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Performance Evaluation of a Two-Row Tractor-Mounted Groundnut Harvester in Comparison with Traditional Harvesting Methods

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ABSTRACT

The study sought to evaluate the performance of a two-row, fully mounted groundnut harvester by comparing vine and pod yields, percentage pod loss, and the proportion of damaged pods with four (4) other harvesting methods namely; hand hoe, hand fork, hand pulling, and cutlass. The experiment was conducted using a randomized complete block design (RCBD) comprising three (3) blocks and five treatments. Data were analyzed using analysis of variance (ANOVA) at a 95% confidence level. The tractor-mounted harvester recorded a vine yield of 1,833 kg ha^{-1} and a total pod yield loss of 25.64%, consisting of 0.19% damaged pods and 25.45% detached pod losses. In comparison with the hand hoe, cutlass, hand pulling, and hand fork harvesting methods, the harvester demonstrated competitive performance. However, a significant portion of the total pod losses associated with the harvester was due to pod detachment, highlighting its potential as a practical alternative to hand pulling for reducing overall harvest losses. Although the machine performed satisfactorily in digging operations, its current design limitations contribute substantially to pod detachment, thereby reducing its overall viability. These findings emphasize the need for further optimization of the harvester's design to enhance its efficiency and minimize pod losses.

INTRODUCTION

Harvesting is the most mechanized operation of groundnut production in developed countries replacing manual labour for harvesting and several designs of harvesters are available to farmers. Harvesting constraints in less-developed countries is commonly caused by the non-availability of tools for digging groundnuts plants from the ground (Yadav, 2020).

Groundnut harvesting consists of the removal of the plant with the pods from soil and carried out in bright sunshine so that vines together with pods can be dried in the field (Hiral, 2018). Groundnut harvesting in Ghana is mostly by hand pulling and becomes difficult when the soil becomes dry due to short raining season resulting in pod yield losses. The dry and hard state of the soil would often require softening the soil before harvesting (Njoroge *et al.*, 2018; Abubakari *et al.,* 2019). In the savannah zone of Ghana, harvesting of groundnuts is carried out by pulling the plant out with the hand or digging the plant out from the soil with a hand hoe and this is a significant operation in the cultivation stages of groundnuts, and therefore, most of the issues relating to harvesting of ground nuts as mentioned earlier, which are often addressed by mechanical harvesters, remains a problem.

Njoroge *et al.* (2018) noted that, the variety of groundnut cultivated affects the method(s) of harvesting employed. The author again noted that, when groundnuts have grown past the stage of physiological maturity and hardening of the soil sets in, it becomes difficult to harvest and harvesting can only take place by loosening the soil either by working with a plough, a blade harrow usually along the plant rows or working with a hand hoe. The difficulty of harvesting is more profound with the spreading type of groundnut and the process of up-rooting the crop from the soil is a rather difficult operation as pod formation takes place all along the creeping branches of the plant and their pegs are comparatively thinner and more delicate.

Negrete (2015) reported that low productivity in groundnuts production to a large extent is attributed to the lack of development of groundnut harvesting technology, which makes it difficult for farmers to consider importing or adopt local mechanized approach to cultivating groundnuts. Zaied *et al.* (2014) and Gautam *et al.* (2023) also indicated that mechanized cultivation of groundnut would reduce cost of production and the influence on pricing of the commodity and market uncertainties as well as increase productivity and increase the volumes of production.

The attendant difficulties of hard soil and harvesting losses associated with the field operation of harvesting groundnuts, especially during drought coupled with the high cost and tedious nature of groundnut harvesting ought to be addressed, thus the need to design a groundnut harvester.

MATERIALS AND METHODS

Study Area

The design was done at Kwame Nkrumah University of Science and Technology while construction of the groundnut harvesting equipment was done at Agricultural Engineering Workshop of Bolgatanga Technical University. Table 1 presents the design specifications of the groundnut harvester.

Table 1. Design specifications of two-row groundnut harvester.

Description	Value
Prime mover	Tractor mounted
Number of rows	2
Draught force	1.0 kN
Weight	150kg
Overall dimensions	1200 mm × 630 mm × 1600 mm

Design, Construction and Testing

Figure 1 illustrates the design of the two-rows tractor mounted groundnut harvesting machine, whiles Figure 2 and 3 illustrate the constructed groundnut harvester in operation respectively.

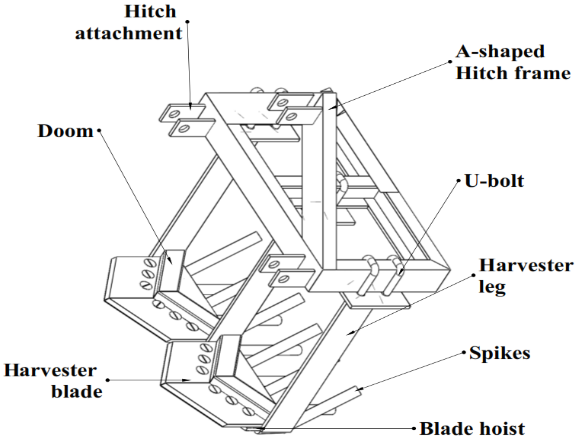

Figure 1. Design of a two-row tractor mounted groundnut harvester

Figure 2. Constructed two-rows groundnut harvester

Figure 3. Two-rows groundnut harvester in operation

Experimental Site

The experiment was conducted at the Sumbrungu campus of Bolgatanga Technical University, located in the Upper East Region of Ghana. The site lies in the northwestern part of the region at latitude 10°49′N and longitude 00°56′W, as determined using a GPSMAP 76CSx device. The total experimental field area, as recorded by the GPS, was 3,010.50 m². The predominant soil type at the site is sandy loam.

Experimental Design

Randomized Complete Block Design (RCBD), comprising five (5) methods of harvesting groundnuts was used and they are as presented in Table 2. Hand pulling is the widely used method of harvesting groundnuts in northern Ghana; hence it is selected as the control method of harvesting.

Table 2. Methods of harvesting groundnuts

S/N	Treatment
1.	Hand pulling (H_0)
2.	Hand fork (H_1)
`3.	Hoe (H_2)
4.	Cutlass (H_3)
5.	Two row groundnut harvest(H_4)

The field for the experiment was ploughed with a disc plough and harrowed with a tine harrow after five days to get an even working soil tilth. A mouldboard ridge was used to make ridges along the length of the field before dividing the field into plots.The planting material was obtained from the Savannah Agricultural Research Institute; the early maturing and semi-erect Chinese variety (*Shitaochi*) of groundnuts was used. The seeds obtained were subjected to a simple seed viability test, where the one hundred (100) seeds were selected from the 10 kg of seeds purchased and planted at depth of 4 cm on a ridge. The number of seedlings germinated were counted after the seventh day and expressed as a percentage of the total seeds planted (100 seeds: 97% germination rate).

Planting was done in seeding ratio of one (1) seed per hole at a depth of 4 cm. A line and pegs were used to mark out the plant distance (50 cm × 20 cm) on the ridges. A hoe was used for planting.

Refilling of holes that had no seed emerging at all on the seventh day to meet the requirement of one seed per hole.

There were fifteen (15) plots on the field with five treatments per block. The field was prepared into plots, measuring 2 m × 5 m, as shown in Figure 4 and ridges ploughed on the plots. Five (5 m) meter spacing was allowed between blocks and 5 m between plots to allow for free movement of the tractor. The recommended plant spacing and seed rate were 50 cm × 20 cm and one seed per hole, see Figure 4.

The estimated plant population density per plot was 240 plants and 3,600 groundnut plants per the entire field. A diesel engine tractor, Agria 885 Thinker, with a horsepower of 57hp (43 kW) was used for the study and operated at a travelling speed of 5 kmh^{-1}. The area of each plot was 10 m^2, therefore the plant population density per plot was 125 plants per square area of a plot.

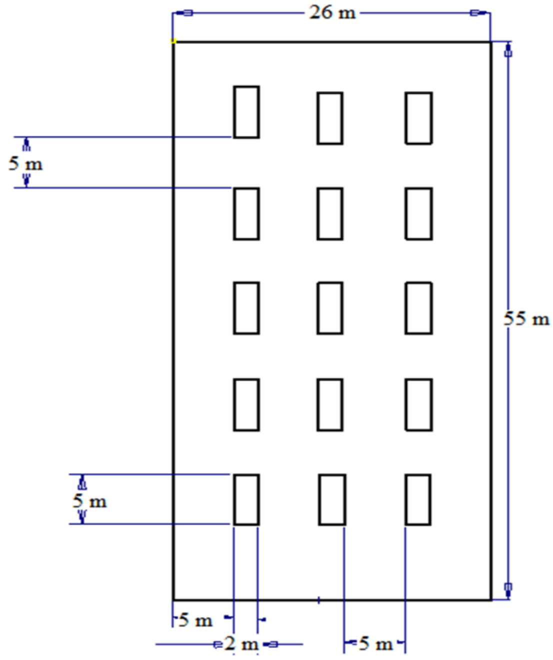

Figure 4. Layout of the experimental field

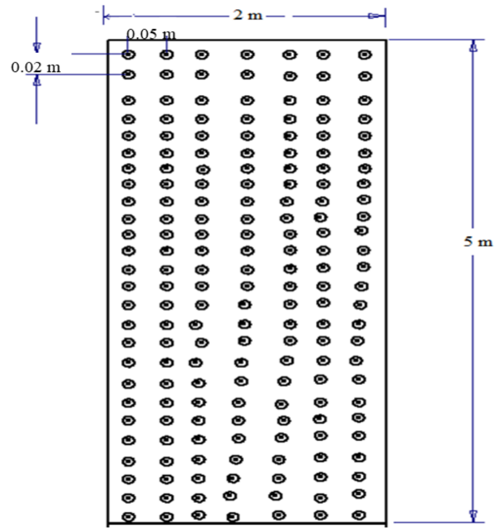

Figure 5. Plot layout showing plant spacing

Harvesting

Harvesting of the groundnuts was done using five (5) different harvesting methods as listed in Table

2 on their treatment plots as indicated on the plot layout and the harvesting was done as follows and the results compared and evaluated.

A block was harvested at a time beginning with block (1) one. Trained data collection staff were positioned on each of the treatment plots in a block at the same time, with stop watches each. The harvesting staff comprised; a tractor operator and eleven other staff. Every treatment in a block was assigned two staff each (one data collection staff and one harvesting staff). The harvesting staff were asked to start harvesting at the same time. This was repeated for each of the remaining blocks and the harvest collected into sacks. The harvest was taken to the laboratory, sorted into polythene bags and weighed.

Vine and Pod Yield

The vine and pod yield of the groundnuts was obtained using Equation 1. was used to compute the vine and pod yield.

$$\text{Vine and pod yield}\left(\text{kgha}^{-1}\right) = \frac{\text{Weight of vine and pod yield (kg)}}{\text{Area harvested (ha)}} \quad \text{Eq. (1)}$$

Percentage Pod Yield Losses

The percentage pod loss was determined by assessing plant material over a 24 m^2 area of individual harvesting equipment and this was done with guidance from the Indian Standards Test Codes for evaluating groundnut harvester (Indian Standards Bureau, 1985; Azmoodeh-mishamandani, Abdollahpoor and Navid, 2014). The groundnuts harvested were collected into polythene bags according to their respective blocks and the method used in harvesting. Damaged and detached pods on the field were also collected into polythene bags according to the harvesting method used. The harvested groundnuts were sent to the farm house where the pods were plucked from the plants. The vegetative foliage was separated and bagged differently from the pods.

The plucked groundnut pods were sorted into damaged pods and whole pods and bagged accordingly and weighed. The percentages of the pods and vines were computed as a percentage of the total quantity of harvest for each method.

Plant material obtained from the test plots were sorted as follows:

a) Total damaged pods: These were obtained by collecting all the harvested plants, plucking all the matured pods and hand picking out the damaged pods.

b) Total exposed detached pods: These were obtained by going round the crop row collecting the detached pods (per treatment) lying exposed on the soil surface.

c) Total unexposed detached pods: These were the detached pods buried in the soil and were obtained by manually digging the entire treatment plot with the aid of a hoe.

d) Total undug pods: These were the pods from the plants that remained undug after the harvesting operation.

The following relations were used for the determination of the pod losses:

$$A = B + C \quad \text{Eq. (2)}$$

Where;

A = Total quantity of pods collected from harvested plants in the plot area,

B = Quantity of clean pods collected from the plants dug in the plot area; exposed pods lying on the surface and the buried pods,

C = Quantity of damaged pods collected from the plants in the plot area,

D = Quantity of detached pods lying exposed on the surface,

E = Quantity of detached pods that remained buried in the soil of the sample area, and

F = Quantity of pods that remained un-detached from the undug plants in the sample area

Percentage of damaged pods loss =

$$\frac{A}{B} \times 100\ \% \quad \text{Eq. (3)}$$

Percentage of exposed pod loss =

$$\frac{D}{A} \times 100\ \% \quad \text{Eq. (4)}$$

Percentage of unexposed pod loss =

$$\frac{E}{A} \times 100\ \% \quad \text{Eq. (5)}$$

Percentage of undug pod loss =

$$\frac{F}{B} \times 100\ \% \quad \text{Eq. (6)}$$

Total percentage of pod loss = percentage of exposed pod loss + percentage of unexposed pod loss + percentage of undug pod loss + percentage of damaged pods.

Moisture Content Determination

The percentage moisture content of the soil of the test site was obtained using a gouge augur, taking samples to a depth of; 30cm, 20cm and10cm. Samples were obtained from five sections of the field. The samples were put into cylinders and

covered before taking samples to the laboratory for moisture content analysis.
Initial mass of samples was taken and samples where oven dried at 105°c for over 24 hours and mass after oven drying taken.
Figure 6 shows the relationship between depth and moisture content, it can be deduced that clearly the moisture reduces increases with depth, this significantly affects the penetrative ability and cutting of the soil by the implement blade.

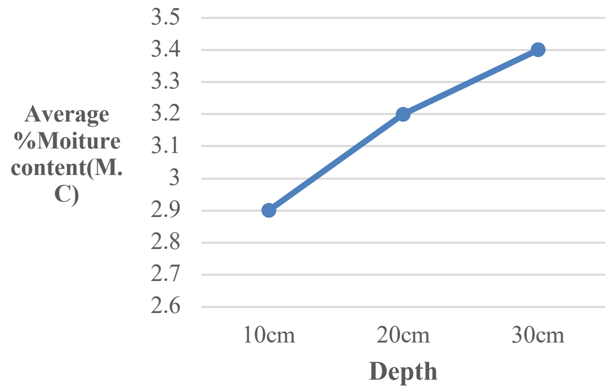

Figure 6. Average moisture content of the field

Bulk Density Determination

For the bulk density, a core sampler was used to obtain undisturbed soil samples, sampling across five (50 sections of the field at a depth of 30cm with rings and taken to the laboratory for analysis. Volume of cylinder used is 250 cm^3

Table 3 presents the average wet bulk density of the field was recorded to be 1.12g/cm^3, with the highest and the lowest bulk density values to be 1.11 g/cm^3 and 1.14 g/cm^3 respectively. This can be attributed to the low moisture content in the soil.

Table 3. Bulk density of the field

Location	Mass of sample (g)	Bulk Density(g/cm^3)
1	279.55	1.11
2	280.89	1.12
3	276.84	1.11
4	281.46	1.13
5	284.66	1.14
Average		1.12

Working Depth

The working depth was obtained with the aid of a tape measure and a ranging pole, the pole was put across the harvested area and with the tape, the distance from the bottom of the harvested area to the horizontal height of the pole is measured. The measurement was sampled from five sections of the harvested area. From table 4, the average working depth of the harvester was 18.90cm with the shallowest working depth of 15.90cm and the deepest working depth to be 20.70cm. It was observed that, the low moisture content of the soil had a major influence on the working depth, the implement could not achieve the desired penetration because of the dry and compact nature of the soil.

Table 4. Working depth during test

Location	Working depth (cm)
1	20.50
2	20.70
3	15.90
4	16.00
5	21.50
average	18.90

Effective Working Width

If effective working width = W_e

N_e = the number of times the implement goes across the length of the field during harvesting

T = total width

Width of the field is 40m and (N_e) = 20

$$W_e = \frac{N_e}{T} \quad \text{Eq. (7)}$$

$$W_e = \frac{20}{40m} = 0.5m$$

This is a function of the effective field capacity, giving a fair idea of how fast or slow the area will be covered in a harvesting operation. A higher value of effective width commensurately translates into high effective field capacity and vice versa.

Data Analysis

Data collected were statistically analysed using MINITAB (version 17) to run a Balanced Analysis of Variance (Balanced ANOVA) to test for significance at 95% confidence level and determine the effect of harvesting method on pod and vine yield and pod yield losses. The least significant difference (LSD) was computed to differentiate between treatment means where significant difference was observed.

RESULTS AND DISCUSSION

Comparison of Yield (Pods and Vines) Across Harvesting Methods

Figure 7 presents the mean pod and vine yields for the different harvesting methods. Analysis of variance indicated no significant difference ($p > 0.05$) among the treatment means for both vine and pod yield. The hand-pulling method (control) recorded the highest yield (4,708 kg ha^{-1}), followed by the hand hoe (4,042 kg ha^{-1}), hand fork (2,403 kg ha^{-1}), groundnut harvester (1,833 kg ha^{-1}), and cutlass (1,861 kg ha^{-1}), which produced the lowest yield.

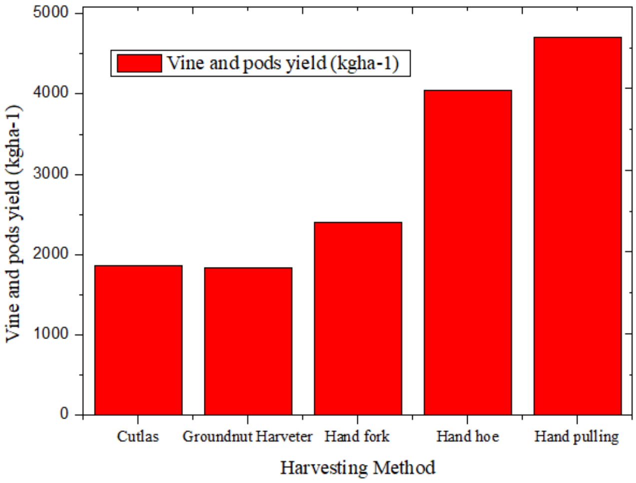

Figure 7. Mean vine and pod yield

Percentage Damaged Pods (%)

There was a statistically significant difference ($p < 0.05$) among the harvesting methods in terms of the percentage of damaged pods. This indicates that one or more methods resulted in a significantly higher proportion of damaged pods compared to the others. It also suggests that the percentage of damaged pods was influenced by the type of harvesting method used.

Figure 8 presents the percentage of pod damage as influenced by different harvesting methods. Pod damage was significantly higher when harvesting with a cutlass compared to the hand hoe, hand fork, and hand-pulling methods. The difference between the control method (hand pulling) and the groundnut harvester was not significant, indicating that neither method had a comparative advantage over the other in minimizing pod damage.

The cutlass recorded the highest percentage of damaged pods (0.44%), followed by the groundnut harvester (0.19%) and the hand hoe (0.11%). Both the hand-pulling and hand-fork methods resulted in no pod damage. Although the control method (hand pulling) showed no pod damage compared to the groundnut harvester, the harvester caused considerably less damage than the cutlass.

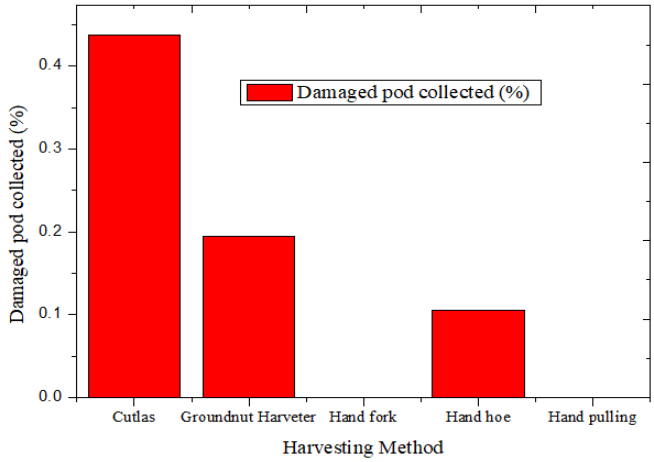

Figure 8. Effect of harvesting method on the percentage of damaged pods.

Percentage Detached Pod

The analysis of variance showed a significant difference ($p < 0.05$) in the treatment means of harvesting methods on the percentage of total pods detached from plant during harvesting. The groundnut harvester had a mean percentage of the total pods detached to be 25.45%, followed by cutlass with 2.21%, hand fork 0.55%, hand pulling 0.22% and the hand hoe with the least percentage of total pods detached of 0.00%.

Figure 9 shows the mean of percentage detached pods as affected by harvesting method. There was significant difference between treatment means of the groundnut harvester and the control method of hand pulling, indicating that the groundnut harvester was significantly higher in percentage of total pods detached during harvesting than the hand pulling method. Furthermore, there was significant difference between the groundnut harvester and the hand hoe, the cutlass and the hand fork methods of harvesting. The differences could be attributed to the huge losses recorded, resulting from both the unexposed detached pod loss and exposed detached pod loss with mean average values of 14.63% and 10.82% respectively for the groundnut harvester. Again, it was observed during the harvesting operation that the middle leg of the harvester which gave the design more stability, offered some resistance to the free movement of plant debris over the digging blade and so the high likelihood of detached pod losses.

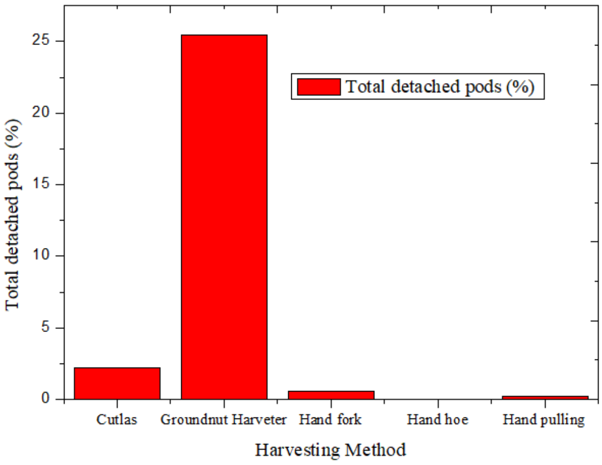

Figure 9. Mean percentage of total detached pods

Effect of Harvesting Method on Pod Yield Loss

The analysis of variance revealed a significant difference ($p < 0.05$) among the harvesting methods in terms of pod yield loss. The groundnut harvester recorded the highest loss (25.65%), followed by the cutlass (1.28%), the hand fork (0.55%), hand pulling (0.22%), and the hand hoe, which had the lowest loss (0.11%). Figure 10 presents the mean percentage pod yield loss for the various harvesting methods. The mean pod loss from hand pulling differed significantly from that of the groundnut harvester, with the latter exhibiting a significantly higher yield loss. Harvesting with the cutlass, hand hoe, and hand fork resulted in significantly lower pod losses compared with the groundnut harvester. The thick groundnut foliage likely contributed to clogging of the harvester, creating resistance during operation and leading to increased yield losses. The amount of foliage at harvest showed a positive correlation with pod losses.

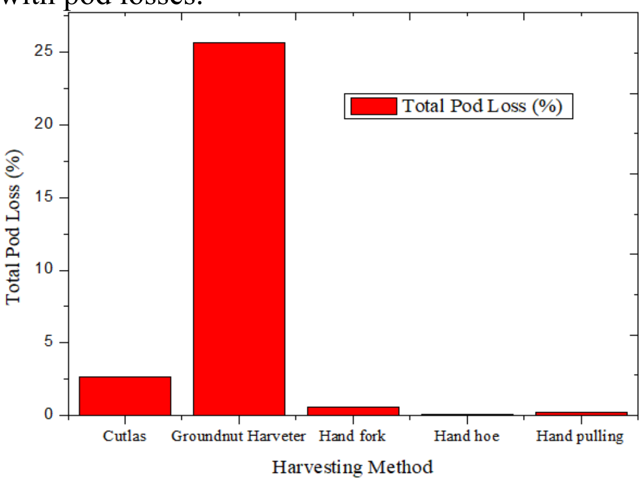

Figure 10. Mean total percentage pod yield loss as affected by different harvesting methods

Harvesting Efficiency

The percentage of exposed pods lost on the soil surface was 31%, as presented in Table 5. This relatively high value, compared to findings reported by Ademiluyi *et al.* (2004), Hiral (2018), and Gautam *et al.* (2023), can be attributed to pod breakage from the groundnut pegs and subsequent detachment due to the moisture content of the groundnut foliage.

Table 5. Digging efficiency of the digger

Exposed pod loss (%)	Unexposed pod loss (%)	Detached pod loss (%)	Undug pod loss (%)	Total loss (%)	Damage pods (%)
31	60.33	92.40	0.00	92.40	0.00

It was also observed that a greater proportion of pods were detached from the plants but remained unexposed on the soil surface. The percentage of unexposed pod loss was 60.33%, mainly attributed to the dry condition of the groundnut foliage, which caused the pegs to break easily. The total pod loss, comprising both exposed and unexposed losses, amounted to 92.40%. However, no undug groundnut plants or pods damaged by the harvester were recorded. The only observed damage was attributed to insect pests.

The digging efficiency was computed as:

Digging efficiency = 100 – Total percentage of loss pods

=100 – 92.40 = 7.6%

This result reflects the proportion of mature groundnut pods that remained attached to the plant. The observation can be attributed to the dry condition of the groundnut foliage, which caused the mature pods to detach from the pegs. These findings are consistent with Lakhani *et al.* (2025), who reported that harvesting long after the physiological maturity of groundnut pods increases pod detachment.

CONCLUSION

The groundnut harvester produced a significantly lower vine and pod yield (1,833 kg ha^{-1}) compared to hand pulling, representing a 38.94% reduction. While the harvesting method influenced pod damage rates, statistical analysis showed no significant difference between hand pulling (0.20% damage) and the harvester (0.00% damage), indicating that both methods are similarly effective in minimizing direct pod damage during harvesting. However, the harvester recorded the highest detached pod loss at 24.45%, significantly higher than the other methods. This detachment is likely due to operational factors such as soil physical properties or clogging, rather than an inherent inefficiency in uprooting pods. Although the harvester effectively dug out groundnuts, these mechanical challenges resulted in substantial pod losses during harvesting.

A substantial portion of total pod loss associated with the harvester was due to detached pods, highlighting that, while it is a practical alternative to hand pulling, its current design limitations exacerbate pod detachment. Under the conditions tested, manual harvesting remains superior in minimizing yield loss, as the harvester's design requires further optimization to reduce detachment-related losses.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest regarding the publication of the paper.

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