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Advancements in mechanical harvesting of chickpea: A comparative analysis with manual harvesting

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Abstract
Chickpea (*Cicer arietinum* L.) stands as a significant pulse crop on a global scale, crucial for its contribution of protein and essential nutrients to human diets. The traditional approach to harvesting chickpeas relies heavily on manual labor, a process known for its labor-intensive nature and prolonged duration. However, recent strides in agricultural technology have spurred the development of mechanical harvesting systems tailored specifically for chickpea cultivation. This paper aims to offer an overview of these mechanical harvesting techniques, contrasting them with the traditional manual methods. It will elucidate their advantages in terms of efficiency, cost-effectiveness, and sustainability. The study compared the operational cost and labor requirements of a newly developed harvester with manual harvesting methods. It found that using the developed harvester resulted in a significant cost savings of ₹598.00 per hectare, which translates to a reduction of 39.34% in harvesting expenses. Additionally, the labor needed for the developed harvester was only 3.57 man-hours per hectare, a substantial decrease from the 32 man-hours required for manual harvesting, representing an 88.84% reduction in harvesting time per hectare.

Keywords: Chickpea, mechanical, harvesting, efficiency, cost-effectiveness

Introduction
Agricultural mechanization involves the utilization of advanced tools and machinery within farm operations to alleviate labor burdens on both human workers and draft animals. This approach facilitates increased crop yields, promotes timely cultivation practices, and optimizes resource utilization, thereby minimizing wastage. The evolution of mechanization has notably transformed agricultural practices, particularly in the domain of cereal crop harvesting. Leveraging technological advancements, farmers can achieve heightened productivity, reduced resource wastage, and environmentally sustainable farming methods. The adoption of upgraded machinery holds the potential to augment farm output by up to 30% while concurrently reducing operational costs by 20% (Gurung *et al*., 2017) [1]. The overarching objective of farm mechanization is to enhance agricultural productivity and efficiency while mitigating production costs.

A developing country like India is expected to continue to rely more on hand tools for the foreseeable future for cultivation. The use of hand tools for land cultivation is still predominant in India because draft animals and tractors require resources that many Indian farmers do not have easy access to. Currently, India's level of mechanization is at 40% compared to 90% across the developed nations yet harvesting of rice (70%) and wheat (80%) are highly mechanized (PwC, 2019) [3]. The need for agricultural mechanization in India must therefore be assessed with a deeper understanding of the small holder farmer's activities and what values farm power generated for them.

Chickpea (*Cicer arietinum* L.) is a vital pulse crop globally, renowned for its nutritional value and adaptability to diverse climates. Its significance in human diets and agricultural economies prompts continuous advancements in cultivation practices. Among these, harvesting stands as a critical stage influencing yield, quality, and labor efficiency. Traditionally, chickpea harvesting has relied on manual methods, where labor-intensive techniques involve handpicking or cutting plants with sickles.

Table 1: Current level of farm mechanization in India for several agricultural activities (NABARD 2018) [4]

Operation	Mechanization level in terms of percentage (Overall: 40%)
Land preparation	40
Seeding/planting	30
Plant protection	34
Irrigation	34
Harvesting	65

This approach, while maintaining certain advantages in small-scale farming systems, poses challenges in larger agricultural enterprises due to labor shortages, increased labor costs, and efficiency concerns.

In chickpea farming, how the plants grow upright and how high their pods are above the ground are really important for deciding which kinds of chickpeas to grow if you want to use machines to harvest them. In India, most chickpeas grow in a way that spreads out a bit and their pods are close to the ground, which makes it hard to use machines to harvest them. Chickpeas that grow like this can lose a lot more when they're harvested by machines compared to ones that grow straight up. Right now, machines are used a lot to harvest rice and wheat in India, and farmers want chickpea plants that can be harvested this way too. But only a few types of chickpeas in India are good for machine harvesting. In chickpea, erectness and first pod height from ground are two important traits that primarily decide a cultivar choice for mechanical harvesting (Singh *et al.*, 2019) [7]. Mostly Indian chickpea cultivars are semi spreading and have low ground clearance, and thus, not suitable for mechanical harvesting. The harvest loss during machine harvest is higher for semi- erect genotype (~20%) and low in tall and erect genotypes (2.6-5.0%). So, there's a big effort happening to develop new kinds of chickpeas that are better for machine harvesting.

In response to these challenges, the agricultural machinery sector has witnessed a surge in innovation, culminating in the development of self-propelled chickpea harvesters. These machines aim to streamline the harvesting process, promising increased efficiency, reduced labor dependency, and enhanced productivity.

This research paper delves into the comparative analysis of self-propelled chickpea harvesters against traditional manual harvesting methods. By examining factors such as productivity, labor requirements, cost-effectiveness, and environmental impact, this study aims to provide comprehensive insights into the adoption and implications of mechanized harvesting in chickpea cultivation.

Materials and Methods

Study of Existing Harvesting methods for Chickpea Crop

To study the existing method of harvesting of chickpea crops a survey was made in the local area of junagadh district. Especially, ghed region which cultivable rainfed varieties of chickpea and used combine harvester for harvesting and threshing of the chickpea, and contacted to different farmers for obtaining the information regarding the existing method of harvesting. The difficulties and challenges faced by farmers in existing method were also noted.

In India, chickpea harvesting is traditionally done manually. Farmers typically use sickles or similar hand tools to cut the chickpea plants and the harvested crops are then manually gathered or bundled for threshing. There are different type of sickles available in the market. This manual approach has been the predominant in small scale farming practices. Some farmers are also uprooting the entire plant using a hand-pulling. Combine harvesters are also used but some modification is needed and used only for rainfed varities of chickpea.

Mechanical Harvesting Manual Harvesting

Fig 1: Existing methods of chickpea harvesting

There are some challenges and difficulties of existing harvesting method are discusses below.

- Due to modernization and some other socioeconomic reason day by day more man power shifting towards industries and other sector. So, at a time of harvesting labour shortage occurred and indirectly cost of harvesting is increased.
- In uprooting of the plant more shattering losses occurred and the loss of nitrogen – fixing bacteria due to uprooting of

the plant.

- Ergonomic point of view, in manual harvesting. the labors keeps a squat posture during harvesting, which causes problem occurred like back pain and knee joint. The discomfort adversely affected the work performance, either by decreasing the quantity of work, the quality of work, or both.
- In combine harvester due to wide header unit excessive pod losses occurs. Low Plant height and spreading characteristic of chickpea harvesting is inappropriate for conventional combine harvester.
- Combine harvesters work well for certain types of chickpea plants that grow tall and upright with their first pods positioned more than 25 cm above the ground. However, they aren't suitable for shorter chickpea plants with semi-upright growth habits.

Working principle of developed chickpea harvester

The developed self-propelled chickpea harvester can also be recommended for the crops having same physiological parameter as chickpea i.e. Mung, Urad and Mustard etc. The developed self-propelled chickpea harvester mainly consists of two main units 1) Self propelled unit and 2) Front attachment. Self propelled unit has a 7.5 Hp stationary diesel engine, a cooling system, a steering system and a front mounted PTO system for transmission of power. While Front attachment consists of a main frame, a conveyor unit, a gear box assembly, a cutter-bar assembly and a reel mechanism.

Self propelled unit is powered by 7.5 hp stationary diesel engine with the help self starter motor. Power produced by engine is transmitted through main gearbox for forward motion for the machine. Engine power is also transmitted to front attachment through front PTO. A cooling system is provided to maintain the system at optimum temperature. A steering system controls the movement of the developed machine. Self propelled unit can also be used separately as a multi purpose tool for other farm operations.

In the Front attachment power from PTO is transmitted to main shaft pulley with the help of universal joint. From main shaft pulley power is then transmitted to gearbox through belt and pulley. A chain and sprocket mechanism with tensionar sprocket is also connected with the gearbox pulley to power the conveyer belt mechanism. The reel unit derives power from the gearbox through belt and pulley arrangement. While cutter bar unit is connected with the help of a crank disk, a tie rod and a knife head.

The developed self propelled harvester performs three operations simultaneously: cutting, conveying and windrowing.

Fig 2: Developed chickpea harvester

Machine performance parameters

The machine was evaluated in the field as per the performance parameters decided for harvesting chickpea crops listed as follows.

1) **Plant height:** The plant heights across five distinct locations within the field were assessed, and subsequently, the mean value was determined.
3) **Row to Row spacing:** The inter-row spacing at various locations within the field was quantified using a measuring tape.
4) **Stem diameter:** The diameter of the stems was assessed utilizing vernier calipers.
5) **Plant population:** Plant was counted in 1 × 1 m area of the field for the plant population.
6) **Forward speed of the operation:** The forward speed was calculated for developed harvester by observing the time (t) taken to travel 25 m length plot. The forward speed of operation was calculated by observing the distance travelled and time taken by following formula.

$$\text{Speed of operation,} \left(\frac{\text{km}}{\text{h}}\right) = \frac{\text{Distance (m)}}{\text{Time taken to cover the distance (s)}} \times 3.6$$

7) **Fuel consumption:** The fuel consumed by the engine was measured during the harvesting of chickpea crop. The fuel consumed by an engine can be measured by determining the volume of fuel in a given time interval. Fuel consumed during each test were computed by topping up at the start of the test and the finish of the test and expressed in l/hr or l/ha After the completion of test, the range of fuel consumed for 25 m was noted and the average fuel consumption of developed harvester were calculated (Mehta *et al.* 2005) [2].
8) **Cutting efficiency:** The number of plants in unit area was counted before operation and the plants left in the same area were counted after the operation.

$$\text{Cutting efficiency}(\%) = \frac{W1 - W2}{W1}$$

Where,
W1 = Number of plants before cutting operation
W2 = Number of uncut plants after cutting operation

9) Effective Field capacity: The effective field capacity is the average rate of coverage by the machine, based upon the total field time. It includes time lost in turning of machine at the end of rows and refilling of fuel. It is calculated by using following formula (Kepner *et al*. 2005) [5].

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

10) Field efficiency Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as a percentage. It includes the effects of time lost in the field and failure to utilise the full width of the machine. (Kepner *et al*., 2005) [5]. It is calculated using following formula.

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

Plant Height Row to Row spacing

Total pod loss

Fig 3: Observation taken during experiment

Result and Discussion

Table 2: Data of Different Parameter Taken During the Experiment

Parameters	Replications					
	1	2	3	4	5	Avg.
Plant height (cm)	44	46	50	48	48	47.2
Row to Row spacing (cm)	40	40	40	40	40	40
Stem diameter (mm)	7.5	7.9	8.1	7.9	8.3	7.94
Plant population	39	35	37	38	38	37
Fuel consumption (l/h)	1.35	1.29	1.33	1.29	1.31	1.31
Cutting efficiency (%)	96.51	98.20	97.62	98.11	96.85	97.46
Effective Field capacity (ha/h)	0.29	0.285	0.27	0.26	0.275	0.276
Field efficiency (%)	69.23	69.59	71.23	72.12	70.69	70.57

Economic Evaluation of the Developed Chickpea Crop Harvester

The adoptability of any mechanized system depends upon its efficacy, cost-effectiveness, and various other determinants. Justifying the development of a chickpea crop harvester necessitates a careful examination of its operational costs and performance metrics, particularly in comparison to established local practices such as manual harvesting. A comparative analysis was undertaken to assess the economic viability of the existing manual harvesting approach against the operational cost of the newly developed chickpea crop harvester. The economic parameters associated with both manual and mechanical harvesting of chickpea crops were quantified and are elucidated below.

Harvesting cost by manual method

The observation was taken for the manual operation of chickpea harvesting. The time and cost of operation for manual chickpea harvesting was calculated and given in Table 3. It was found that total time required and cost of operation for the manual harvesting methods were 32 man hours/ha and ₹ 1520/- per ha respectively. The unskilled labour charge was taken as ₹ 380/- per day for 8h work.

Table 3: Cost estimation of manual chickpea crop harvesting

Sr. No.	Chickpea crop harvesting by manual method	
1	Man hour required for chickpea crop harvesting per ha	32
2	No. of labour required for chickpea crop harvesting per ha	4
3	Wages per day of labour (8 hours)	380
	Total cost of manual chickpea crop harvesting (₹ per ha)	1520

Harvesting cost by developed chickpea crop harvester

The developed chickpea crop harvester can also recommended for harvest multiple crop which crop physiological parameter like chickpea. the time and cost of operation for the developed chickpea harvester were determined as per the IS: 9164, 1979 [6]. It was found that total time required and cost of operation were 3.57 h/ha and ₹ 922/- per ha for the developed chickpea crop harvester, respectively. The skilled labour charge was taken as ₹ 380/- per day for 8h work.

Economical comparison of chickpea crop harvesting method

A comparison was made between manually harvesting chickpeas and using a developed chickpea crop harvester. The operational cost for the developed harvester was analyzed, and it was found to be ₹922.00 per hectare, while manual harvesting cost ₹1520.00 per hectare. This means a savings of ₹598.00 per hectare or 39.34% in harvesting costs with the developed harvester. The labor required for the developed harvester was 3.57 man-hours per hectare, significantly less than the 32 man-hours needed for manual harvesting. This represents an 88.84% reduction in harvesting time per hectare.

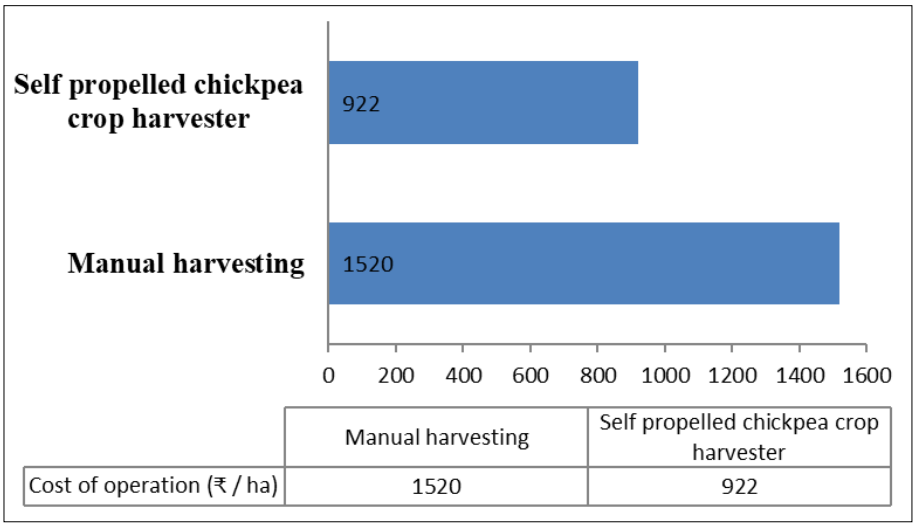

Fig 4: Cost of operation (₹/ha)

The break-even point for the developed chickpea crop harvester was determined to be 256 hours per year. The payback period for the machine was found to be 3.65 years, and the benefit-cost ratio was 2.73. In simple terms, the developed chickpea crop harvester proves to be economically feasible as it reduces both time and cost compared to the manual method. Additionally, it addresses issues like manual labor fatigue and shortages, making it a practical solution for chickpea harvesting.

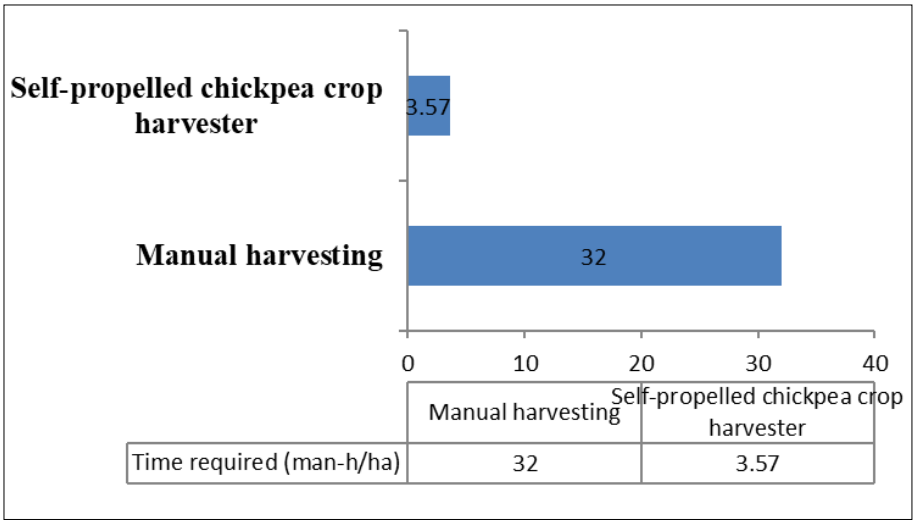

Fig 5: Time required (man-h /ha)

Conclusion

The integration of mechanical harvesting technologies in chickpea cultivation represents a significant advancement in agricultural practices, offering numerous benefits over traditional manual harvesting methods. By enhancing efficiency, reducing costs, and improving crop quality, mechanical harvesting contributes to the sustainability and profitability of chickpea production systems. Further research and technological innovations in this field are essential to optimize mechanical harvesting techniques and facilitate their widespread adoption among farmers globally.

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