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DEVELOPMENT AND PERFORMANCE EVALUATION OF A SELF-PROPELLED CHICKPEA HARVESTER FOR ENHANCING MECHANIZATION IN INDIA

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ABSTRACT

India is the world's largest producer of chickpea, contributing approximately 70% of global production. Despite this dominance, chickpea remain a secondary focus in the nation's agricultural mechanization efforts. Many current chickpea cultivars are poorly suited for mechanical harvesting due to their plant height and architecture, resulting in significant challenges for Indian chickpea producers. Manual harvesting, predominantly carried out by female laborers, struggles to meet the labor demands, highlighting the need for more efficient mechanization. Given the critical role of chickpea in providing protein to India's predominantly vegetarian population, enhancing mechanized harvesting is essential to meeting nutritional demands amid a growing population. This study focused on designing, developing, and evaluating the performance of a self-propelled riding-type chickpea harvester. The harvester was tested across three crank speeds (200, 300, and 400 rpm) and three forward speeds (2.0-2.5 km/h, 2.5-3.0 km/h, and 3.0-3.5 km/h). Key performance indicators, including field capacity, field efficiency, cutting efficiency, fuel consumption and harvesting losses, were analyzed under varying operational conditions. The highest effective field capacity was 0.326 ha/h at 300 rpm and 3.0-3.5 km/h, while the lowest was 0.231 ha/h at 400 rpm and 2.0-2.5 km/h. Maximum field efficiency, 74.27%, occurred at 300 rpm and 2.0-2.5 km/h, with a minimum of 68.92% at 400 rpm and 3.0-3.5 km/h. Cutting efficiency peaked at 98.73% at 400 rpm and 2.5-3.0 km/h and dropped to 93.90% at 200 rpm and 3.0-3.5 km/h. Fuel consumption varied between 1.20 l/h and 1.41 l/h.

Key words : Chickpea, Efficiency, Mechanization, Speeds.

Introduction

Harvesting of Chickpea

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops worldwide, particularly valued for its nutritional profile and role in sustainable agriculture. Its cultivation spans arid and semi-arid regions, contributing to food security and soil health through nitrogen fixation. However, the harvesting process remains a significant challenge, particularly in mechanized farming systems.

The traditional method of chickpea harvesting, which relies heavily on manual labor, is labor-intensive, time-consuming, and prone to inefficiencies. Additionally, manual harvesting often results in higher post-harvest losses, especially due to shattering and pod breakage, which can lead to economic losses. Given the global trend toward mechanization in agriculture, it is essential to develop efficient harvesting equipment tailored for chickpea crops.

Mechanized harvesting not only minimizes labor dependency, but also improves the timeliness of operations, ensuring that crops are harvested at optimal moisture levels. However, developing a specialized chickpea harvester presents several challenges, including variability in plant height, pod location, moisture content, and stem toughness, which can affect the performance of conventional harvesters. Therefore, a need exists for a harvester specifically designed to handle the unique physical and agronomic characteristics of chickpea plants.

Chickpea and its importance

Chickpea is an ancient legume crop widely cultivated in countries such as India, Australia, Turkey, and Canada. It plays a key role in human diets due to its high protein content, essential amino acids, and micronutrients. The crop is broadly classified into two types: Desi and Kabuli. Desi varieties have smaller, darker seeds with thicker seed coats, while Kabuli varieties are characterized by larger, lighter-colored seeds.

Apart from its dietary significance, chickpea is recognized for its agronomic benefits, particularly in crop rotations. It helps in maintaining soil fertility by fixing atmospheric nitrogen and reducing the dependency on synthetic fertilizers. The growing global demand for chickpea makes it imperative to improve productivity and reduce post-harvest losses through better harvesting solutions.

Need for a Self-Propelled Riding-type chickpea Harvester

While conventional combine harvesters have been employed for harvesting legumes, chickpea harvesting poses unique challenges. The stem diameter and moisture content of chickpea plants vary across growth stages, which can influence the cutting force required and lead to inefficiencies with standard harvesters. Additionally, chickpea pods are typically situated at varying heights along the plant, making it challenging to achieve a clean cut without leaving behind unharvested pods or damaging the crop.

A self-propelled riding-type harvester offers several advantages:

- **Precision and Efficiency:** Such a harvester can be equipped with adjustable cutter bars to match the variability in plant height.
- **Reduced Losses:** A dedicated design minimizes pod shattering and ensures more complete harvesting.
- **Improved Operator Comfort:** Riding-type models enhance operator ergonomics, allowing for longer working hours without fatigue.
- **Adaptability to Small and Medium Farms:** The harvester can be designed for use in smaller fields where large combines are inefficient or impractical.

This research focuses on the design and development of a self-propelled riding-type chickpea harvester that optimizes the harvesting process by accounting for the physical properties of chickpea stems, including stem diameter and moisture content. The proposed harvester aims to enhance efficiency, reduce harvesting losses, and provide a cost-effective mechanization solution for chickpea farmers.

Materials and Methods

Self- propelled chickpea harvesting machine was tested on the innovative farmer of vadal village located near Junagadh in March 2023. The test was conducted in a 0.1 ha area, by varying selected machine parameters as per the plan of experiments.

The field observations were recorded for each test run. All the test were replicated 4 times as mentioned. The experiments were conducted for three crank Speed (200, 300, 400 rpm) and three forward speed (2.0-2.5, 2.5-3.0 and 3.0-3.5 km/h). The variation in forward speed of operation was obtained by hand throttle.

Experimental Design

Cutting and conveying Windrowing

Fig. 1 : Developed self-propelled chickpea harvester.

Effective Field Capacity

The effective field capacity represents the machine's average rate of coverage, accounting for total field time including turning and refueling. For the developed harvester, a fixed area of 25 m length and 1.5 m width was used, with time recorded to calculate the actual area covered in hectares per hour. It is calculated by using following equation (Kepner *et al*., 2005).

Table 1. Parameters for performance evaluation of the machine.

S. no.	Variables	Parameters	Levels
1	Independent parameters	Crank speed, C	C_1=200 rpm C_2=300 rpm C_3=400 rpm
		Forward speed, S	S_1= 2-2.5 km/h S_2= 2.5-3 km/h S_3= 3-3.5 km/h
2	Dependent parameters	➢ Cutting efficiency (%) ➢ Field efficiency (%) ➢ Fuel consumption (l/ha) ➢ Effective field capacity (ha/h)	

$$\text{Effective field capacity}\left(\frac{\text{ha}}{\text{h}}\right) = \frac{\text{Width of cut}(\text{m})\times\text{Length of strip}(\text{m})}{\text{Time taken }(\text{h})\times 10000} \qquad (1)$$

Field Efficiency

Field efficiency is defined as the ratio of the effective field capacity to the theoretical field capacity. It accounts for time lost in the field and the inability to fully utilize the machine's working width. To calculate the field efficiency of the developed harvester, an area with a fixed length of 25 meters and a width of 1.5 meters was designated. A stopwatch was used to record both productive and non-productive time during the operation (Kepner *et al.*, 2005). It is calculated using following formula.

$$\text{Field efficiency, (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}}\times 100 \qquad (2)$$

Cutting Efficiency

Cutting efficiency was measured by counting the number of plants in a 1.0 × 1.0 m area before and after the harvester's operation. It represents the percentage of plants cut, based on the total number before operation. The developed harvester's cutting efficiency was calculated over an area of 25 m by 1.5 m.

$$\text{Cutting efficiency, (\%)} = \frac{W_1 - W_2}{W_1} \qquad (3)$$

Where, W_1 = Number of plants before cutting operation

W_2 = Number of uncut plants after cutting operation

Fuel Consumption

The fuel consumed by the engine was measured during the harvesting of chickpea crop. The fuel consumption of the developed harvester was calculated by fixing the area of which had the fixed length of 25 m and fixed width of 1.5 m. The fuel consumed during operation was measured by measuring cylinder and the stop, watch was used to measure the time. The fuel consumption of the developed machine was calculated by following equation (Mehta *et al.*, 2005).

$$\text{Fuel consumption}\left(\frac{1}{\text{h}}\right) = \frac{\text{Fuel consumed}(\text{ml})\times 3.6}{\text{Time taken}(\text{s})} \qquad (4)$$

Statistical analysis : Experiment was based on large plot technique with nine treatments and four replications. The observed data was analysed by factorial completely randomized design (FCRD).

Results and Discussion

Effective Field Capacity

ANOVA (Analysis of Variance) was performed to examine the influence of crank speed, Forward speed and their interaction on effective field capacity, as shown in Table 2.

Effect of different Crank Speed on effective Field capacity

Three Crank Speed of 200, 300 and 400 rpm were selected to perform the experiment. Results were analysed statistically and ANOVA (Table 2) shows that crank speed had a non-significant effect on the effective field capacity.

It was found that a crank speed of 300 rpm (C2) yielded the maximum effective field capacity of 0.283 ha/h, whereas a crank speed of 400 rpm (C3) resulted in the minimum effective field capacity of 0.272 ha/h. The reduced performance at 400 rpm was attributed to increased machine vibrations compared to those observed at 200 rpm, making the machine more challenging to handle.

Effect of different Forward Speed on Effective Field Capacity

Three forward speed range were selected to perform the experiment *i.e.* 2-2.5 km/h, 2.5-3.0 km/h and 3.0-3.5 km/h. Results were analysed statistically and ANOVA (Table 2) shows that forward speed had a significant effect on the effective field capacity at 1 per cent significant level.

It was found that operating at a forward speed of 3.0-3.5 km/h (S3) resulted in the maximum effective field capacity of 0.316 ha/h, whereas a forward speed of 2.0-2.5 km/h (S1) produced the minimum effective field capacity of 0.234 ha/h. This is because forward speed is directly proportional to effective field capacity.

Table 2 : ANOVA showing effect of crank speed and forward speed on effective field capacity.

S.V.	ANOVA TABLE								
	df	SS	MSS	CAL F	Ftab5%	Ftab1%	TEST	SEM	CD
C	2	0.001	0.0004	3.31	3.35	5.49	NS	0.003	NS
S	2	0.040	0.0200	184.75	3.35	5.49	**	0.003	0.009
C X S	4	0.000	0.0000	0.39	2.73	4.11	NS	0.005	NS
Error	27	0.003	0.0001	CV % = 3.75					
Total	35	0.044							

Table 3 : Mean values of effective field capacity at different crank speed.

Crank speed, rpm	200 (C1)	300 (C2)	400 (C3)
Effective field capacity, ha/h	0.276	0.283	0.272

Table 4 : Mean values of the effective field capacity at different forward speed.

Forward speed, km/h	2.0-2.5 (S1)	2.5-3.0 (S2)	3.0-3.5 (S3)
Effective field capacity, ha/h	0.234	0.280	0.316

Table 5 : Mean values of effective field capacity with respect to different interactions of crank speed and forward speed.

Effective field capacity, (ha/h)			
Forward speed (S), km/h	Crank speed (C), rpm		
	200 (C1)	300 (C2)	400 (C3)
2.0-2.5 (S1)	0.235	0.237	0.231
2.5-3.0 (S2)	0.280	0.285	0.277
3.0-3.5 (S3)	0.314	0.326	0.307

Combined effect of different Crank Speed and Forward Speed on effective Field Capacity

Table 2 (ANOVA) shows the Interaction between crank speed and forward speed on effective field capacity was found non-significant. Mean values of effective field capacity with respect to different interactions of crank speed and forward speed are given in Table 5.

The maximum value of effective field capacity was found to be 0.326 ha/h, when crank speed was 300 rpm (C2) and forward speed was 2.5-3.0 km/h (S2) and the least value was found to be as 0.231 ha/h when crank speed was 400 rpm (C3) and forward speed was 2.0-2.5 km/h (S1), which is presented in Table 4. It shows that effective field capacity was best for forward speed 3.0-3.5(S3) and 300 rpm (C2). This treatment combination best for appropriate reel speed index.

Bheda (2019) reported similar trends in their study on the effect of forward speed and cutter bar speed on the effective field capacity of a leafy crop harvester. The study found that effective field capacity increased with higher forward speeds. The maximum values, influenced by crank speed, were achieved when the reel speed and forward speed were optimally coordinated.

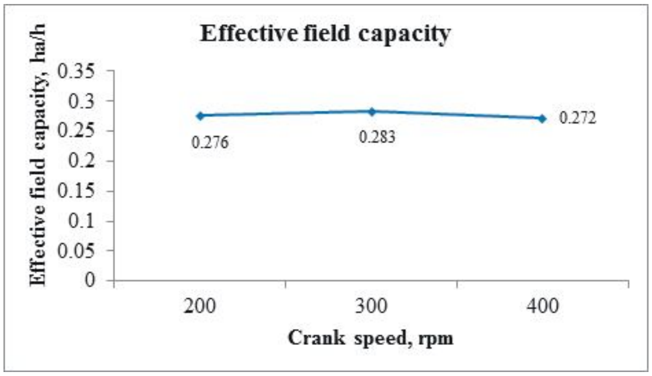

Fig. 2 : Mean values of effective field capacity at different crank speed.

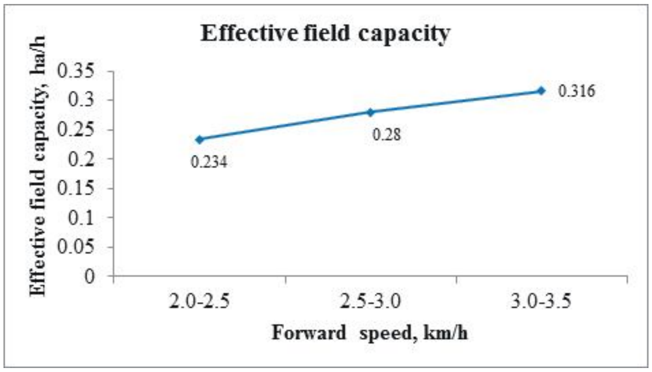

Fig. 3 : Mean values of effective field capacity at different forward speed.

Field efficiency

Field efficiency refers to the percentage of total time spent in the field that is effectively utilized for the intended operation. It is the ratio of productive time to the total time taken by the developed harvester. Statistical analysis was performed to study the effect of different crank speed (C) and forward speed (S) and their interaction on field efficiency which is presented as ANOVA in Fig. 6.

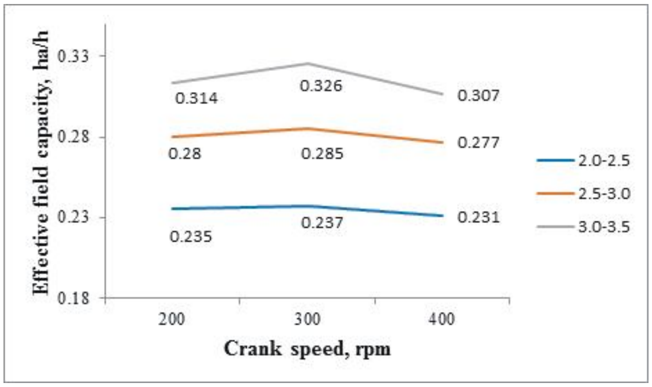

Fig. 4 : Effect of interaction of crank speed and forward speed on effective field capacity.

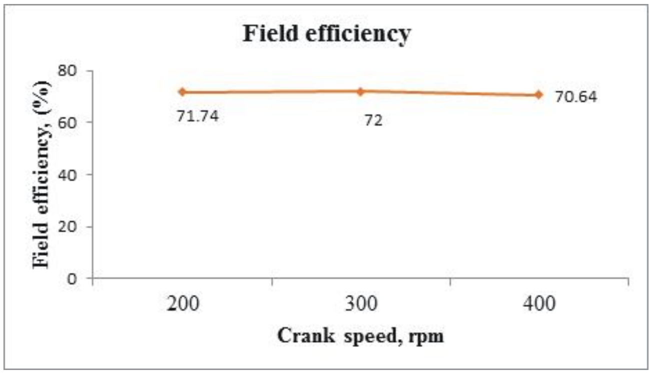

Fig. 5 : Mean values of field efficiency at different crank speed.

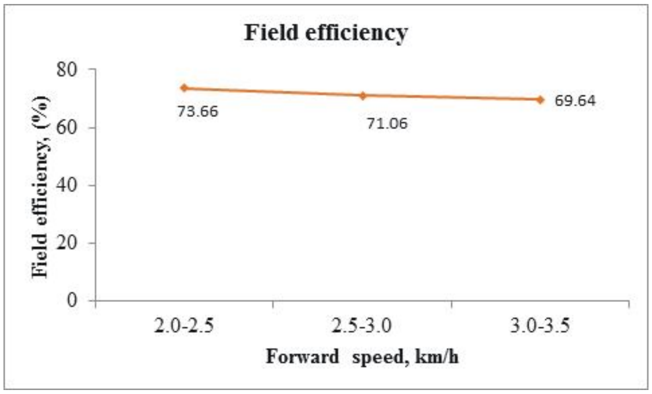

Fig. 6 : Mean values of field efficiency at different forward speed.

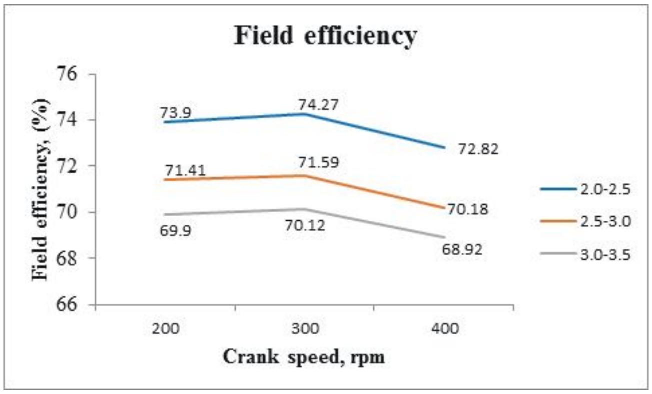

Fig. 7 : Effect of interaction of crank speed and forward speed on field efficiency.

Table 6 : ANOVA showing effect of crank speed and forward speed on field efficiency.

S.V.	ANOVA TABLE								
	df	SS	MSS	CAL F	Ftab5%	Ftab1%	TEST	SEM	CD
C	2	12.37	6.19	2.18	3.35	5.49	NS	0.487	NS
S	2	99.66	49.83	17.54	3.35	5.49	**	0.487	1.412
D X S	4	0.12	0.029	0.01	2.73	4.11	NS	0.843	NS
Error	27	76.71	2.84	CV% =2.358					
Total	35	188.86							

Effect of different Crank Speed on Field efficiency

Three Crank Speed of 200, 300 and 400 rpm were selected to perform the experiment. Results were analysed statistically and ANOVA (Table 6) shows that crank speed had a non-significant effect on the field efficiency.

It was found that crank speed 300 rpm (C2) was working with maximum field efficiency (72.00%) whereas crank speed 400 rpm (C3) was working with minimum field efficiency (70.64%). This was because at 400 rpm crank speed machine vibrate more compare to other level. So, handling the developed machine was slightly difficult due to that productive time is slightly decreased.

Effect of different Forward Speed on Field efficiency

Three forward speed range were selected to perform the experiment *i.e.* 2.0-2.5 km/h, 2.5-3.0 km/h and 3.0-3.5 km/h. Results were analysed statistically and ANOVA (Fig. 6) shows that forward speed had a significant effect on the field efficiency at 1 per cent significant level.

It was observed that operating at a forward speed of 2.0-2.5 km/h (S1) resulted in the highest field efficiency of 73.66%, whereas a forward speed of 3.0-3.5 km/h (S3) resulted in the lowest field efficiency of 69.64%. This is because forward speed is directly proportional to productive time.

Combined effect of different crank speed and forward speed on field efficiency

Interaction between crank speed and forward speed

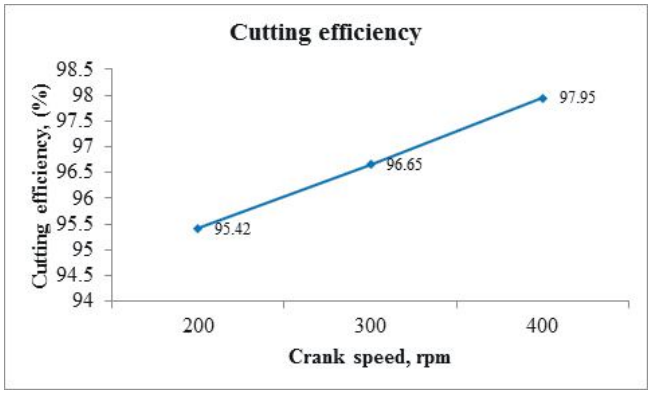

Fig. 8 : Mean values of cutting efficiency at different crank speed.

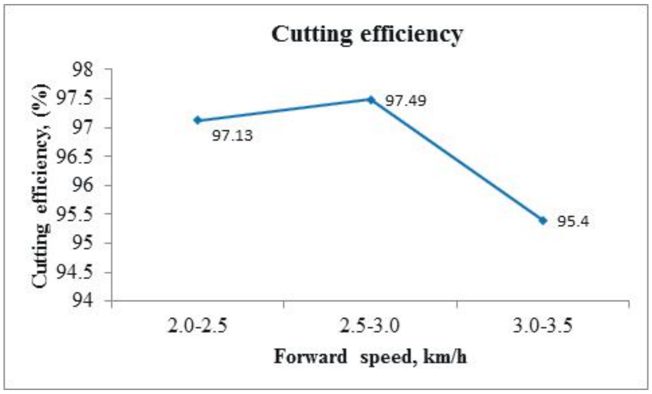

Fig. 9 : Mean values of cutting efficiency at different forward speed.

Table 6a : Mean values of field efficiency at different crank speed.

Crank speed, rpm	**200 (C1)**	**300 (C2)**	**400 (C3)**
Field efficiency, %	71.74	72.00	70.64

Table 7 : Mean values of the field efficiency at different forward speed.

Forward speed, km/h	**2.0-2.5 (S1)**	**2.5-3.0 (S2)**	**3.0-3.5 (S3)**
Field efficiency, %	73.66	71.06	69.64

Table 8 : Mean values of field efficiency at different interactions of crank speed and forward speed.

Field efficiency, (%)			
Forward speed (S), km/h	**Crank speed (C), rpm**		
	200 (C1)	**300 (C2)**	**400 (C3)**
2.0-2.5 (S1)	73.90	74.27	72.82
2.5-3.0 (S2)	71.41	71.59	70.18
3.0-3.5 (S3)	69.90	70.12	68.92

on field efficiency was found non-significant. Mean values of field efficiency with respect to different interactions of crank speed and forward speed are given in Table 8.

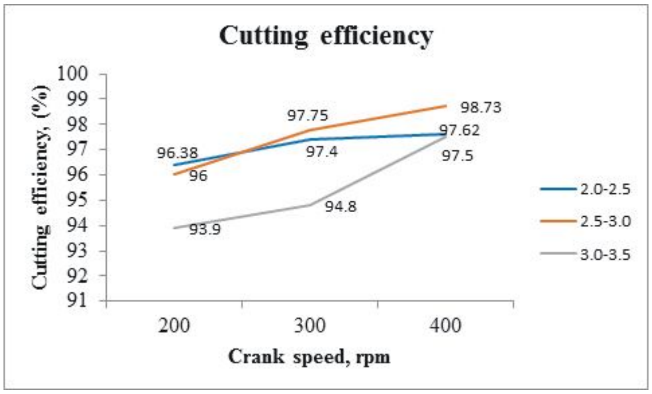

Fig. 10 : Effect of interaction of crank speed and forward speed on cutting efficiency.

The maximum value of field efficiency was found to be 74.27%, when crank speed was 300 rpm (C2) and forward speed was 2.0-2.5 km/h (S1) and the least value was found to be as 68.92% when crank speed was 400 rpm (C3) and forward speed was 3.0-3.5 km/h (S3), which is presented in Fig. 6. It shows that field efficiency was best for the 300-rpm crank speed among three crank speed level and 2.0-2.5 (S1) forward speed among three forward speed level because this combination suitable for reel speed index and also increasing forward speed productive time for cover 25 m length of strip is reduce but non-productive time remain same.

In a study conducted by Mohit (2022), the influence of forward speed and cutter bar speed on the field efficiency of a developed battery-operated cumin harvester was examined. The findings demonstrated a similar trend to our results, showing a decrease in field efficiency with an increase in forward speed

Cutting efficiency

The cutting efficiency is the important parameter to evaluating the performance of the harvester. Achieving optimal cutting efficiency is essential for improving overall field efficiency and profitability.

Statistical analysis was performed to study the effect of different crank speed (C) and forward speed (S) and their interaction on cutting efficiency which is presented as ANOVA in Table 10.

Effect of different Crank Speed on Cutting efficiency

Three crank speeds of 200, 300 and 400 rpm were selected to perform the experiment. Results were analysed statistically and ANOVA (Table 9) shows that crank speed had a non-significant effect on the cutting efficiency.

It was observed that a crank speed of 400 rpm (C3) achieved the highest cutting efficiency of 97.95%, whereas a crank speed of 200 rpm (C1) resulted in the lowest cutting efficiency of 95.42%. This is because at

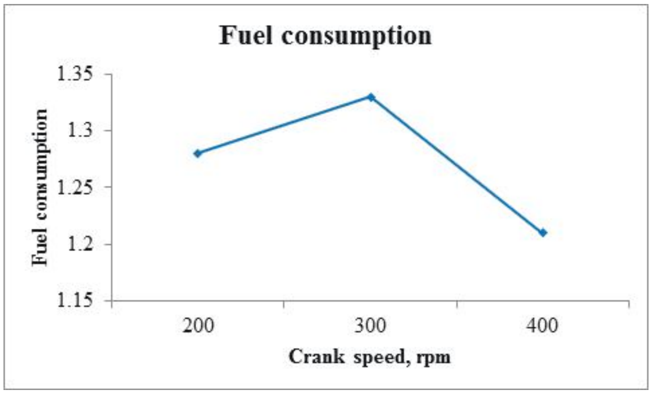

Fig. 11 : Mean values of fuel consumption at different crank speed.

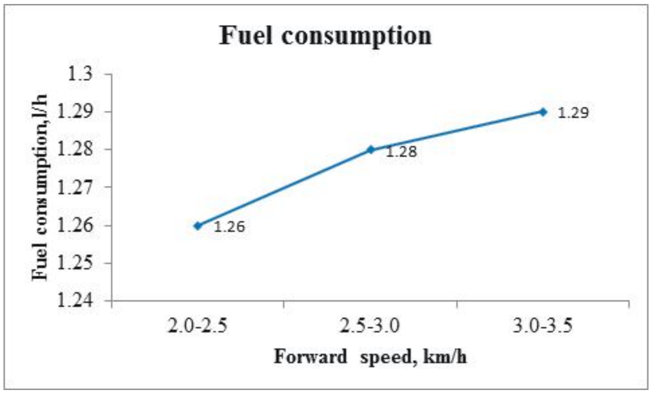

Fig. 12 : Mean values of fuel consumption at different forward speed.

Table 9 : ANOVA showing effect of crank speed and forward speed on cutting efficiency.

S.V.	ANOVA TABLE								
	df	**SS**	**MSS**	**CAL F**	**Ftab5%**	**Ftab1%**	**TEST**	**SEM**	**CD**
C	2	38.12	19.10	3.24	3.35	5.49	NS	0.70	NS
S	2	30.06	15.03	2.55	3.35	5.49	NS	0.70	NS
D X S	4	8.67	2.17	0.37	2.73	4.11	NS	1.21	NS
Error	27	159.23	5.90	**CV % = 6.69**					
Total	35	236.18							

Table 10 : Mean values of cutting efficiency at different crank speed.

Crank speed, rpm	**200 (C1)**	**300 (C2)**	**400 (C3)**
Cutting efficiency, %	95.42	96.65	97.95

400 rpm, the cutter bar cuts more plants compared to its performance at 200 rpm.

Effect of different Forward Speed on Cutting efficiency

Three forward speed range were selected to perform the experiment *i.e.* 2.0-2.5 km/h, 2.5-3.0 km/h and 3.0-3.5 km/h. Results were analyzed statistically and ANOVA (Table 10) shows that forward speed had a non-significant effect on the cutting efficiency. The mean value of cutting efficiency for different forward speed is shown in Table 11.

It was found that a forward speed of 2.0-2.5 km/h (S1) resulted in the highest cutting efficiency of 97.13%, whereas a forward speed of 3.0-3.5 km/h (S3) resulted in the lowest cutting efficiency of 95.40%. The reduction in cutting efficiency at higher forward speeds was due to decreased time available to cut the plants, leading to an increased number of uncut plants.

Combined effect of different Crank Speed and Forward Speed on Cutting efficiency

Interaction between crank speed and forward speed on cutting efficiency was found non-significant. Mean values of cutting efficiency with respect to different interactions of crank speed and forward speed are given in Table 12.

The maximum value of cutting efficiency was found to be 98.73 % when crank speed was 400 rpm (C3) and forward speed was 2.5-3.0 km/h (S1). The least value was found to be as 93.90 % when crank speed was 200 rpm (C1) and forward speed was 3.0-3.5 (S3), which is presented in Table 12. It shows that cutting efficiency was increased with crank speed C1 followed by C2 and C3, respectively.

Table 11 : The mean value of cutting efficiency for different forward speed.

Forward speed, km/h	**2.0-2.5 (S1)**	**2.5-3.0 (S2)**	**3.0-3.5 (S3)**
Cutting efficiency, %	97.13	97.49	95.40

Tanti (2019) studied the effect of forward speed and crank speed on wheat crops and observed similar results. They found that cutting efficiency increased with higher crank speeds, while it decreased as forward speed increased.

Fuel consumption

The fuel consumption was the fuel consumed by the machine during time of operation. It was calculated by

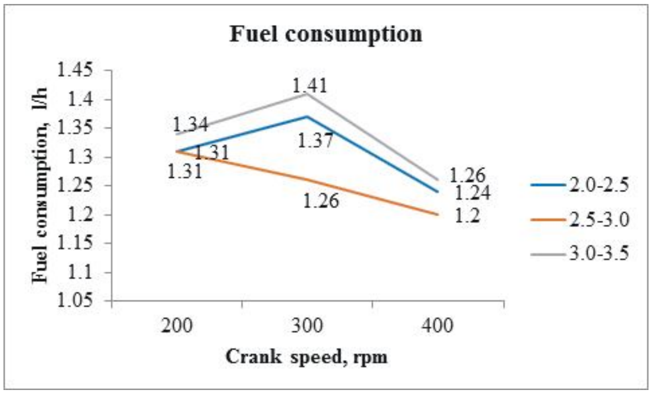

Fig. 13 : Effect of Interaction of Crank speed and Forward speed on Fuel consumption.

Table 12 : Mean values of cutting efficiency at different interactions of crank speed and forward speed.

Cutting efficiency, (%)			
Forward speed (S), km/h	**Crank speed (C), rpm**		
	200 (C1)	**300 (C2)**	**400 (C3)**
2.0-2.5 (S1)	96.38	97.40	97.62
2.5-3.0 (S2)	96.00	97.75	98.73
3.0-3.5 (S3)	93.90	94.80	97.50

Table 13 : ANOVA showing effect of crank speed and forward speed on fuel consumption.

S.V.	**ANOVA TABLE**								
	df	**SS**	**MSS**	**CAL F**	**Ftab5%**	**Ftab1%**	**TEST**	**SEM**	**CD**
C	2	0.084	0.042	15.79	3.35	5.49	**	0.015	0.043
S	2	0.004	0.002	0.66	3.35	5.49	NS	0.015	NS
D X S	4	0.009	0.002	0.81	2.72	4.11	NS	0.026	NS
Error	27	0.072	0.003	**CV % = 3.74**					
Total	35	0.168							

Table 14 : Mean value of fuel consumption at different crank speed.

Crank speed, rpm	**200 (C1)**	**300 (C2)**	**400 (C3)**
Fuel consumption, l/h	1.28	1.33	1.21

observing the fuel consumed and the time required.

Statistical analysis was performed to study the effect of different crank speed (C) and forward speed (S) and their interaction on fuel consumption which is presented as ANOVA in Table 13.

Effect of different Crank Speed on Fuel Consumption

Three crank speed of 200, 300 and 400 rpm were selected to perform the experiment. Results were analysed statistically and ANOVA (Table 14) shows that crank speed had a highly significant effect on the fuel consumption at 1 per cent significant level.

It was observed that a crank speed of 300 rpm (C2) resulted in the highest fuel consumption at 1.33 l/h, while a crank speed of 400 rpm (C3) had the lowest fuel consumption at 1.21 l/h. The higher fuel consumption at 300 rpm is attributed to the optimal reel speed index at this crank speed, leading to increased productive time compared to other speeds. Consequently, this higher productive time demands more power, directly increasing fuel consumption.

Effect of different Forward Speed on Fuel consumption

Three forward speed range were selected to perform the experiment *i.e.*; 2.0-2.5, 2.5-3.0 and 3.0-3.5. Results were analysed statistically and ANOVA (Table 15) shows that forward speed had a non-significant effect on the fuel consumption at 1 per cent significant level.

It was found that forward speed of 3.0-3.5 (S3) was working with maximum fuel consumption of 1.29 l/h, whereas forward speed of 2.0-2.5 km/h (S1) was working with minimum fuel consumption of 1.26 l/h.

Combined effect of different Crank Speed and Forward Speed on Fuel consumption

Interaction between crank speed and forward speed on fuel consumption was found non-significant. Mean values of fuel consumption with respect to different interactions of crank speed and forward speed are given in Table 16.

The maximum value of fuel consumption was found to be 1.41 l/h when crank speed was 300 rpm (C2) and forward speed was 3.0-3.5 km/h (S3) and the least value was found to be as 1.20 l/h when crank speed was 400 rpm (C3) and forward speed was 2.5-3.0 km/h (S2). which is presented in Table 12. It shows that fuel consumption was minimum for 400 rpm (C3) and 2.5-3.0 km/h (S2) treatment combination because this combination observed appropriate reel speed index and

Table 15 : Mean values of the fuel consumption at different forward speed.

Forward speed, km/h	**2.0-2.5 (S1)**	**2.5-3.0 (S2)**	**3.0-3.5 (S3)**
Fuel consumption, l/h	1.26	1.28	1.29

Table 16 : Mean values of fuel consumption with respect to different interactions of crank speed and forward speed.

Fuel consumption, (l/h)			
Forward speed (S), km/h	**Crank speed (C), rpm**		
	200 (C1)	**300 (C2)**	**400 (C3)**
2.0-2.5 (S1)	1.31	1.37	1.24
2.5-3.0 (S2)	1.31	1.26	1.20
3.0-3.5 (S3)	1.34	1.41	1.26

indirectly increased the productive time.

Same trend was observed by Bheda (2019), who studied the effect of forward speed and cutter bar speed on leafy crop harvester. During the studied he founded the fuel consumption directly related with productive work. 300 rpm gives highest effective field capacity among the crank speed. So, this crank speed observed maximum fuel consumption.

Conclusion

The developed chickpea crop harvester exhibited superior performance compared to manual harvesting. It underwent comprehensive testing for both independent and dependent parameters. Physiological characteristics such as crop height, stem diameter, plant population, and moisture content were assessed for chickpea crop. The performance evaluation of the harvester included cutting efficiency, field capacity, field efficiency and fuel consumption. The experiments demonstrated significant time and cost savings in the harvesting of chickpea crops. Consequently, the study's results lead to the following conclusions.

- The highest effective field capacity was recorded at 0.326 ha/h with a crank speed of 300 rpm and a forward speed ranging from 3.0 to 3.5 km/h. Conversely, the lowest effective field capacity was 0.231 ha/h, observed at a crank speed of 400 rpm and a forward speed between 2.0 and 2.5 km/h.
- The maximum field efficiency reached 74.27% at a crank speed of 300 rpm with a forward speed of 2.0 to 2.5 km/h. The minimum field efficiency was 68.92%, occurring at a crank speed of 400 rpm and a forward speed of 3.0 to 3.5 km/h.
- Cutting efficiency peaked at 97.58% when the crank speed was set to 400 rpm and the forward speed was maintained between 2.0 and 2.5 km/h.
- The highest fuel consumption was measured at 1.41 l/h with a crank speed of 300 rpm and a forward speed of 3.0-3.5 km/h. In contrast, the lowest fuel consumption was 1.20 l/h, recorded at a crank speed of 400 rpm and a forward speed of 2.5 to 3.0 km/h.

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