots one for a conventional digger blade and the second for a KMC digger-inverter.

An 85 and 50-hp Messey Ferguson tractors were used for a 2-row digger-inverter and conventional digger blade respectively. Forward speed was determined by taking the time at a specific distance. The conveyor angle was fixed at 43 degrees and the conveyor speed matched the forward speed. After completion of digging, three areas of 1×1 m2 were selected randomly from each field for measuring harvesting losses. From sample areas, the harvested plants along with pods were collected and the damaged pods were separated. The exposed pods, buried pods, and undug pods were also collected to determine the harvesting losses. The Indian standard test codes (IS: 11235-1985) were used for the determination of losses. The following formula was used in the computation.

$$A = B + C \quad \text{(I)}$$

$$\text{\% of damaged Pods} = \frac{C}{A} \times 100 \quad \text{(II)}$$

$$\text{\% of exposed pods} = \frac{D}{A} \times 100 \quad \text{(III)}$$

$$\text{\% of unexposed pods} = \frac{E}{A} \times 100 \quad \text{(IV)}$$

$$\text{\% of undug pods} = \frac{F}{A} \times 100 \quad \text{(V)}$$

Digging Efficiency= 100 – Total % of pod loss (VI)

Where,

A = Total quantity of pods collected from plants in a sample area.

B = Quantity of clean pods collected from the plants dug, exposed, and buried pods.

C = Quantity of damaged pods collected from the plants.

D = Quantity of detached pods lying exposed on the surface

E = Quantity of left-out pods buried in the soil.

F = Quantity of pods remained undetached from the undug plants.

Total Percentage of Pod Loss = Percentage of Exposed Pod Loss + Percentage of Buried Pod Loss + Percentage of Undug Pod Loss

2.1. Conventional groundnut digger:

Conventional groundnut digger (Figure 1) consists of a main frame with 3-point linkages. Its frame is made from a 75×75×6 mm MS angle with length and width 1524, 560 mm respectively. For the attachment of the digging blade, a 16 mm V-type MS Plate having a width from the sides is 114 mm and from the center is 178 mm is welded from the sides with a two-side support made with the 16 mm MS flat having a length 570 mm. Side supports were drilled 15 mm diameter holes at 25 mm spacing for height adjustment of the blade attached to the mainframe through nut bolts. The digging blade is mounted on the bottom of the MS plate with the help of 10 mm nuts and bolts having a cutting width of 1524 mm and made from a 90×12.5 mm spring steel flat bar.

Figure1. Conventional blade

2.2. Groundnut digger-inverter

The new 2-row groundnut digger-inverter procured from the USA (Figure 2) consists of a mainframe with a cat II 3-point hitch. Colter discs are attached to the mainframe to cut the biomass/vines and soil to define the swath with digging blades. V-type two digging blades attached to the mainframe to dig the crop. A conveyor at a 43-degree angle is attached to lift the crop from the ground and convey it to the rear hinge fender to form the width of the windrow created during inverting. The inverted cylinders on the rear of the machine invert the crop and inverter rods drop the inverted crop smoothly on the ground making windrow. The conveyor and inverted cylinders are operated via a hydraulic motor and pump through the tractor's hydraulic system. Wheels on the rear side of the machine for the height adjustment according to the crop height. the overall length, width, and height of the machine are 3905, 2197, and 2184 mm respectively.

Figure 2. KMC 2-row groundnut digger-inverter

2.3. Description of field trails

The conventional groundnut digger and newly imported digger inverter were tested at three field trails and the data was collected according to these trails and their average as shown in Table 1.

2.4. Statistical analysis

The data collected during the experiment were statistically analyzed by using "Statistix 8.1" software. For post-ANOVA mean separation, the LSD test was used 5% level of probability.

3. Result and Discussion:

The performance of the conventional digger (M_1) and digger inverter (M_2) was evaluated at three levels of tractor forward speeds S_1, S_2, and S_3 (2,3 & 4 km/h). Various machine performance indicators were measured during crop harvesting season 2023. The statistical analysis of different variables was conducted. The mean values of different parameters are presented in Tables 2-7 for retrieving useful information for end users.

3.1. Effect of forward speed on pod damage percentage

The mean groundnut pod damage percentage (Table 2) for both machines (M_1 & M_2) was recorded. The statistical analysis showed a significant difference between the performance of both machines at a 5% probability level. The conventional machine performed better with less pod damage percentage (0.53%) as compared to the imported one (0.81%). The mean value of pod damage percentage shows that there was a significant difference at three forward speeds. The maximum pod damage percentage was noted at speed S_1 (0.95%) while the minimum values were observed at speed S_3 (0.44%). This shows that increasing the forward speed of the tractor decreases the pod damage percentage.

The results correlate with the study of Saakuma et al. (2016) who concluded that the weight of damaged pods decreased with the increase of the tractor's speed. They designed and developed a tractor-mounted groundnut harvester/digger. Its performance was evaluated at different

Table 1. Description of field trails

Sr. No.	Observations	Field Trials			
		I	II	III	Average
1	Speed of operation (km/hr)	2	3	4	3
2	Width of cut (cm)	150	150	150	150
3	Time required for 50m (sec)	41	42	42	41.67
4	Starting time	09:00	12:00	04:00	-
5	Finish time	10:05	01:08	05:10	-
6	Total time (min)	65	68	70	67.65
7	Total time loss (min)	05	06	12	7.65
8	Total working time (min)	60	62	58	60
9	Power requirement (hp)	85	85	85	85
10	Theoretical field capacity (ha/hr)	0.654	0.654	0.654	0.654
11	Effective field capacity (ha/hr)	0.549	0.582	0.562	0.564
12	Field efficiency	83.94	88.99	85.93	86.33
13	Fuel consumption (l/hr)	6	5.9	6.1	6
14	Wheel slip (%)	8	10	9.3	9.1

Table 2. Effect of speed on both machines on the base of pod damaged percentage

	M_1	M_2	Mean
S_1	0.74 A	1.14 A	0.95 A
S_2	0.48 B	0.90 B	0.64 B
S_3	0.37 B	0.40 C	0.44 C
Mean	0.53 B	0.81 A	

Mean with similar letters are statistically non-significant at a 5% level of probability

forward speeds (1.6 km/hr, 2.4 km/hr, and 3.2 km/hr) while maintaining a constant depth of 10 cm. Each speed was tested three times using a Randomized Complete Block Design (RCBD). Analysis of Variance (ANOVA) at a significance level of $P \leq 0.05$ revealed a significant difference in the weight of harvested groundnuts and damaged or un-uprooted groundnuts.

3.2. Effect of forward speed on exposed pods percentage

The data was recorded for the mean exposed pod percentage for both machines (M_1 & M_2) as shown in Table 3. The statistical analysis showed that there was a significant difference between the performance of both machines at a 5% level of probability. The imported machine performed better with less exposed pod percentage (0.48%) as compared to the conventional one (6.27%). At three tractors forward speeds the mean value of the exposed pod percentage shows that there was not any significant difference. The maximum exposed pod percentage was observed at speed S_1 (3.55%) while the minimum values were noted at speed S_3 (3.17%). This shows that increasing the forward speed of the tractor decreases the exposed pod percentage.

The results are parallel to the study of Azmoodeh et al. (2014) who fabricated the groundnut digger and evaluated it at different speeds of operation. The test results indicated that the lowest exposed pod loss occurred at a high forward speed of 1.8 km/h. so the increase in the speed resulted in to increase of exposed pod losses by 30%.

3.3. Effect of forward speed on buried pods percentage

Table 4 shows the mean buried pod percentage for both machines (M_1 & M_2). The statistical analysis showed that there was a significant difference between the performance of both machines at a 5% level of probability. The imported machine performed better with less buried pod percentage (2.68%) as compared to the conventional one (16.69%).

Table 3. Effect of speed on both machines on the base of exposed pod percentage

	M_1	M_2	Mean
S_1	6.68 A	0.41 A	3.55 A
S_2	6.31 A	0.49 A	3.40 A
S_3	5.80 A	0.55 A	3.17 A
Mean	6.27 A	0.48 B	

Mean with similar letters are statistically non-significant at a 5% level of probability

Table 4. Effect of speed on both machines on the base of buried pod percentage

	M_1	M_2	Mean
S_1	17.40 A	3.09 A	10.24 A
S_2	16.59 A	2.12 B	9.36 B
S_3	16.09 A	2.84 A	9.46 AB
Mean	16.69 A	2.68 B	

Mean with similar letters are statistically non-significant at a 5% level of probability

The mean value of buried pod percentage shows that there was a significant difference at forward speeds S_1 as compared to S_2 and S_3 while the speeds S_2 and S_3 are not significantly different from each other. The maximum mean buried pod percentage was recorded at speed S_1 (10.24%) while the minimum values were recorded at speed S_2 (9.36%). This shows that the buried pod percentage depends on decreasing or increasing tractor forward speed.

The results are in favor with the study of Shen et al. (2023) who reported that the reduction in the tractor's speed resulted in the increase of buried pods. The tractor-operated digger inverter results showed that at a tractor speed of 1.01 m/s and an inverting roller speed of 2.12 m/s, the vine inverting rate was 71.07%, the buried pods rate was 0.2%, and the fallen pods rate was 0.22%. At a tractor speed of 1.06 m/s, and an inverting roller speed of 1.88 m/s, the vine inverting rate was 74.29%, the buried pods rate was 0.14%, and the fallen pods rate was 0.33%. A paired t-test comparing the digger inverter's performance with pressed and unpressed vines at different speeds showed that while there was little difference in the rates of fallen and buried pods, there was a significant difference in the vine inverting rate.

3.4. Effect of forward speed on undug pods percentage

The mean groundnut undug pod percentage (Table 5) for both machines (M_1 & M_2) was recorded. The statistical analysis showed that there was a significant difference between the performance of both machines at a 5% level of probability. The imported machine performed better with less undug pod percentage (0.79%) as compared to the conventional machine (4.30%). The mean value of the undug pod percentage shows that there was not any significant difference at three forward speeds. The maximum undug pod percentage was noted at speed S_3 (2.81%) while the minimum values were observed at speed S_2 (2.34%). This shows that the undug pod percentage increased by increasing or decreasing the speed than the speed S_2.

The results are parallel with Azmoodeh et al. (2014) who tested a groundnut digger at three different speeds. The test results indicated that the undug pod percentage was lower at the speed of 1.8 km/h. The t-test was used to compare the mean losses of pods across different mechanical harvesting methods. Results demonstrated that all variables were significant, except for the percentage of undug pods at the 1% probability level. It illustrates the proportion of various pod losses in the total mechanical harvesting loss including undug pods at 5%.

3.5. Effect of forward speed on total percentage of undamaged pods

The mean total percentage of undamaged pods (Table 6) for both machines (M_1 & M_2) was recorded. The statistical analysis

Table 5. Effect of speed on both machines on the base of undug pod percentage

	M_1	M_2	Mean
S_1	4.07 B	0.93 A	2.50 A
S_2	3.62 B	1.05 A	2.34 A
S_3	5.23 A	0.40 B	2.81 A
Mean	4.30 B	0.79 A	

Mean with similar letters are statistically non-significant at a 5% level of probability

Table 6. Effect of speed on both machines on the basis of the total percentage of undamaged pods

	M_1	M_2	Mean
S_1	71.23 A	94.36 C	82.79 A
S_2	71.78 A	96.09 A	83.94 A
S_3	72.44 A	95.29 B	83.87 A
Mean	71.82 B	95.25 A	

Mean with similar letters are statistically non-significant at a 5% level of probability

showed that there was a significant difference between the performance of both machines at a 5% level of probability. The imported machine performed better with a higher amount of total percentage of the undamaged pod (95.25%) as compared to the conventional machine (71.82%). For conventional groundnut digger (M_1), the mean value of the total percentage of undamaged pods shows that there were no significant differences at three forward speeds while there was a significant difference between imported machine (M_2) at three different speeds. The maximum mean total percentage of undamaged pods was recorded at speed S_2 (83.94%) while the minimum values were recorded at speed S_1 (82.79%). This shows that the total percentage of undamaged pods depends on decreasing or increasing tractor forward speed.

The results are in favor with Saakuma et al. (2016) who tested a tractor-mounted groundnut harvester. Analysis of Variance (ANOVA) at a significance level of $P \leq 0.05$ revealed a significant difference in the weight of harvested undamaged groundnuts. Results indicated that the weight of harvested undamaged groundnuts decreased as speed increased and the harvesting efficiency decreased with higher speeds,

3.6. Effect of forward speed on total percentage of pod losses

Table 7 shows the total percentage of pod losses for both machines (M_1 & M_2). The statistical analysis showed that there was a significant difference between the performance of both machines at a 5% level of probability. The imported machine performed better with less total percentage of pod losses (4.76%) as compared to the conventional machine (28.26%). The mean value of the undug pod percentage shows that there was not any significant difference at three forward speeds. The maximum total percentage of pod losses was noted at speed S_1 (17.20%) while the minimum values were observed at speed S_3 (16.04%). This shows that increasing the tractor's forward speed decreases the total percentage of pod losses.

The results are correlating with the study of Mareppa et al., 2014) who carried out an experiment at 10%, 12.5%, and 15% moisture content. The results revealed that the pod loss decreased as forward speeds increased. However, the lowest pod loss was noted at a forward speed of 2 km/h with a 15-degree rake angle. Statistical analysis of the individual and combined effects of these operational parameters indicated that the speed of operation affected pod loss at a 1% significance level, with each variable having an individual impact on pod loss.

Table 7. Effect of speed on both machines on the basis of the total percentage of pod losses

	M_1	M_2	Mean
S_1	28.75 A	5.64 A	17.20 A
S_2	28.63 A	4.67 B	16.30 A
S_3	27.41 A	3.98 B	16.04 A
Mean	28.26 A	4.76 B	

Mean with similar letters are statistically non-significant at a 5% level of probability

3.7. Cost Analysis

3.7.1. Operational cost/Acre and benefits

After digging the groundnut with digger-inverter no labor is required for picking and inverting the crop. Therefore, operational cost Rs. 2,050/- per acre save as well as on the other hand, almost 30% of pods losses were reduced with the digger-inverter (Figure 3&4). If these losses will be recovered by involving labor after digging the blade the 50% share goes to labor. The worth of 50% losses is Rs. 12,000 which will be almost zero by using a digger-inverter. The final saving by digger inverter was calculated as Rs 16552/- per Acre (Table 8).

4. Conclusion

The recent study results showed that the forward speed is an important factor on the groundnut digger and digger inverter that has a significant effect on total pod losses. It was revealed that the conventional digger and newly imported digger inverted have a significant difference in the harvesting losses. Conventional groundnut digger obtained higher losses than the imported digger inverter in all variables. The results of conventional groundnut digger reveal the total pod damage percentage (0.53%), exposed pods (6.27%), buried pods (16.69%), undug pods (4.30%), undamaged pods (71.82%) and total losses

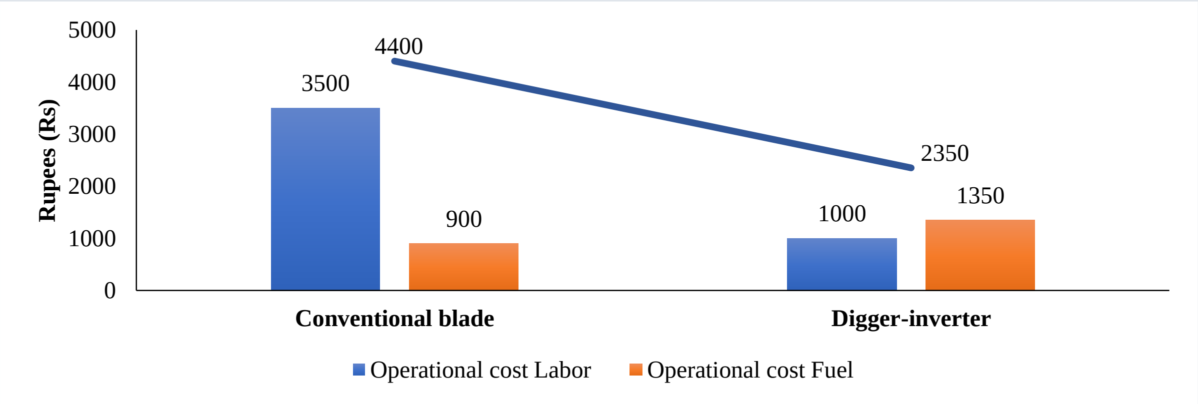

Figure 3. The operation cost of a conventional digger and digger inverter

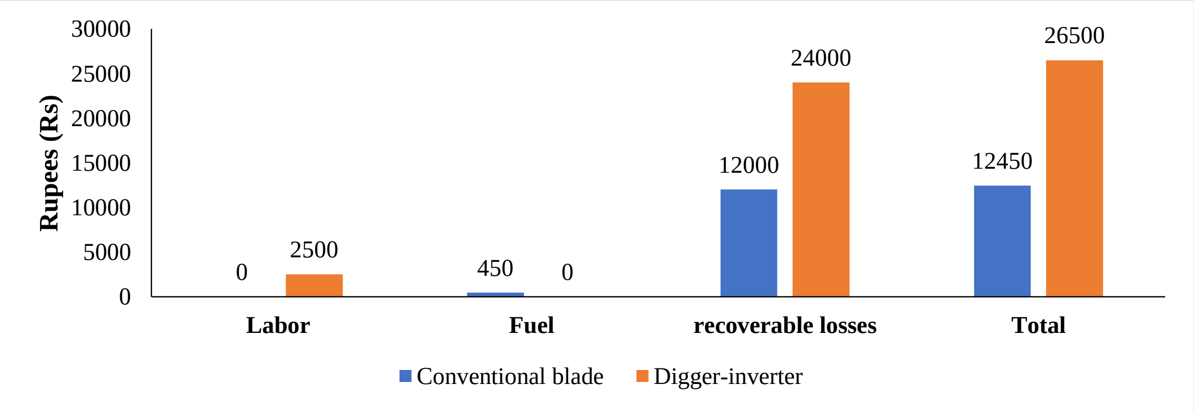

Figure 4. Total benefits of conventional digger and digger inverter

Table 8. Operational cost for conventional digger and digger inverter

Parameters	Existing digger Rs./Acre	Digger-Inverter Rs./Acre
Fuel Consumption	Rs. 1080 (4 liter)	Rs. 1620 (6 liters)
Labor cost	Rs. 1000 (Operator) Rs. 2500 (Picking inverting)	Rs. 1000 (Operator)
losses @ 8000 Rs./mound Avg. Yield 20 mound/acre	Rs. 44352 (5.544 mound losses) Recoverable 50% goes to labor and 50% farmer Rs. 22176	Rs. 7584 (0.948 mound losses)
Total	Rs. 26756	Rs. 10204
Saving with digger-inverter Rs.16552/- per Acre		

(28.26%). The losses in the imported groundnut digger inverter were revealed as pod damage percentage (0.81%), exposed pods (0.41%), buried pods (2.68%), undug pods (0.79%), undamaged pods (95.25%), and total pod losses (4.76%). Results also showed that the imported groundnut digger inverter in relation to the conventional digger reduces the cost of operation as well as harvesting losses.

5. Conflict of Interest

None

6. Acknowledgement:

None

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