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Performance Evaluation of Groundnut Digger in Chhattisgarh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Groundnut (*Arachis hypogaea* L.), is a significant oilseed crop. It is grown in Chhattisgarh during rabi and kharif seasons, with traditional manual harvesting being labor-intensive and costly. To enhance efficiency, a study evaluated a tractor-operated groundnut digger in Chhattisgarh, focusing on factors such as crop size, shape, depth, spacing, and soil parameters like bulk density, true density, and moisture content. Performance metrics included exposed pod loss, buried pod loss, damaged pod loss, total pod loss, field efficiency, and digging efficiency. In this study found that at a 30° rake angle and 3.5 km h^{-1} speed, the maximum buried pod loss was 7.37%, exposed pod loss was 9.89%, and total pod loss was 23.79%. Conversely, the digger achieved a high digging efficiency of 96.92% with a 25° rake angle and 2 km h^{-1} speed. The operational cost was 972.57 Rs h^{-1}, with a breakeven point of 100.42 hours per year and a payback period of 0.91 years. Compared to manual harvesting, which costs 37.5 Rs h^{-1}, the tractor-operated digger significantly reduces time and costs, offering substantial improvements in harvesting efficiency.

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Keywords: Groundnut digger; digging efficiency; field efficiency; pod loss; forward speed; rake angle.

1. INTRODUCTION

Groundnut (*Arachis hypogaea L*.), an essential oilseed crop from the Leguminosae family, plays a crucial role in global agriculture, particularly in India where it occupies two-thirds of the oilseed crop area. Known as peanuts in India, groundnuts thrive in well-drained sandy loam, loamy, and black soils but are unsuitable for heavy, compacted soils. They are highly nutritious, with about 50% oil content, 25-30% protein, and significant amounts of vitamins E, K, and B. Groundnuts are cultivated in tropical and subtropical regions, with the kharif season being the primary growing period, covering around 80% of the cultivated area. Globally, groundnuts are grown on 26.4 million hectares, producing 37.1 million tons. India cultivates approximately 4.6 million hectares, yielding 6.7 million tons with an average productivity of 1,400 kg/ha [1].

In India, groundnut production is widespread, with major contributions from states like Gujarat, Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, and Chhattisgarh. Chhattisgarh itself covers 67.7 thousand hectares, producing 70.2 thousand tons with a productivity rate of 1,036 kg/ha [2]. This state is recognized for its growing groundnut cultivation, particularly in districts like Raigarh, which contribute significantly to the state's total production. The average cultivation cost is approximately Rs. 18,276.43 per hectare. Improved irrigation and low-cost technologies have facilitated the growth of groundnut farming in regions with both entisol and vertisol soils.

Harvesting groundnuts presents significant challenges due to its labor-intensive nature. Traditional methods, including manual uprooting, spade digging, and animal-powered diggers, are time-consuming and physically demanding. Manual harvesting, especially for spreading types, requires extensive bending and sitting, leading to physical strain [3]. Mechanization offers a solution by reducing manual labor and increasing efficiency. Semi-mechanized methods involve machines for harvesting combined with human effort for digging, while fully mechanized harvesting uses advanced diggers that handle multiple tasks such as digging, lifting, and shaking. Fully mechanizing the process can substantially save time and labor, enhancing productivity and reducing the physical burden on workers.

2. MATERIALS AND METHODS

The performance evaluation of the groundnut digger was conducted at the research farm in village Parsada, Tehsil/Block Arang, District Raipur (Chhattisgarh). The site is located at a longitude of 81° 50' 30" East and a latitude of 21° 12' 14" North. The soil at this location is classified as black soil, locally known as 'kanhar mitti.' This soil type is known for its high water retention capacity and rich content of calcium, magnesium, iron, aluminum, and potassium, which enhance its fertility. Two different variables were selected viz. rake angle and forward speed denoted by A and S respectively with four levels of each factor. The specifics of the independent and dependent parameters are detailed in Table 1. The data collected were analyzed using a factorial randomized block design.

2.1 Independent Parameters

Rake angle: The rake angle is the angle formed by the front or cutting face of the tool and a line perpendicular to the work piece and it was examined by using abney level instrument and protractor. Four Rake angles were selected for the study: 15°,20°,25° and 30°.

Forward speed: The actual speed of operation was measured by two points at 30 metres apart, and the time taken by the tractor to cover the marked distance was recorded using stopwatch [4]. Four forward speeds were selected for the study: 2.0 km h^{-1}, 2.5 km h^{-1}, 3.0 km h^{-1} and 3.5 km h^{-1}. These speeds were available when the machine was used in the field with different gear settings and throttle positions.

2.2 Dependent Parameters

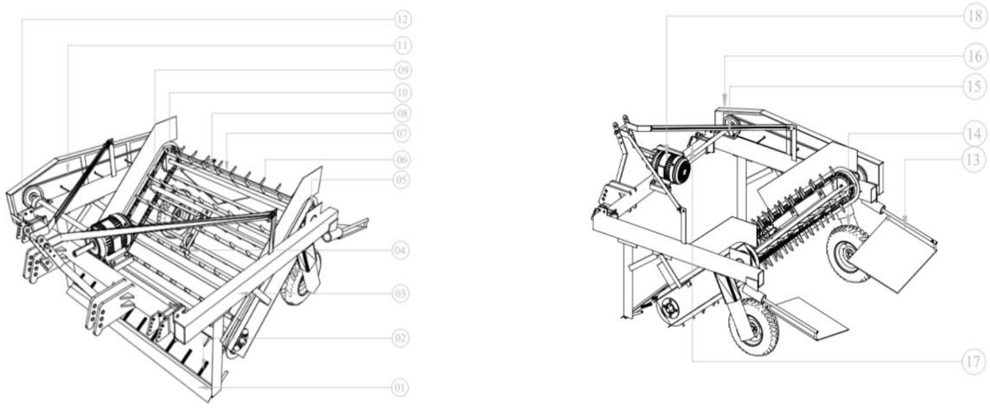
Total quantity of pods, A [5].

$$A = B + C$$

Where,

A = The total amount of groundnut pods taken from the plant within the sample's zone.

B = Quantity of clean pods collected from the plant dug in the sample area, exposed pods lying on the surface and the buried pods



1. Digging blade	2. Digging rod	3. Frame
4. Idler pulley	5. Supporting frame	6. Peg (Spikes)
7. Conveyor	8. Joint chain drive	9. Chain drive
10. Sprocket wheel	11. V-belt drive	12. Upper link
13. Wing	14. Ground wheel	15. Hitch point
16. Frame cover plate	17. Shaft	18. Gear box

Fig. 1. Component of groundnut digger

Table 1. Different independent and dependent parameter for the performance evaluation of groundnut digger

S. NO.	**Independent parameters**		**Dependent parameters**
	Factors	Levels	Crop parameters
1	Rake angle (A)	a) 15	Damage pod ,%
		b) 20	Exposed pod loss,%
		c) 25	Buried pod loss,%
		d) 30	Total pod loss,%
2	Forward speed (S)	a) 2.0	Machine parameters
		b) 2.5	Field efficiency,(%)
		c) 3.0	Digging efficiency,(%)
		d) 3.5	

Damage pod: Groundnut damage percentage measures the proportion of damaged pods relative to the total number of pods in a sample, expressed as a percentage. It is calculated by dividing the number of damaged pods by the total number of pods and multiplying by 100. This metric helps evaluate the extent of pod damage and overall crop quality.

$$\text{Damaged pods (\%)} = \frac{C}{A} \times 100$$

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

Exposed pod loss: Exposed pod percentage measures the proportion of detached groundnut pods that are lying exposed on the ground relative to the total number of pods, expressed as a percentage. It is calculated by dividing the number of exposed pods by the total number of pods and multiplying the result by 100. This metric helps assess the extent of pod loss due to exposure.

$$\text{Exposed pods loss (\%)} = \frac{G}{A} \times 100$$

Where,

G = Amount of detached groundnut pods laying exposed on the ground

Buried pod loss: Buried Pods Loss Percentage measures the proportion of groundnut pods that are left buried in the soil compared to the total number of pods, expressed as a percentage. It is calculated by dividing the number of buried pods by the total number of pods and multiplying by 100. This metric helps evaluate the amount of loss due to pods being buried and provides information about the overall quality of the crop.

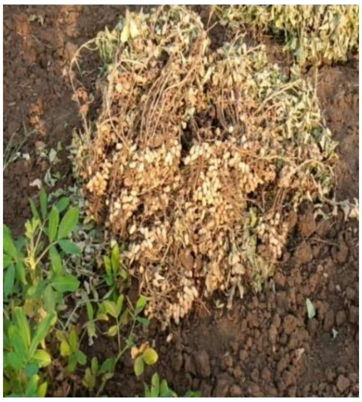



Fig. 2. Field testing by the machine

$$\text{Buried pods loss (\%)} = \frac{\text{H}}{\text{A}} \times 100$$

Where,

H = Quantity of left out pods buried into the soil in the sampled area

Total pod loss: Total percentage of pod loss = exposed pods loss(%)+ buried pod loss (%)+ undug pods loss(%)

Digging efficiency: Digging efficiency (DE) is defined as the ratio of the mass of lifted pods to the mass of pods that remain unlifted or buried in the field, along with the mechanical and physical damage sustained.

$$\text{Digging efficiency (\%)} = 100 - \text{total pod loss (\%)}$$

Field efficiency: The ratio of actual field capacity and theoretical field capacity is called field efficiency [6].

$$\text{Field efficiency (\%)} = \frac{\text{AFC}}{\text{TFC}}$$

Where,
AFC =Actual field capacity (ha h^{-1}); and
TFC = Theoretical field capacity (ha h^{-1}).

3. RESULTS AND DISCUSSION

The results from the experiments are thoroughly presented and analyzed in the following section. Additionally, the impact of various independent parameters on the performance of the groundnut digger is examined in detail.

3.1 Effect of Speed of Operation and Blade Angle on Field Efficiency of Groundnut

The analysis of field efficiency for different digger rake angles and operation speeds revealed significant variations. At the 5% significance level, the highest average field efficiency of 82.10% was achieved with a 25° rake angle, compared to the lowest of 72.49% with a 30° rake angle. Additionally, field efficiency improved with higher operation speeds, peaking at 80.44% at 3.5 km h^{-1} and dropping to 74.05% at 2.0 km h^{-1}. The interaction between rake angle and operation speed was also significant, with the highest field efficiency of 85.82% recorded at a 25° rake angle and 3.5 km h^{-1}, while the lowest of 69.36% was observed at a 30° rake angle and 2.0 km h^{-1}. These findings are consistent with the results reported by Kavad *et al*. (2020) for groundnut crops [7].

Table 2. Mean table of effect of rake angle and speed of operation on field efficiency

Rake angle, (°)	Speed of operation(km h^{-1})				Mean(A)
	2.0	**2.5**	**3.0**	**3.5**	
15	72.72	74.39	76.17	78.70	75.49
20	75.31	77.32	79.55	81.43	78.40
25	78.82	80.36	83.42	85.82	82.10*
30	69.36	71.16	73.643	75.82	72.49
Mean(S)	74.05	75.81	78.19	80.44*	
Factors			C.D.	SE(d)	SE(m)
Factor (Rake angle, A)			0.019	0.009	0.007
Factor (Speed of operation, S)			0.019	0.009	0.007
Interaction (A×S)			0.038	0.019	0.013

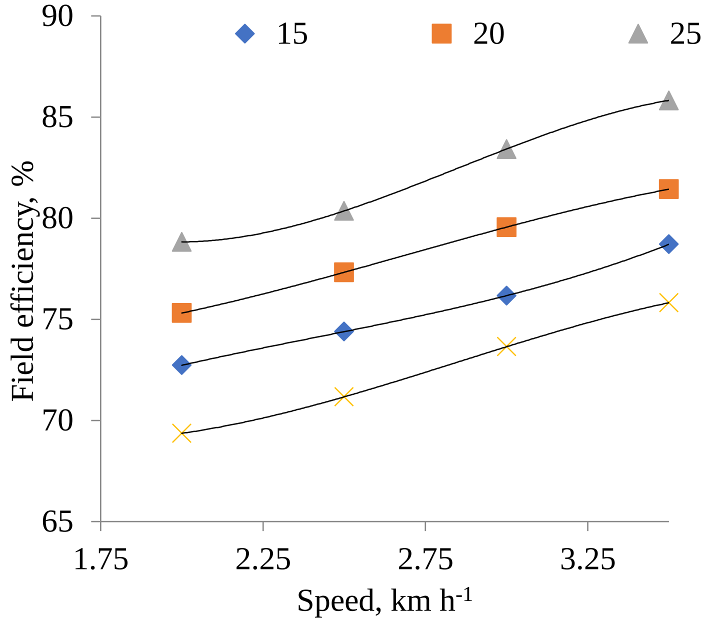


Fig. 3. Effect different rake angle and speed of operation on field efficiency

Table 3. Mean table of effect of rake angle and speed of operation on exposed pod loss percentage

Rake angle, (°)	Speed of operation (km h^{-1})				Mean(A)
	2.0	**2.5**	**3.0**	**3.5**	
15	5.49	6.73	8.54	9.44	7.55
20	3.53	4.57	5.70	6.51	5.08
25	1.97	2.61	3.46	4.26	3.07
30	6.89	7.52	9.22	9.89	8.38*
Mean(S)	4.47	5.36	6.73	7.53*	
Factors			C.D.	SE(d)	SE(m)
Factor (Rake angle, A)			0.07	0.034	0.024
Factor (Speed of operation, S)			0.07	0.034	0.024
Interaction (A×S)			0.141	0.069	0.048

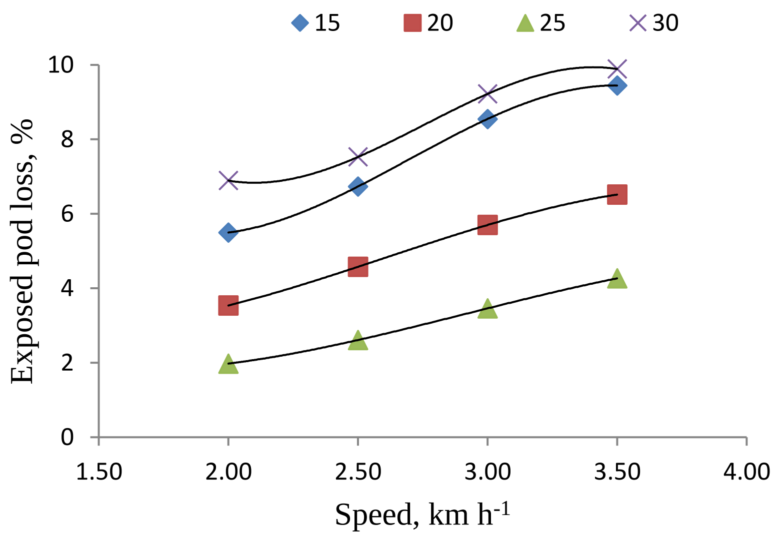


Fig. 4. Effect different rake angle and speed of operation on exposed pod loss percentage

3.2 Effect of Speed of Operation and Blade Angle on Exposed Pod Loss Percentage of Groundnut

The study investigated the impact of different digger rake angles and operation speeds on exposed pod loss in groundnuts. ANOVA results and mean tables revealed significant differences based on these variables. The highest exposed pod loss was 8.38% at a 30° rake angle, while the lowest was 3.07% at a 25° rake angle, suggesting that a 25° angle is more effective in minimizing pod loss. Additionally, the operation speed significantly influenced pod loss, with the percentage increasing from 4.47% at 2.0 km h^{-1} to 7.53% at 3.5 km h^{-1} due to greater friction from handling more soil and crops. The interaction between rake angle and speed was also significant, with the highest pod loss of 9.89% occurring at a 30° angle and 3.5 km h^{-1}, and the lowest of 1.97% at a 25° angle and 2.0 km h^{-1}. These findings underscore the importance of optimizing both rake angle and speed to reduce pod loss and enhance harvesting efficiency, similar findings regarding pod loss in groundnuts have been reported by researchers such as Bako *et al.* (2015) for groundnut crops [8].

3.3 Effect of Speed of Operation and Blade Angle on Buried Pod Loss Percentage of Groundnut

The study examined how different digger rake angles and operation speeds affect buried pod loss in groundnuts. Results from ANOVA and mean tables show that variations in both rake angle and operational speed significantly influence buried pod loss. The highest average buried pod loss was 5.92% at a 30° rake angle, while the lowest was 2.00% at a 25° angle. Additionally, buried pod loss increased with higher operational speeds, ranging from 2.85% at 2.0 km h^{-1} to 5.64% at 3.5 km h^{-1}. A significant interaction between rake angle and speed was found, with the highest buried pod loss of 7.37% occurring at a 30° angle and 3.5 km h^{-1}, and the lowest of 0.56% at a 25° angle and 2.0 km h^{-1}. These findings suggest that increasing operational speed and a steeper rake angle lead to greater buried pod loss due to increased friction from handling more soil and pods.

3.4 Effect of Speed of Operation and Blade Angle on Damaged Pod Loss Percentage of Groundnut

The study investigated the impact of varying rake angles and operational speeds on groundnut pod damage. Analysis revealed significant differences in damage percentages based on rake angles, ranging from 15° to 30°. The average damage percentages were 3.98% at 15°, 2.57% at 20°, 1.92% at 25°, and 5.07% at 30°. Damage decreased as the angle increased from 15° to 25°, but increased again at 30° due to deeper cutting that resulted in larger soil clods and more pod damage. Additionally, significant variations in pod damage were observed with different operational speeds, with the highest damage of 4.97% at 3.5 km h^{-1} and the lowest of 1.95% at 2.0 km h^{-1}. The interaction between rake angle and speed was also significant, with the highest damage of 6.52% occurring at a 30° angle and 3.5 km h^{-1}, and the lowest of 0.53% at a 25° angle and 2.0 km h^{-1}. These results highlight the importance of optimizing both rake angle and operational speed to minimize pod damage and improve harvesting efficiency. These findings align with similar results reported by Gautam *et al.* (2021) for onions [9].

Table 4. Mean table of effect of rake angle and speed of operation on buried pod loss percentage

Rake angle, (°)	Speed of operation(km h^{-1})				Mean(A)
	2.0	**2.5**	**3.0**	**3.5**	
15	3.77	4.48	5.64	6.33	5.06
20	2.43	3.53	4.55	5.25	3.94
25	0.56	1.36	2.48	3.61	2.00
30	4.64	5.45	6.24	7.37	5.92*
Mean(S)	2.85	3.71	4.73	5.64*	
Factors			C.D.	SE(d)	SE (m)
Factor (Rake angle, A)			0.033	0.016	0.011
Factor (Speed of operation, S)			0.033	0.016	0.011
Interaction (A×S)			0.066	0.032	0.023

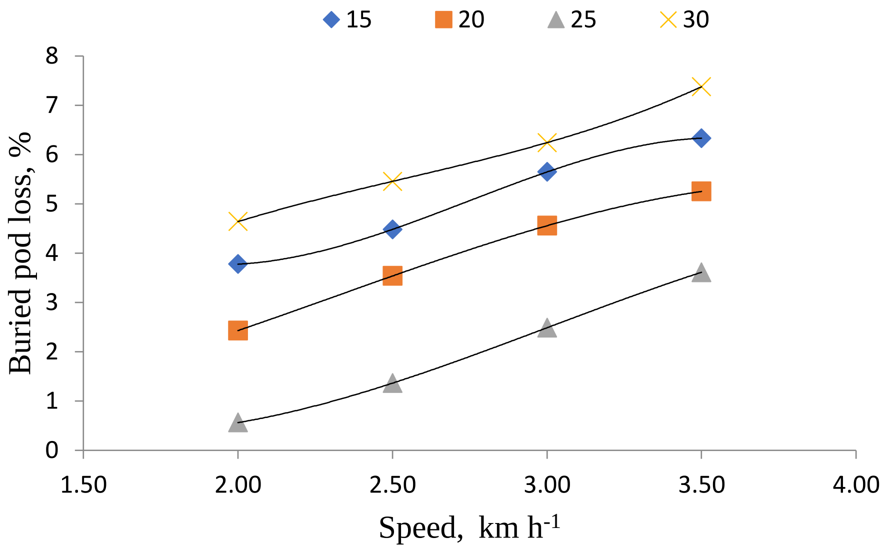


Fig. 5. Effect different rake angle and speed of operation on buried pod loss percentage

Table 5. Mean table of effect of rake angle and speed of operation on damaged pod loss

Rake angle, (°)	Speed of operation(km h^{-1})				Mean(A)
	2.0	**2.5**	**3.0**	**3.5**	
15	2.39	3.50	4.64	5.57	3.98
20	1.25	1.98	2.69	4.36	2.57
25	0.53	1.41	2.31	3.44	1.92
30	3.64	4.52	5.61	6.52	5.07*
Mean(S)	1.95	2.85	3.77	4.97*	
Factors			C.D.	SE(d)	SE(m)
Factor (Rake angle, A)			0.021	0.01	0.007
Factor (Speed of operation, S)			0.021	0.01	0.007
Interaction (A×S)			0.042	0.021	0.015

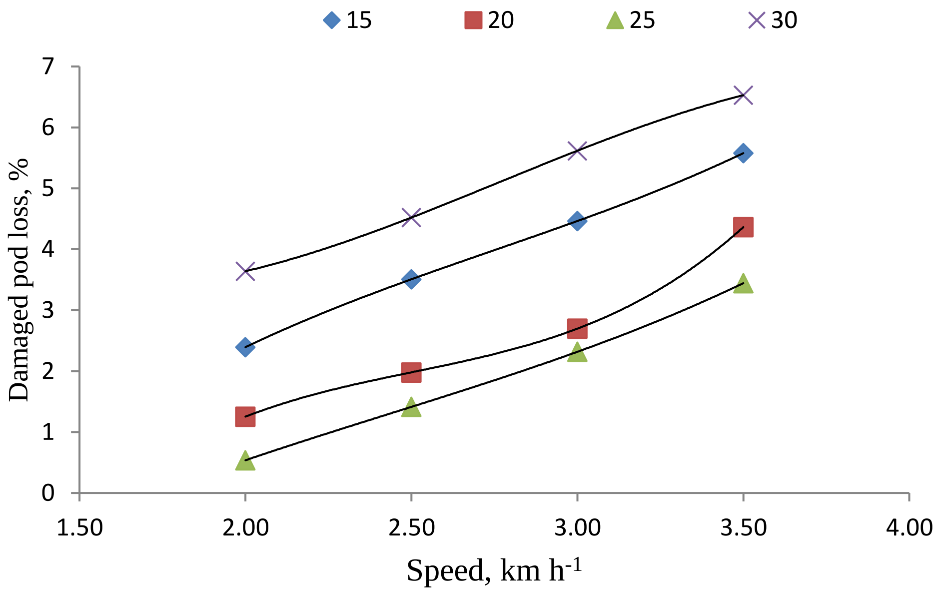


Fig. 6. Effect different rake angle and speed of operation on damaged pod loss percentage

Table 6. Mean table of effect of rake angle and speed of operation on total pod loss percentage of groundnut

Rake angle, (°)	Speed of operation (km h^{-1})				Mean(A)
	2.0	**2.5**	**3.0**	**3.5**	
15	11.66	14.72	18.65	21.35	16.60
20	7.22	10.09	12.95	16.13	11.60
25	3.07	5.38	8.26	11.32	7.01
30	15.17	17.50	21.08	23.79	19.38*
Mean(S)	9.28	11.92	15.23	18.15*	
Factors			C.D.	SE(d)	SE(m)
Factor (Rake angle, A)			0.088	0.043	0.03
Factor (Speed of operation, S)			0.088	0.043	0.03
Interaction (A×S)			0.175	0.085	0.06

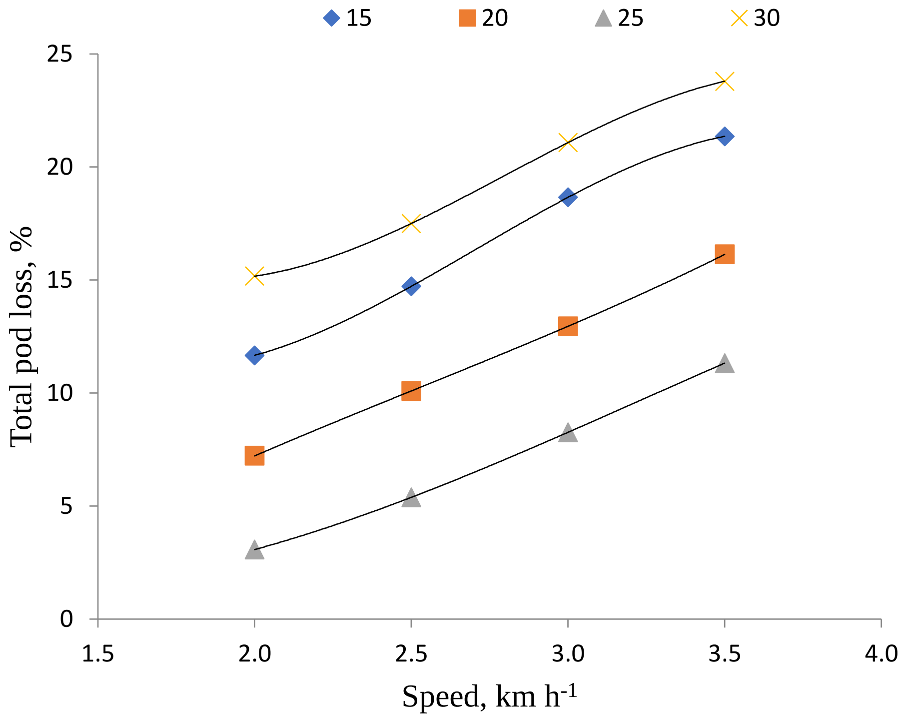


Fig. 7. Effect different rake angle and speed of operation on total pod loss percentage

Table 7. Mean table of effect of rake angle and speed of operation on digging efficiency

Rake angle, (°)	Speed of operation(km h^{-1})				Mean (A)
	2.0	**2.5**	**3.0**	**3.5**	
15	88.33	85.27	81.34	78.64	83.39
20	92.78	89.90	87.04	83.86	88.4
25	96.92	94.61	91.73	88.67	92.98*
30	84.82	82.49	78.92	76.20	80.61
Mean(S)	90.71*	88.07	84.76	81.84	
Factors			C.D.	SE(d)	SE(m)
Factor (Rake angle, A)			0.082	0.04	0.028
Factor (Speed of operation, S)			0.082	0.04	0.028
Interaction (A×S)			0.164	0.08	0.056

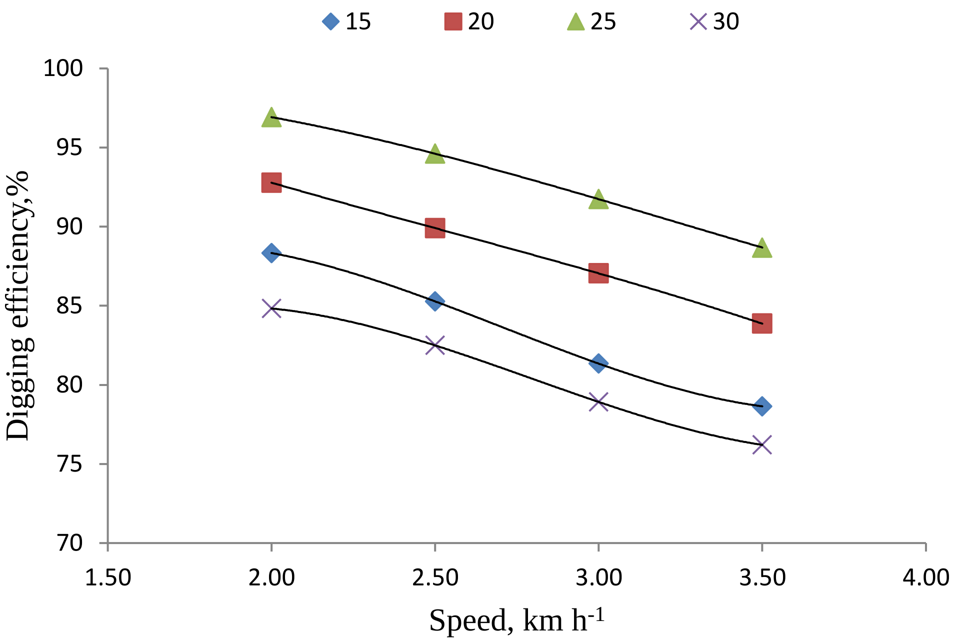


Fig. 8. Effect different rake angle and speed of operation on digging efficiency

3.5 Effect of Speed of Operation and Blade Angle on Total Pod Loss Percentage of Groundnut

The study analyzed the impact of various digger rake angles and operational speeds on total pod loss in groundnuts. Significant variations in pod loss were observed based on these factors, with the highest average loss of 19.38% at a 30° rake angle and the lowest of 7.01% at a 25° angle. At a 5% significance level, pod loss increased with higher operational speeds, reaching 18.15% at 3.5 km h^{-1} and decreasing to 9.28% at 2.0 km h^{-1}. The interaction between rake angle and speed was also significant, showing the highest total pod loss of 23.79% at a 30° angle and 3.5 km h^{-1}, and the lowest of 3.07% at a 25° angle and 2.0 km h^{-1}. These findings highlight that faster speeds and steeper angles contribute to greater pod loss due to increased friction and handling of soil and pods.

3.6 Effect of Speed of Operation and Blade Angle on Digging Efficiency of Groundnut

The study explored the effects of varying digger rake angles and operational speeds on digging efficiency. Significant differences in efficiency were observed, with the highest average efficiency of 92.98% achieved at a 25° rake angle, compared to the lowest of 80.61% at a 30° angle. This suggests that a 25° angle provides optimal soil engagement and pod extraction, while a 30° angle may reduce efficiency due to increased soil disturbance. Additionally, digging efficiency improved with slower operational speeds, reaching 90.71% at 2 km h^{-1} and decreasing to 81.84% at 3.5 km h^{-1}. The interaction between rake angle and speed was also significant, with the highest efficiency of 96.92% occurring at a 25° angle and 2.0 km h^{-1}, and the lowest of 76.20% at a 30° angle and 3.5 km h^{-1}. These findings indicate that slower speeds and a 25° rake angle yield the most effective digging performance, while higher speeds and steeper angles lead to decreased efficiency due to less precise soil engagement and increased disturbance [10].

4. CONCLUSION

The study aimed to assess the digger's efficiency under different rake angles and operational speeds, optimize its performance, and compare its economic viability to traditional methods. Results showed that the digger's efficiency varied with rake angles and speeds, achieving the highest efficiency of 96.92% at a 25° angle and 2.0 km h^{-1}, and the lowest of 76.20% at a 30° angle and 3.5 km h^{-1}. Total pod losses were minimized at the same optimal settings, while higher speeds resulted in increased losses. The digger proved to be cost-effective, demonstrating significant improvements in efficiency, reduced damage, and lower operational costs, making it a valuable tool for groundnut harvesting in Chhattisgarh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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