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RESEARCH ARTICLE

Gender-Neutral Pedal Operated Paddy Thresher for Small and Hill Farmers

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Abstract

Paddy is one of the major staple crops cultivated in India, occupying approximately 47.82 million hectares, which represents the largest rice-growing area globally. However, Indian agriculture is predominantly characterized by small and marginal land holdings, with nearly 86% of farmers owning less than 2 ha of land. Because of fragmented farm sizes, the adoption of large threshing equipment remains limited, particularly in hilly and remote regions. Conventional paddy threshing practices are generally labor-intensive, require considerable time, and impose high physical drudgery, especially on women workers. To overcome these limitations, a gender-neutral pedal-operated paddy thresher was designed and developed at ICAR–Indian Sugarcane Research Institute (ISRI), Lucknow. The machine performance was evaluated under both institute and farmers' field conditions using different crop varieties, moisture levels, and feed rates. The developed thresher achieved a threshing efficiency ranging from 91.62 to 98.78% and a threshing capacity of 90 to 106 kg/h. The machine can be operated comfortably by a single person in a seated posture, thereby reducing physical strain and operator discomfort. The operational cost was estimated at approximately ₹55 to 60 per quintal, indicating its economic suitability for small-scale farming. Owing to its portability, ease of operation, low maintenance requirement, and affordability, the developed thresher offers a practical threshing solution for small and marginal farmers.

Keywords: Gender-neutral, Pedal-operated paddy thresher, Rice threshing, Smallholder farmers, Threshing performance, Portability.

Introduction

Paddy is one of the most important food crops cultivated in India and contributes significantly to national food security. India occupies approximately 47.82 million ha under rice cultivation, representing the largest rice-growing area globally. Over the last several decades, rice production has shown substantial growth, increasing from 20.58 million tonnes in 1950–51 to 137.82 million tonnes in 2023–24, with an average productivity of nearly 2882 kg/ha (Anonymous, 2025). Among different states, Uttar Pradesh records the maximum area under paddy cultivation (5.76 million ha) and contributes 15.99 million tonnes of production with an average productivity of 2772 kg/ha, which remains lower than the national average. Despite only a moderate increase in cultivated area (about 1.4 times), total rice production expanded more than six times primarily because of improvements in crop productivity from 0.7 to 2.8 t/ha.

The agricultural sector in India is dominated by small and marginal landholders. As reported in the Agriculture Census (2015–16), nearly 86% of operational holdings are below 2 ha, whereas medium-size holdings (2–10 ha) account for only 13.3% of total farms (Anonymous, 2019). Farm mechanization plays an important role in improving labour efficiency, productivity, profitability, and timely completion of agricultural operations (Singh *et al.*, 2008). However, adoption of large agricultural machinery by small farmers is limited due to small and fragmented land holdings, low investment capacity, and high operational costs. Mechanical harvesting and threshing are considered economically feasible mainly for farms larger than 1 ha and are generally unsuitable for small and fragmented farms (Hussain, 1982).

Threshing is a key post-harvest activity in rice cultivation and contributes approximately 25% of the total energy requirement during paddy production. In many remote and hilly areas, farmers still depend on traditional threshing practices, including animal treading, manual striking, and grain separation through foot rubbing (Datt, 2003; Singh *et al.*, 2008a; Singh, 2014; Singh and Singh, 2018; Singh, 2007). Such practices are associated with greater labour demand, increased operation time, higher drudgery, and

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post-harvest losses. Women constitute a major share of the agricultural workforce and frequently participate in threshing operations, exposing them to physical strain, muscular fatigue, shoulder discomfort, and work-related injuries during manual activities (Singh *et al.*, 2008a; Singh and Vatsa, 2015). Previous studies have indicated that pedal-operated mechanisms can utilize human muscular power more efficiently and reduce fatigue compared with hand-operated systems (Tiwari *et al.*, 2011). Therefore, considering the requirement for an affordable, drudgery-reducing, and inclusive mechanization option for smallholder agriculture, a gender-neutral pedal-operated paddy thresher was developed and evaluated at ICAR–Indian Sugarcane Research Institute (ISRI), Lucknow. The machine was designed to enhance threshing performance while minimizing physical effort and operational cost for small and marginal paddy farmers.

Materials and Methods

Design of pedal-operated paddy thresher

The following design considerations were taken into account during the development of the pedal-operated paddy thresher:

- The machine should be designed for operation by a single user with minimum physical effort.
- The machine should remain cost-effective and economically feasible for small and marginal farming communities.
- The design should ensure ease of operation along with low maintenance requirements.
- The machine should be lightweight, ergonomically suitable, and gender-friendly.
- It should be portable, easily detachable, and convenient for transportation.
- The machine should be fabricated using locally available materials and manufacturing facilities.
- It should thresh paddy efficiently with minimum grain damage and should also facilitate partial cleaning/ winnowing operation.

Description of machine and operation

The developed pedal-operated paddy thresher mainly consists of a main frame, threshing cylinder, power transmission unit (chain and sprocket drive, bearings, shafts, and bearing housings), polycarbonate sheet body (canopy), pedal-operated assembly with operator seat, and transport wheels. The machine was developed using readily available local materials to minimize manufacturing cost and promote ease of fabrication at the local level.

The seat and hand-rest arrangement were designed ergonomically to maintain a comfortable posture for the operator during pedalling. The relative position of the upper and lower arms was adjusted in such a way that the operator could maintain proper spinal posture and minimize fatigue during operation.

Main frame

The main frame acts as the structural support for all machine components and was fabricated using mild steel (MS) angle iron of size 35 × 35 × 5 mm. The frame was designed to withstand operational vibrations and loads developed during threshing. The fabricated machine was designed with overall dimensions measuring 1400 × 700 × 1100 mm (length × width × height).

The frame width was selected to provide sufficient clearance between the threshing drum and side frame members during the threshing operation. The height of the frame was determined considering the position of the threshing drum and the average anthropometric dimensions of the operator. A support handle was also provided for maintaining operator balance during pedalling operation (Agrawal, 2008).

Threshing unit

The threshing cylinder was designed with a length of 500 mm to facilitate convenient holding and feeding of paddy bundles by a single operator (Fig. 1, and Table 1`). The cylinder was fabricated using six equally spaced MS flats of size 35 × 5 × 500 mm mounted on two circular end rings. The drum diameter was maintained at 260 mm using MS flats of size 25 × 5 mm.

Two MS flats were welded diagonally across the end rings to support and fix the central shaft. The shaft was connected rigidly to the cylinder using bolts and nuts. The threshing teeth were fabricated from galvanized iron (GI) wire of 4 mm diameter. The wires were bent in a loop shape and mounted on the MS flats with a spacing of 40 mm between adjacent teeth. Approximately 60 mm of tooth length projected outside the cylinder surface for effective threshing action.

The straight ends of the teeth were inserted through drilled holes and bent inward to prevent slipping during operation. The teeth arrangement on adjacent flats was staggered to improve threshing action and ensure uniform grain separation. During operation, the operator manually feeds paddy bundles onto the rotating threshing cylinder, where the wire-loop teeth comb the ear heads and separate grains from straw.

Shaft and bearing arrangement

The threshing cylinder shaft was manufactured from a mild steel rod with a total length of 800 mm and a diameter of 25 mm. The shaft was firmly mounted to the threshing cylinder to provide structural stability and was designed to sustain the mechanical loads encountered during threshing operations. The shaft was supported on radial ball bearings fitted inside bearing housings to ensure smooth rotation and reduce frictional losses during operation.

Threshing cylinder diameter of wire loop type thresher

Peripheral speed (v) of the threshing cylinder per sec is given by,

$$v = \frac{\pi DN}{60}$$

Where, D= Diameter of cylinder (m)

N = Rotational speed of cylinder (rpm)

Let the peripheral speed of the cylinder (v) for the paddy threshing be 4 m/s and the speed of the cylinder be 300 rpm.

Therefore, the diameter of the cylinder is given by

$$D = \frac{60\ v}{\pi \times\ n} = \frac{60 \times 4\, m/s}{\pi \times 300} = 0.25\ \text{m} \approx 26\ \text{cm}\ (260\ \text{mm})$$

Threshing cylinder diameter: 260 mm

Power transmission unit

The power transmission system of the developed pedal-operated paddy thresher comprised a shaft assembly, chain–sprocket drive, bearings, and a pedal-operated mechanism. The threshing drum was securely mounted on the shaft and integrated with the transmission unit to transfer rotational motion. A combination of four sprockets and two chains was incorporated to efficiently transmit pedal-generated power to the threshing cylinder. The machine was designed to be manually operated through foot pedalling while maintaining a seated working posture to improve operator comfort and reduce physical fatigue. The operator pedals the machine while seated on a seat positioned at a height of 800 mm from the ground. Power generated through pedalling was transmitted from the pedal sprocket having 48 teeth to a smaller sprocket of 18 teeth through chain drive. This arrangement rotated the intermediate shaft of 25 mm diameter in the opposite direction. The intermediate shaft carried another sprocket of 22 teeth, which further transmitted power to the 18-tooth sprocket mounted on the threshing cylinder shaft (Fig. 2).

As the shaft rotated, the threshing cylinder also rotated and facilitated the separation of grains from the straw. The chain–sprocket transmission mechanism was incorporated to enhance the rotational speed of the threshing drum, thereby improving threshing efficiency and reducing operator fatigue, energy requirement, and total threshing duration. Similar observations regarding improved operational efficiency of pedal-operated threshers were also reported by Singh and Vinay (2014).

Seatinga rrangement

A bicycle-type seat was provided for the operator to sit comfortably during operation. The seat was mounted on the bicycle frame fabricated using hollow steel pipes. The pedal assembly consisted of a sprocket of 195 mm diameter fitted with a pedal arrangement. The sitting posture enabled easy pedalling and reduced operator fatigue during the threshing operation. The pedal operating assembly was detachable from the main frame for ease of transportation and maintenance. Provision for seat height adjustment was also made, allowing adjustment within a range of 5–10 cm to suit operators of different body dimensions.

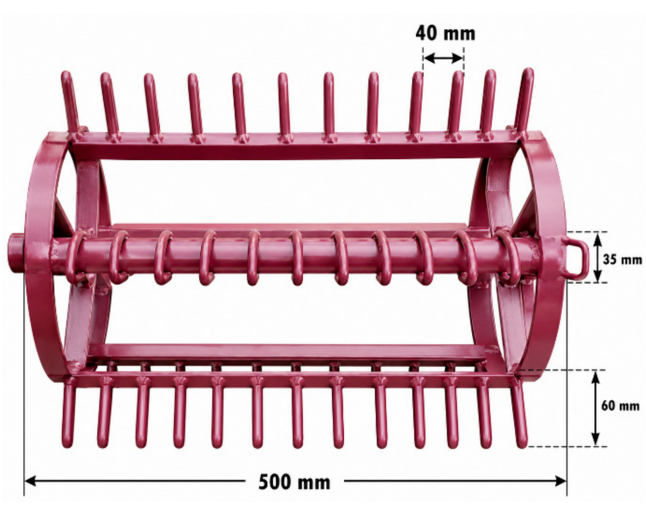

Fig. 1: Threshing cylinder of the developed thresher

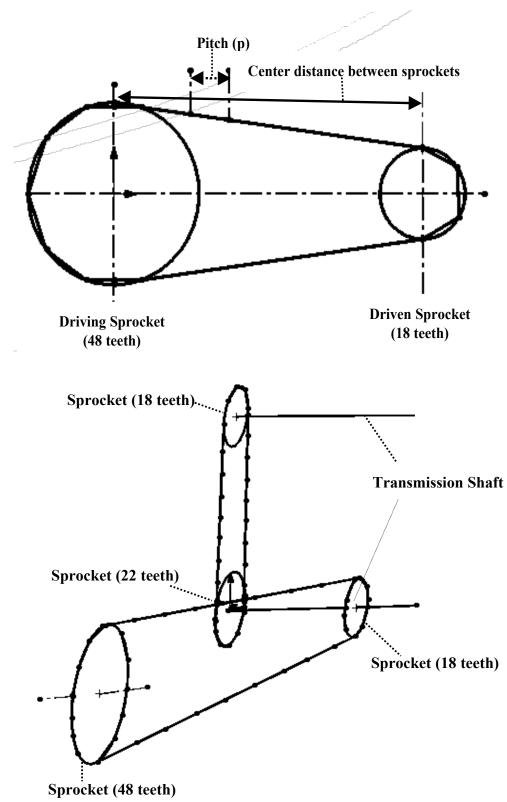

Fig. 2: Chain sprockets arrangements

Table 1: Technical description of the developed pedal-operated paddy thresher

Sr. No.	*Parameters*	*Values*
1	Overall size of machine (L × B × H), mm	1400 × 700 × 1100
2	Diameter of threshing drum with wire-loops, mm	380
3	Diameter of threshing drum without wire-loops, mm	260
4	Shape of wire-loops	U-shape
5	Wire-loop spacing, mm	40
6	Wire-loop tip height, mm	60
7	Number of strips on drum	6
8	Distance between two strips, mm	100
9	Number of wire-loops per strip	12–13
10	Length of drum, mm	500
11	Height of operator's seat from ground, mm	800
12	Average speed of threshing drum, rpm	300
13	Power transmission system	Chain and sprocket arrangement
14	Number of teeth on sprockets	22 & 18 and 48 & 18
15	Power source	One person
16	Operating mode	Sitting posture
17	Weight of machine, kg	55

Pedal operating unit

The developed pedal-operated paddy thresher utilized human leg power for operation, thereby eliminating fuel requirements and reducing operational cost. The developed machine was designed for convenient use by both male and female operators and was found suitable for small, hilly, and terraced farming conditions due to its lightweight construction and ease of portability.

The pedal operating assembly included a chain–sprocket arrangement in which a large sprocket transmitted power to a smaller sprocket connected to the threshing mechanism. The pedalling speed was maintained around 60 rpm, which is considered a comfortable pedalling rate for human-powered operations (Mutai *et al.*, 2018). Human beings are capable of generating approximately 75 W (0.1 hp) power through continuous pedalling operation (Sahay, 2019). Therefore, the pedal drive system was designed to efficiently utilize human power for threshing operation.

To obtain a higher rotational speed at the threshing drum, a larger pedal sprocket with 48 teeth was selected. The sprocket-chain transmission system helped in increasing drum speed and improving threshing performance while maintaining operator comfort during continuous operation.

Canopy (Protection Cover)

A protective canopy was provided around the threshing unit to minimize grain spillage during operation and reduce grain losses around the machine. The canopy also helped in preventing the scattering of grains in the surrounding area during threshing. The overall width of the canopy was maintained at 610 mm to ensure proper collection and protection of grains falling from the threshing cylinder. The canopy was fabricated using a good-quality PVC/polycarbonate sheet due to its lightweight, durability, and ease of fabrication.

Transportation wheels

The developed machine was equipped with three small ground wheels, including one free wheel, each having a diameter of 300 mm to enable convenient movement and easy transportation between operating locations. The machine could be conveniently pulled manually using a handle provided on the frame. During transportation, the wheels supported the machine movement, whereas during operation, the wheel assembly could be lifted and adjusted by removing a split pin and bolt arrangement. In operational condition, the handle also acted as a support stand for the operator's seat during pedalling. Due to its lightweight and wheel arrangement, the thresher could be easily transported by a single person.

Feed rate (Q) of the thresher on the basis of grain output and straw grain ratio (δ)

The straw grain ratio range of paddy is given below:

Crop	Range of straw grain ratio	Moisture content	
		Grain (%)	Straw (%)
Paddy	1.0–2.5	15–25 (IS 6284: 1985)	20–65

Using the relationship given by Sharma and Mukesh, 2013

$$\delta = \frac{Q_s}{Q_g}$$

Where, δ = Straw grain ratio (1.5)
Q_s = Straw output
Q_g = Grain output (1 quintal/h)

The feed rate for an output of 1 quintal/h grain having straw grain ratio of 1.5

Thus, $Q_s = \delta \times Q_g = 1.5\times1 = 1.5$ quintal/h

Therefore, feed rate Q = $Q_s + Q_g$
= 1.5 + 1 = 2.5 quintal/h = 0.069 kg/sec

Feed rate of thresher: 0.069 kg/sec (Fig. 3).)

Selection of variables

Independent Variables

The developed pedal-operated paddy thresher was experimentally evaluated under different operating

Fig. 3: Developed pedal-operated paddy thresher

conditions by selecting three independent variables, namely paddy variety, moisture content and feed rate. The experimental factors along with their respective levels used during performance evaluation are summarized in Table 2.

Dependent variables

The performance of the developed paddy thresher was evaluated based on two performance indicators, namely threshing efficiency and threshing capacity.

Threshing efficiency

Threshing efficiency was determined as the percentage ratio of the mass of threshed grain collected at the outlet to the total grain fed into the machine (Parihar, 2018; Lad *et al.*, 2020).

$$\text{Threshing Efficiency} = \frac{\text{Threshed grain collected, g}}{\text{Total grain collected, g}} \times 100$$

Threshing capacity

Threshing capacity, also referred to as output capacity, was calculated as the amount of grain discharged from the main outlet per unit operating time. (IS: 6284–1985, 1986; Amare *et al.*, 2015).

$$\text{Output Capacity}\left(\frac{\text{kg}}{\text{h}}\right) = \frac{\text{Weight of grain threshed (kg)}}{\text{Time taken (h)}}$$

Table 2: Details of experimental variables for performance evaluation

Sr. No.	*Independent factor*	*Level*	*Code*	*Details/Value*
1	Variety (V)	3	V1	Indira Sugandhit Dhan-1
			V2	IGKV R 1244 Maheshwari
			V3	Pusa Basmati-1
2	Moisture content (M), %	3	M1	14
			M2	15
			M3	16
3	Feed rate (F), kg	3	F1	1.0
			F2	1.5
			F3	2.0

Number of replications: 3

Results and Discussion

Field evaluation

Field evaluation trials were carried out at the institute farm as well as selected farmers' fields to assess the performance of the developed pedal-operated paddy thresher under varying operating conditions. The influence of experimental variables, namely crop variety, moisture content, and feed rate, on threshing efficiency and threshing capacity was investigated (Fig. 4). The results revealed that all the selected parameters significantly influenced the performance of the machine. The threshing efficiency ranged from 91.62 to 98.78%, whereas threshing capacity varied between 90 and 106 kg/h. Singh *et al.* (2008a) reported similar findings for pedal-operated paddy threshers and concluded that drum speed, crop moisture, and feed rate significantly affect machine efficiency and output performance.

Fig. 4: Developed pedal-operated paddy thresher in operation

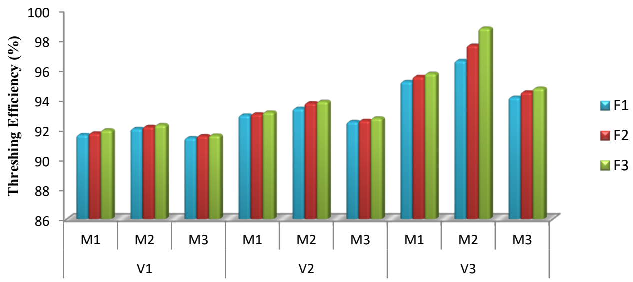

Fig. 5: Effect of moisture content (M) and variety (V) at different feed rate (F) on threshing efficiency

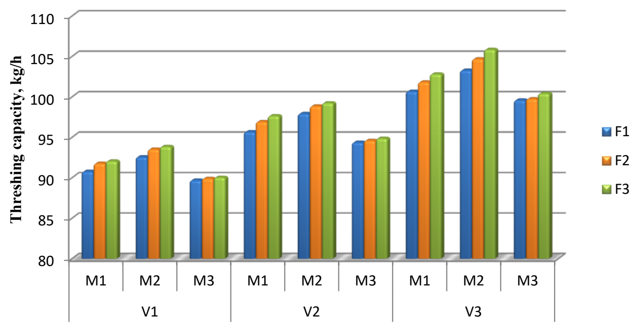

Fig. 6: Effect of moisture content (M) and variety (V) at different feed rate (F) on threshing capacity

Threshing efficiency

The combined influence of moisture content, crop variety, and feed rate on threshing efficiency is illustrated in Fig. 5. Statistical analysis revealed that each of these factors significantly affected threshing efficiency at a significance level of α = 0.05. The maximum threshing efficiency of 98.78% was obtained at 14% moisture content with feed rate F3 in Variety-3. The higher efficiency at moderate moisture content may be attributed to better grain separation and reduced grain breakage during threshing.

Similar findings were reported by Singh *et al.* (2008a), who found that the threshing efficiency of a pedal-operated paddy thresher increased at optimum moisture levels due to effective combing action between the crop and the threshing cylinder. Lad *et al.* (2020) also reported improved performance of modified pedal-operated portable paddy threshers at optimum moisture content and feed rate combinations. Furthermore, Amare *et al.* (2015) observed that maintaining suitable crop moisture improves grain separation and reduces unthreshed losses in pedal threshers.

Threshing cpacity

The interaction between moisture content and crop variety at varying feed rates and its influence on threshing capacity is presented in Fig. 6. A significant increase in threshing capacity was observed with an increase in feed rate, with the highest capacity of 105 kg/h recorded for Variety-3 at 14% moisture content under feed rate F3. The increase in threshing capacity may be due to improved feeding of crop material and effective transmission of pedal power to the threshing cylinder.

These findings are in accordance with the results concluded by Singh *et al.* (2008a) and Lad *et al.* (2020), who reported that higher feed rate and optimum moisture level enhanced threshing output of pedal-operated threshers. Similarly, Mutai *et al.* (2018) reported threshing capacities ranging from 90–110 kg h^{-1} for pedal-powered rice threshers under suitable operating conditions.

Effect of moisture content on threshing efficiency and capacity

The effect of moisture content on threshing efficiency and threshing capacity for different paddy varieties is depicted in Figs. 7 and 8. The results demonstrated that both threshing efficiency and output capacity increased as moisture content increased up to 14%, after which a reduction in performance was observed at moisture levels ranging from 15% to 16%.

At lower moisture content, increased grain breakage and shattering losses were observed, whereas at higher moisture content, separation of grains from panicles became difficult. In addition, at higher moisture levels, paddy bundles tended to float over the rotating cylinder, reducing the combing action between the wire loops and crop material. Therefore,

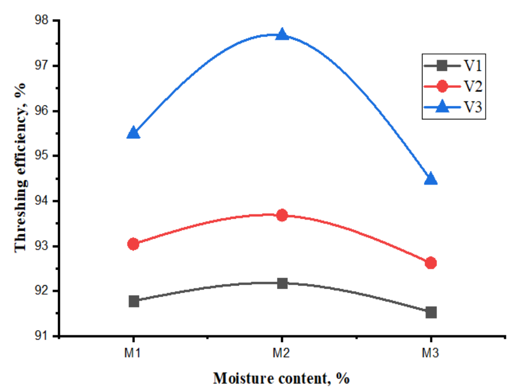

Fig. 7: Threshing efficiency *vs* Moisture content

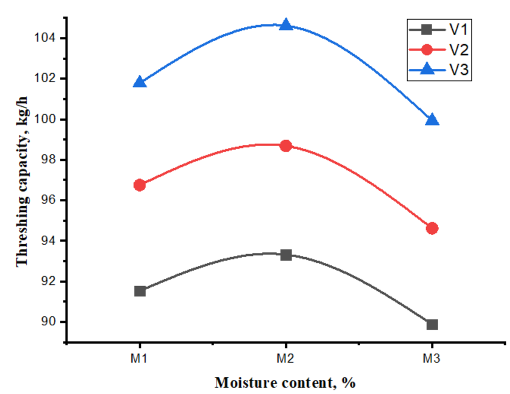

Fig. 8: Threshing capacity *vs* Moisture content

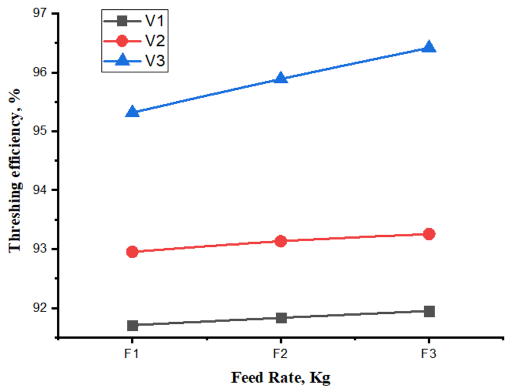

Fig. 9: Threshing efficiency *vs* feed rate

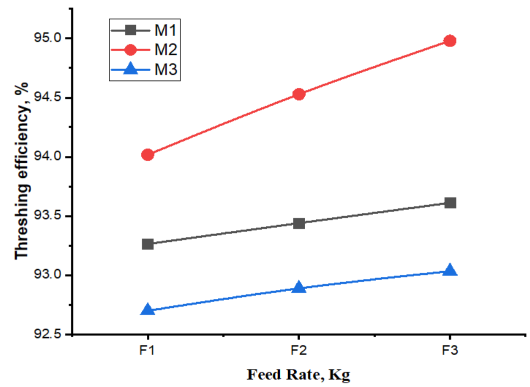

Fig. 11: Threshing efficiency *vs* Feed Rate

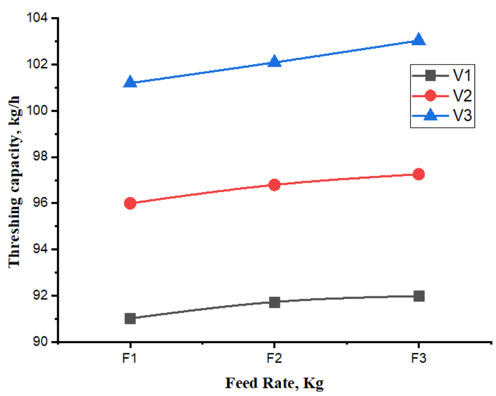

Fig. 10: Threshing capacity *vs* feed rate

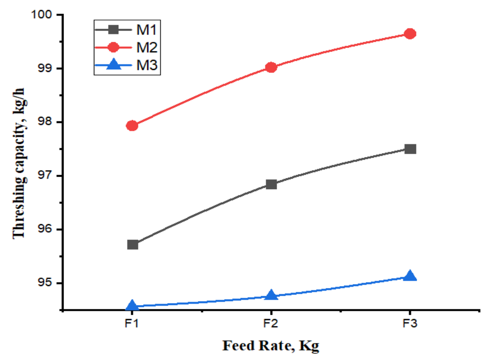

Fig. 12: Threshing capacity *vs* Feed Rate

optimum threshing performance was achieved at 14% moisture content (w.b.).

Similar trends were reported by Singh *et al.* (2008a), Singh *et al.* (2008b) and Dewangan (2007), who concluded that moderate moisture content provides better threshing and cleaning efficiency in pedal-operated paddy threshers. Amare *et al.* (2015) also reported that excessive moisture content adversely affects grain separation and machine efficiency.

Effect of feed rate on threshing efficiency and capacity

The influence of feed rate on threshing efficiency and threshing capacity is illustrated in Figs 9 and 10. The findings revealed that both threshing efficiency and output capacity increased with increasing feed rate and attained their highest values at a feed rate of 2 kg for Variety-3. Beyond this level, threshing efficiency started decreasing due to overloading of the threshing cylinder.

The decline in threshing efficiency at higher feed rates may be associated with non-uniform feeding, incomplete grain separation, and increased physical exertion experienced by the operator during pedalling. Similar observations were reported by Singh *et al.* (2008a), who found that excessive feed rate reduced threshing efficiency because the crop material could not be uniformly handled by the cylinder. Lad *et al.* (2020) also reported that optimum feed rate is essential for balancing machine output and threshing efficiency.

Combined Effect of Feed Rate and Moisture Content

The combined effect of feed rate and moisture content on threshing efficiency and threshing capacity is shown in Figs 11 and 12. The results demonstrated that threshing efficiency and capacity increased with an increase in feed rate up to an optimum level, while increasing moisture content beyond 14% caused a reduction in machine performance.

The improvement in performance with an increase in feed rate may be due to increased cylinder speed and effective utilization of pedal power. However, excessive moisture content reduced the threshing action due to poor grain separation. The optimum operating condition for the developed pedal-operated paddy thresher was found to be 14% moisture content with a feed rate of 1–2 kg.

These findings are consistent with those of Singh *et al.* (2008a), Dewangan *et al.* (2009) and Mohanty *et al.* (2009), who also reported that optimum moisture content and feed rate significantly improve the ergonomic and functional performance of pedal-operated threshers.

Cost of operation

The fabrication cost of the developed machine was estimated to be approximately ₹11,000 based on prevailing raw material and labour costs. The operational cost was calculated as ₹55 to 60 per quintal, considering annual usage of 300 hours and machine life of 10 years.

The operational cost obtained in the present study was comparatively lower than that of manual threshing methods, indicating the economic suitability of the machine for small and marginal farmers. Similar economic feasibility of pedal-operated threshers was reported by Singh *et al.* (2008b) and Srikanthnaik (2024), who highlighted that pedal-powered threshers reduce labour requirement and operational expenditure while improving work efficiency.

Conclusion

The developed pedal-operated paddy thresher performed efficiently under different operating conditions. Maximum threshing efficiency (98.78%) and threshing capacity (90–106 kg/h) were obtained at 14% moisture content with optimum feed rate in Variety-3. The machine was found suitable for small and marginal farmers due to its low cost, portability, simple operation, and reduced labour requirement. The study also confirmed that proper moisture content and feed rate significantly improved threshing performance. The developed thresher can be considered an economical and women-friendly technology for paddy threshing in rural and hilly areas.

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