DEVELOPMENT AND PERFORMANCE EVALUATION OF A ROTARY POWER WEEDER FOR PADDY CULTIVATION
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रोटरी पावर वीडर का विकास एवं धान की खेती में मूल्यांकन

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ABSTRACT
Manual weeders reduce labour requirements compared with hand weeding but remain time-consuming and physically demanding in paddy cultivation. A rotary power weeder powered by a 4.5 hp single-cylinder, air-cooled engine and equipped with three rotary units was developed for direct-seeded paddy and evaluated under field conditions. The machine was tested at three forward speeds and compared with manual weeding using a khurpi. Weeding efficiency decreased with increasing forward speed, whereas plant damage and power requirement increased. The highest grain yield and benefit–cost ratio were obtained at 1.27 km h⁻¹, which was identified as the optimum operating speed. Field evaluation demonstrated that the developed machine reduced labour requirements, provided effective weed control, and improved the operational efficiency of mechanical weed management in direct-seeded paddy cultivation.

सारांश
मैनुअल वीडर हाथ से निराई की तुलना में श्रम की आवश्यकता को कम करते हैं, किंतु धान की खेती में ये अभी भी समय-साध्य एवं श्रमसाध्य बने रहते हैं। डायरेक्ट सीडेड धान के लिए 4.5 हार्सपावर एकल-सिलेंडर वायु-शीतित इंजन तथा तीन रोटरी इकाइयों से युक्त एक रोटरी पावर वीडर का विकास कर क्षेत्रीय परिस्थितियों में मूल्यांकन किया गया। मशीन का परीक्षण तीन अग्र गतियों पर किया गया तथा इसकी तुलना खुरपी द्वारा मैनुअल निराई से की गई। अग्र गति बढ़ने पर निराई दक्षता में कमी, जबकि पौधा क्षति एवं शक्ति आवश्यकता में वृद्धि पाई गई। सर्वाधिक उपज एवं लाभ–लागत अनुपात 1.27 किमी प्रति घंटा की गति पर प्राप्त हुआ, जिसे सर्वोत्तम कार्य गति पाया गया। क्षेत्रीय मूल्यांकन से श्रम आवश्यकता में कमी, प्रभावी खरपतवार नियंत्रण एवं धान की खेती में यांत्रिक निराई द्वारा बेहतर परिचालन दक्षता सिद्ध हुई।

INTRODUCTION
Paddy is the main crop of the Asia and the world with share 60% and 25% of its global production, respectively (*Timmer, 2010*). Paddy is cultivated in 43.86 million hectares in India with 104.80 million tonne production and 2.39 tonne/ha productivity (*Ministry of Agriculture & Farmers Welfare, 2022*). Bihar is progressing fast in paddy production with present productivity level 4.02 tonne/ha (Finance Department, 2023).

Intensive need of resources in traditional method of paddy cultivation has forced the scientists and policy makers for advocacy of direct seeded paddy cultivation. Paddy production by direct seeding method is adversely affected by the heavy infestation of weed resulting into reduction in grain yield 40-65% (*Farooq et. al., 2011b; Kumar et. al., 2016, Roy et. al., 2011*). Weeds reduce the yield between 40-65%. Weed eradication or its effect control is the critical challenge for the paddy growing farmers (*Sharma et. al., 1977*). Weeding alone contributes to one-third of the total cost of cultivation as the loss in total estimated cost of production of paddy (*Rangasamy et. al., 1993*). The loss of yield due to weed in direct seeding method may be up to 70-80% (*Singh et. al., 2007; Hussain et. al., 2008; Mahajan et. al., 2009*). Cultivation of direct seeded rice may give 27-30% more yield than the transplanted rice under effective weed management practices (*Mishra et. al., 2012*). Use of traditional tools and equipment for mechanical weeding increases the cost of operation besides enhanced drudgery, wastage of inputs as well as damage to the produce (*Shrivastava, 2000*).

Chemical weeding method is highly adopted practice by the farmers in paddy cultivation, where yield is reduced significantly in comparison to mechanical weeding method. Mechanical weeding method retards the growth rate of the weed without adversely affecting the growth of the plants (*Kwangwaropas, 1999*). However, hand held mechanical weeders or tools require lot of time, energy and labour (*Patel et. al., 2018*). Development of effective power weeder may reduce the time of weeding and associated drudgery to the operators in weeding operation. Power weeding in maize requires approximately 10 labour-hours per hectare, compared with 167 labour-hours per hectare for manual weeding using traditional tools (*Dixit and Syed, 2008*). Undoubtedly, power weeder is advantageous for the farmers on account of enhanced field capacity in comparison to all types of manually and animal driven weeders (*More et. al., 2020*).

Agricultural mechanization is essential for improving labour productivity and operational timeliness, particularly in weed management, which remains one of the most labour-intensive field operations (*Hunt, 2001*). In small and medium landholdings, tractor-mounted implements are often unsuitable due to economic and field constraints; consequently, self-propelled and engine-operated rotary power weeders have emerged as effective intermediate mechanization options (*FAO, 2011*). These machines perform shallow soil working and weed uprooting using rotary tools, offering higher field capacity, reduced drudgery and improved weeding efficiency compared with manual methods (*Manuwa, 2009; Tewari et al., 2014;Kumar et al., 2023*). Several studies have reported labour savings exceeding 60% and significant improvements in operational efficiency in row crops and horticultural systems (*Singh and Singh, 2012; Kumar, et al., 2026*). However, the performance of rotary power weeders is strongly influenced by design parameters, soil conditions and crop geometry, underscoring the need for systematic design and field-level performance evaluation (*Kepner et al., 2018*).

Manual weeding remains the most widely adopted method of weed control in India; however, it is highly labour-intensive, time-consuming, and significantly increases the cost of cultivation. Weeding requires approximately 900–1200 labour-hours per hectare, accounting for nearly 25% of the total labour requirement in crop production (*Nag and Dutta, 1979*). Delayed or inadequate weeding can reduce crop yield by 30–60% (*Singh, 1988*), while yield losses due to weeds alone have been reported to range from 16–42%, depending on crop and location, contributing nearly one-third of the cultivation cost (*Rangasamy et al., 1993*). In India, approximately ₹4.2 billion is spent annually on weed control, and nearly 40 million tonnes of major food grains are lost each year due to weed infestation (*Singh and Sahay, 2001*). Yield losses of 5–60% have been reported under different weed intensities and management conditions and may reach 80% when weeds are not controlled during the critical stage of crop growth (*Dutta, 1981; Goel et al., 2008; Paraforos, et al., 2018*).

Several mechanical weeders, including manual, push–pull, bullock-drawn, and self-propelled rotary weeders, have been developed to reduce labour dependency. However, their adoption remains limited due to labour scarcity, increasing wage rates, low field efficiency, dependence on optimum soil moisture, and inconsistent weed control performance. In particular, most commercially available self-propelled rotary weeders require multiple passes for inter-row weeding in wide-row crops, resulting in lower effective field capacity, increased fuel consumption, higher operational cost, and reduced overall productivity.

Despite these developments, limited research has focused on designing and evaluating a high-capacity rotary power weeder capable of simultaneously improving field capacity, field efficiency, weeding efficiency, and operational economy under wide-row crop conditions. Furthermore, comprehensive field performance evaluation considering operational parameters such as forward speed, field efficiency, fuel consumption, power requirement, and weeding effectiveness is scarce. This knowledge gap limits the optimization and wider adoption of rotary power weeders in Indian farming systems.

Therefore, the present study was undertaken to develop and evaluate an improved rotary power weeder with enhanced operational performance under field conditions. The study aims to optimize key operational parameters to improve weeding efficiency, reduce labour requirement and operating cost, minimize operator drudgery, and enhance crop productivity.

MATERIALS AND METHODS

The power weeder was developed in the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology (CAET), Pusa. The design procedure is described below.

Drive Wheel

The design of the power weeder wheel is critical for ensuring effective traction, stability and soil engagement during operation. The wheel has a diameter of 44.80 cm and a hub bore diameter of 2.50 cm, providing sufficient clearance for mounting on the drive shaft while maintaining structural integrity.

The overall width of the wheel is 9.00 cm, with the spiked tread extending 7.00 cm, allowing adequate soil contact for propulsion and minimal slippage on soft or wet soils. The depth and geometry of the spikes, measured at 4.92 cm in height with a radial spacing of 6.45 cm, are designed to penetrate the soil effectively, loosening the top layer without causing excessive compaction. Triangular cut-outs on the wheel body reduce weight without compromising strength, while the rounded edges with radii R1.25 cm and R2.50 cm provide wear resistance and facilitate smooth rotation. The lateral thickness of the tines, ranging from 3.67 cm to 4.66 cm, ensures durability under repetitive loading and abrasive soil conditions as shown in fig. 1. Overall, the wheel design balances traction, mechanical strength and soil interaction to optimize the performance of the power weeder in various field conditions.

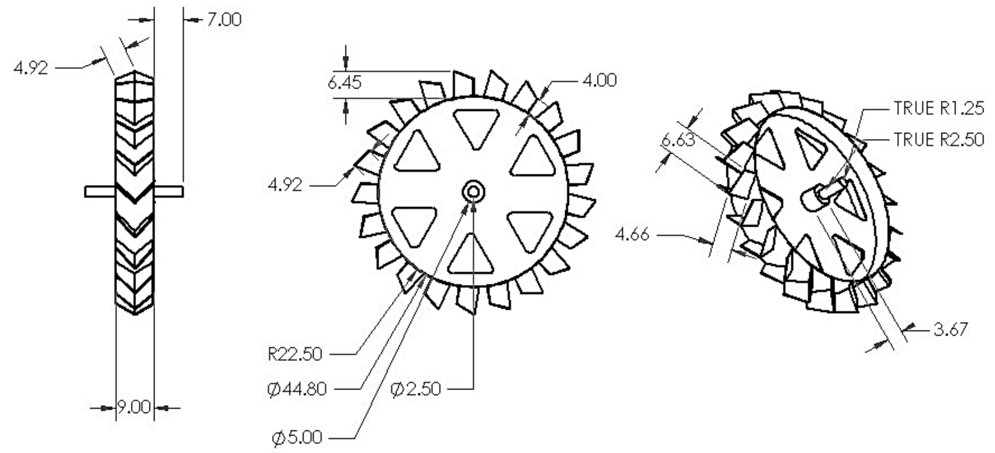

Fig. 1 - Different views of drive wheel

Vertical Rotary Blade

The power weeder blade design incorporates three rotary blades mounted on a 92.0 cm wide chain-driven assembly, with individual blade offset of 12.0 cm, ensuring balanced soil penetration and weed uprooting across varied field conditions. Key structural parameters include a 20.0 cm vertical height for the assembly, 9.50 cm and 4.0 cm horizontal spans for mounting stability, blade thickness of 0.5 cm, hub dimensions of 1.0 cm width by 12.0 cm length and a 12.0 cm base separation, which collectively optimize cutting width, torsional strength and minimal soil compaction during operation as shown in fig. 2. These dimensions support highly efficient weeding efficiency in multi-crop applications while maintaining operational safety and durability.

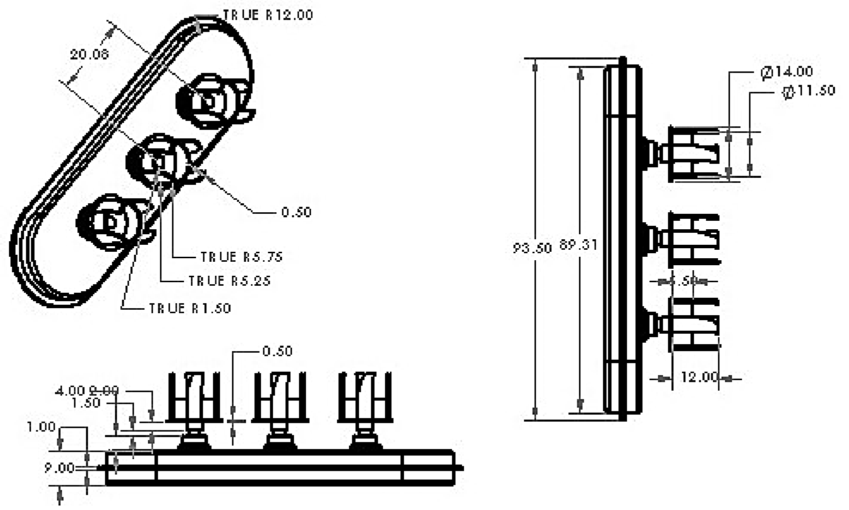

Fig. 2 - Different views of vertical rotary blade

Isometric view of the developed power weeder modeled in Solid Edge, illustrating the overall machine layout and spatial arrangement of major functional components and schematic diagram as shown in fig. 3. The view highlights the integration of the power unit, transmission system, rotary weeding mechanism and operator controls for design visualization and analysis.

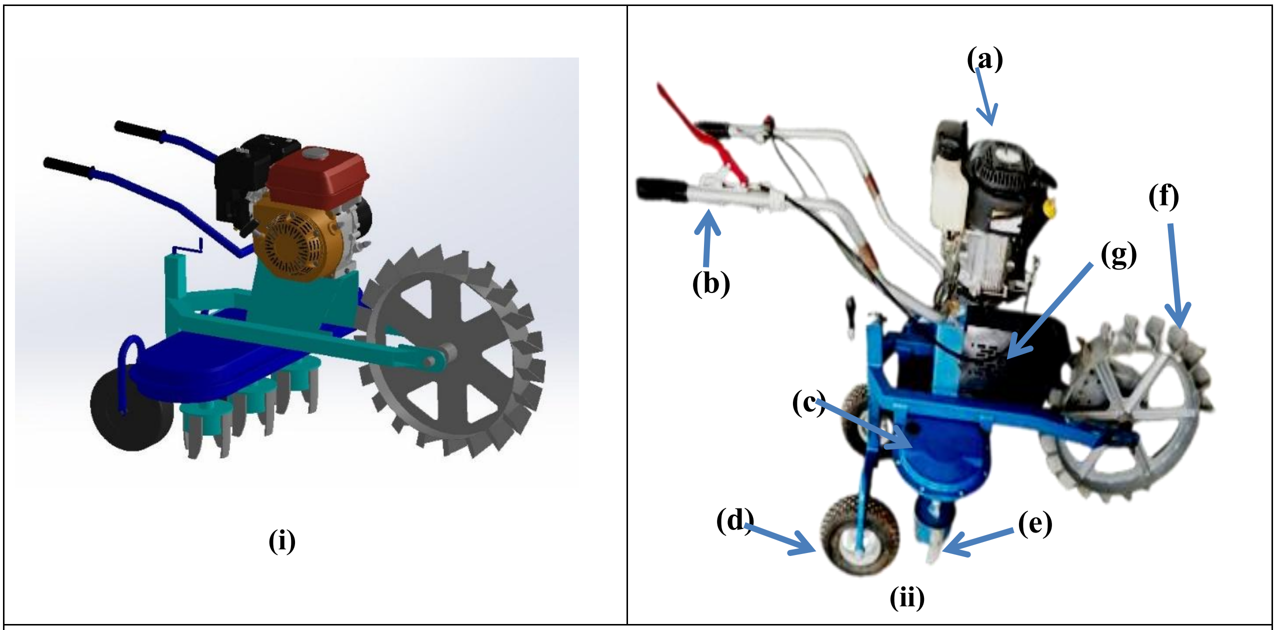

Fig. 3 - (i) 3-D model and (ii) a view of Schematic diagram of rotary power weeder showing major functional components;
(a) Engine; (b) Handle; (c) Gear box; (d) Depth control wheel; (e) Vertical rotor blade; (f) Drive wheel; (g) Gear Box

Component of Power Paddy Weeder

The drive wheel generates power for the forward movement of the machine. The vertical rotor wheel has a conical-shaped blade that cuts the soil as it rotates and helps the machine achieve the desired working depth. The Gear Box-I multiplies the engine speed (rpm) and transmits it to the rotor shaft, while Gear Box-II reduces the engine speed and delivers a lower rpm (about 10) to the drive wheel. The depth control wheel maintains a uniform cutting depth across the field.

The engine supplies power to operate all the other components of the machine. The specifications of the developed power weeder are given in Table 1. The cost of the machine was considered as ₹90,000.00 per unit for the purpose of cost calculation.

Table 1

Specification of developed power paddy weeder

Sl. No.	Machine components		Specification
1.	**Overall dimensions, mm (L×W×H)**	:	1600×740×1050
2.	**Type**	:	Self-propelled 3 row, walk behind type vertical axis rotary weeder,
3.	**Engine**		
	Type	:	4.5 hp, single cylinder, 4 stroke, 175 cc, air cooled, petrol engine
	Engine speed (recommended)		
	High idle speed, rpm	:	3600±100
	Lower idle speed, rpm	:	1900±100
	Rated speed, rpm	:	3600
	Speed at maximum torque, rpm	:	2500±100
4.	**Machine weight, kg**	:	85
5.	**Ground clearance, mm**	:	60
6.	**Rotor speed, rpm**	:	545
7.	**Fuel tank**		
	Material	:	Plastic
	Capacity, l	:	1.2
8.	**Drive wheel**		
	Material	:	G.I.
	Method of drive	:	Through chain & sprocket
	No. of sprocket teeth		
	Drive	:	18
	Driven	:	27
	No. of sprocket	:	02

Sl. No.	Machine components		Specification
9.	**Transmission ratio**		
	Primary reduction		
	Type	:	Crown and pinion
	No. of teeth on pinion	:	9
	No. of teeth on crown	:	29
	Ratio	:	3.2:1
	Secondary reduction		
	Type	:	Crown and pinion
	No. of teeth on pinion	:	16
	No. of teeth on crown	:	40
	Ratio	:	2.5:1
10.	**Rotor**		
	Rotor shaft		
	Type	:	Round
	Material	:	Medium carbon steel (EN9)
	Type of disc and number	:	Round and 3
	Rotor blades		
	Type	:	'J' shape
	Material	:	High carbon steel (EN42J)
	Number	:	12
	Cutting angle	:	45°
	Hardness(HRC)		
	At the cutting edge	:	42.67 (Average)
	At the shank	:	40.67 (Average)

Experimental Field

The evaluation of developed paddy power weeder was carried out in the research farm of Dr. Rajendra Prasad Central Agricultural University in Kharif 2023. The experimental plot was located at Latitude 25°98' N, Longitude 85°67' E and altitude 53.0 meter above the mean sea level. The soil of the plot was calcareous sandy loam with pH 8.5, composed with 90.3% sand, 9.7% silt and clay, 10-12% $CaCO_3$, 0.06% organic matter. The bulk density of the experimental plot was 1.43g/cm^3. The Rajendra Bhagwati paddy variety was grown by direct seeding method in a plot having area 1200 m^{2}and size 40×30m (Table 2) under dry condition.

Table 2

Crop and field parameters

Crop parameters		
Variety	:	Rajendra Bhagwati
Method of planting	:	Direct seeding
Field parameter and performance		
Plot size	:	40m x 30m
Soil type	:	Sandy loam
Soil P$_H$	:	8.1
Average soil moisture, %	:	10.80 to 12.40
Average bulk density, g/cc	:	1.84 to 1.90
Average depth of cut, mm	:	23.3 to 27.7
Average width of cut, mm	:	6 to 6.1
Average fuel consumption, l/h	:	0.88 to 1.20
Weed parameters		
Type of weed	:	Seasonal (Motha, *Cyperus rotundus*) (Sama or Sanwa, *Echinochloa colona*)
Height of weed, mm	:	80 to 120 (At the time of weeding)

Experimental Procedure

The experiment was conducted under the Randomized Block Design by operating the power weeder at three variable speeds i.e. 1.10 km/h, 1.27 km/h and 1.45 km/h. Weeding by hand tool *Khurpi* was taken as check treatment in the present experiment. Data were recorded in five replications of each treatment. Machine, crop, and economic parameters were evaluated to assess the performance of the developed machine and its effects on paddy yield and production economics. The results were compared with the farmers' commonly adopted practice of manual weeding using a khurpi or trowel.

The average working depth was 27.7 mm, with an engine speed of 3600 rpm and a rotor speed of 545 rpm. During the field evaluation, operator feedback regarding ease of operation and machine vibration was recorded qualitatively at the end of each experimental run. The standard formulae adopted for calculating the performance parameters of the developed power weeder are presented in Table 3.

Table 3

Standard formulae used for evaluating the performance of a power weeder

No.	Parameter	Formula [Units]	Citation
1.	Theoretical field capacity (TFC)	$\text{TFC} = \frac{S \times W}{10}$ [ha h^{-1}]	*Kepner et al., 2018; Ragesh et al., 2018*
2.	Effective field capacity (EFC)	$EFC = \frac{Effective\ coverage\ area\ by\ the\ machine\ (m^2)}{Total\ time\ taken\ in\ in\ hour\ (t) \times 1000}$ [ha h^{-1}]	*Kepner et al., 2018; Ragesh et al., 2018*
3.	Field efficiency (FE)	$FE = \frac{Effective\ field\ capacity\ (ha/h)}{Theoretical\ field\ capacity\ (ha/h)} \times 100$ [%]	*Islam et al. 2017; Ragesh et al., 2018*
4.	Weeding efficiency (WE)	$WE = \frac{w_1 - w_2}{w_1} \times 100$ [%]	*Thorat et al. 2014; Ragesh et al., 2018*
5.	Performance index (PI)	$PI = \frac{Effective\ field\ capacity \times (100 - Damage\ factor) \times Weeding\ index}{Input\ power}$ [ha hp^{-1}h^{-1}]	*Thorat et al. 2014; Ragesh et al., 2018*

Assessment of Grain and Straw Yield

The grain yield was recorded by using a wire square of 1m^2 by throwing it randomly in each treatment. In each treatment grain yield was recorded at five different locations, treated as replications. The straw yield was worked out by considering the grain straw ratio 1:1.15 for Rajendra Bhagwati paddy variety. The evaluation of machine parameters, including theoretical and effective field capacities, field and weeding efficiencies, fuel consumption and power consumption, was carried out as per the methodology outlined by *Sanjay (2024)*. Whereas, the performance index of weeder was determined by method described by *Rangasamy et al. (1993.)*

Cost Economics of Paddy and Straw

It was taken as per local market rate available in Samastipur town of Bihar. The paddy and straw cost were Rs 19.00/kg and 1.50 Rs/ kg, respectively. The cost of machine was carried out as per the methodology mentioned by *Sanjay (2024).*

RESULTS AND DISCUSSIONS

The average data of the replications with regards to the field capacity and field efficiency of the machine in all the treatments is presented in Table 4 and at the end of the operation, the operator reported that the machine was easy to operate and produced minimal vibration.

Table 4

Determination of Field Capacity & Field Efficiency of the machine in different treatments

Treatments	TFC (ha/h)	Theoretical Time (h/ha)	No. of Turns	Turning time/ turn (s)	Turning time (h/ha)	Actual Time (h/ha)	AFC (ha/h)	Field Efficiency (%)
T_1	0.0825	12.12	39	16	1.44	13.56	0.074	89.69
T_2	0.0953	10.49	39	16	1.44	11.93	0.084	85.45
T_3	0.1087	9.20	39	19	1.72	10.92	0.092	84.63

From the data recorded in Table 3 above, it was observed that the highest field capacity was recorded in treatment T_3 (0.092 ha/h) followed by treatment T_2 (0.084 ha/h*)* & treatment T_1 (0.074 ha/h)*.* The field efficiency of machine was found having antagonistic relationship with the field capacity. The field efficiency of machine was maximum 89.69% in treatment T_1 followed by treatment T_2 (85.45%) and the minimum in treatment T_3 (84.63%).

Since the actual field capacity (AFC) is not dependent on the theoretical field capacity, which in turn is influenced by the forward speed of the machine, the AFC was observed to increase with the increase in forward speed from treatment T1 (1.10 km/h) to treatment T3 (1.45 km/h) *(Kumar et al., 2018; Verma et al., 2020)*. When the machine speed was increased, operational control at the terminal points and near the headland required more time, resulting in higher turning time (*Bhoi & Dash, 2021*). Consequently, this adversely affected the overall field efficiency of the machine, which was found minimum (84.63%) in treatment T3 (*Ghosh et al., 2022; Yadav & Patel, 2023*). Field efficiency decreased with increasing forward speed because the actual field capacity did not increase proportionally with the theoretical field capacity. At higher operating speeds, turning losses at headlands, implement overlap, missed areas requiring correction, and time required for machine adjustments increased. In addition, higher speeds reduced the operator's ability to maintain precise machine guidance, resulting in greater operational inefficiencies. Consequently, the ratio of actual field capacity to theoretical field capacity declined, leading to a reduction in field efficiency.

The weeding efficiency of the machine as well as *khurpi* as control treatment was determined at 25 and 45 days after seeding (Table 5). There was a similar trend in variation of weeding efficiency of the machine both at 25 and 45 days after seeding (DAS).

Table 5

Determination of weeding efficiency (%) of machine in different treatments

Treatment	Forward speed of the machine (km/h)	Weeding at 25 DAS			Weeding at 45 DAS		
		Weed count/m^2 area before weeding	Weed count/m^2 area after weeding	Weeding efficiency (%)	Weed count/m^2 area before weeding	Weed count/m^2 area after weeding	Weeding efficiency (%)
T_1	1.10	134	18	86.57	63	7	88.89
T_2	1.27	169	23	86.39	63	8	87.30
T_3	1.45	161	27	83.23	60	10	83.33
T_4	-	152	7	95.39	66	3	95.45

At 25 days after seeding, the weeding efficiency in treatment T_1 and T_2 were 86.57% and 86.39%, respectively. In treatment T_3, the machine had exhibited lower weeding efficiency i.e. 83.23%. At 45 days after seeding, the weeding efficiency in treatment T_1 and T_2 were 88.89% and 87.30% respectively. However, the same was 83.33% in treatment T_3 at 45 days after seeding.

The manual weeding by *khurpi* in control treatment had registered highest weeding efficiency among all the treatments with values 95.39% and 95.45% at 25 and 45 days after seeding respectively.

The weeding efficiency of the machine at 45 DAS was found to be slightly higher, possibly due to the vigorous growth of paddy plants, which restricted the survival of weeds around the root zone (*Devi et al., 2021; Mehta et al., 2020*).

However, when the forward speed of the machine exceeded 1.27 km/h, there was a significant decline in the weeding efficiency of the vertical rotary weeder. This reduction occurred due to the smaller overlapping portion of the tilth soil during each blade rotation, which caused incomplete uprooting and allowed some weeds to survive within the tilled zone (*Rajendran & Manian, 2019; Dash et al., 2021; Singh et al., 2023*).

The plant damage reported in percentage (%) was increasing with increase in forward speed of the machine (Table 6). The trend in variation of plant damage by the machine recorded in different treatments had the antagonistic relationship with the performance index (Table 6).

The plant damage at 25 DAS was ranging between 2.63% to 2.98% in treatments from T_1 to T_3. However, at 45 DAS the same was minimum (5.34%) in treatment T_1, followed by treatment T_2 (5.81%) and treatment T_3 (6.78%) respectively. The power requirement of the machine for weeding was minimum 3.2 hp in treatment T_1 and maximum 4.1 hp in treatment T_3 followed by 3.8 hp in treatment T_2. However, the weeding efficiency of machine was increasing marginally in all the treatments at 45 DAS in comparison to weeding efficiency reported at 25 DAS. The performance index of the machine was maximum in treatment T_1, both at 25 DAS (190.19%) and 45 DAS (189.85%). The minimum performance index 181.98% was recorded at 25 DAS in treatment T_3 followed by 175.06% at 45 DAS.

Table 6

Determination of performance index of the machine

Treatments	AFC (ha/h)	Power (hp)	Weeding efficiency (%)		Plant damage (%)		Performance Index	
			At 25 DAS	At 45 DAS	At 25 DAS	At 45 DAS	At 25 DAS	At 45 DAS
T_1	0.0722	3.2	86.57	88.89	2.63	5.34	190.19	189.85
T_2	0.0825	3.8	86.39	87.30	2.46	5.81	182.94	178.52
T_3	0.0924	4.1	83.23	83.33	2.98	6.78	181.98	175.06

There was more plant damage in all the treatments at 45 DAS, probably due to the higher tillering per hill in the paddy crop, where plants often came in contact with the rotating blades, causing mortality during the forward movement of the machine (*Patel et al., 2020; Reddy et al., 2020*). The trend of increased plant damage percentage and decreased weeding efficiency with an increase in the forward speed of the machine resulted in the highest performance index in treatment T1 and the lowest in treatment T3 (*Kumar & Singh, 2022*).

The power requirement of the machine from treatment T1 to T3 was found to be in increasing order, primarily due to the higher operational speed during the weeding process (*Sharma et al., 2021*). Therefore, the observed increase in both plant damage percentage and power requirement for weeding from treatment T1 to T3 was responsible for the decreasing trend of the performance index of the machine across treatments (*Deshmukh & Tiwari, 2019*). Power requirement increased with increasing forward speed because the rotary blades engaged a larger volume of soil and weed biomass per unit time. This increased the soil-cutting force, draft resistance, and torque required to rotate the blades. Consequently, the engine was required to deliver higher power to overcome the increased operational load while maintaining the desired rotor speed. Additionally, the higher rate of soil fragmentation and biomass cutting at elevated forward speeds contributed to greater energy demand, resulting in an increase in power consumption.

The data of plant height recorded from 30 days after seeding in different treatments at successive interval of 15 days clearly indicates that the plant growth in all the treatments were symmetric and presented in Table 7. The plant height recorded at 45 days after seeding shown maximum growth of the crop (48.48 cm) in treatment T_1 and minimum (44.42 cm) in treatment T_4 (Control Treatment). However, after 60 days of seeding the plant height in treatment T_1, T_3 and T_4 were at par. In treatment T_1, there was maximum plant growth with crop height 780.8 mm.

Table 7

Measurement of plant height at different stages during crop growth

Treatments	Average of plant height after 30 days, mm	Average of plant height after 45 days, mm	Average of plant height after 60 days, mm
T_1	258.4	484.8	780.8
T_2	254.2	464.0	776.9
T_3	243.6	478.8	765.0
T_4	254.6	444.2	762.5

The weeding in paddy crop by machine had a positive effect on plant growth due to inter-row soil pulverization, which enhanced soil aeration and nutrient availability for the plants (*Deshmukh & Tiwari, 2019; Patel et al., 2020*). The change in machine speed had no significant impact on the extent of soil pulverization and therefore, only marginal variation was observed in plant height at 45 and 60 days after seeding across all treatments (*Kumar & Singh, 2022*).

The weeding by *khurpi* was also found to be equally effective because of its high weeding efficiency, coupled with improved soil aeration near the root zone of the plants (*Sharma et al., 2021*). The plant height in the control treatment at 45 and 60 DAS was statistically at par with the plant height in treatment T3, where the machine operated at a higher forward speed (1.45 km/h), indicating that increased speed did not significantly affect crop growth (*Reddy et al., 2020*).

The cost of cultivation of paddy crop by using power weeder and khurpi for weeding operation were worked out to determine the Benefit-cost ratio in all the treatments. The data with regards to B-C ratio in different treatments of machine operation and weeding by khurpi as control treatment is presented in Table 8.

Table 8

Economic assessment of Power Weeder vis-à-vis manual weeding in paddy crop

Treatments	Cost of common operation (Land preparation, Sowing, Irrigation & Harvesting and Threshing (Rs/ha)	Cost of weeding (Rs/ha)	Total Cost of cultivation (Rs/ha)	Cost of Produce (Rs/ha)			Benefit in cultivation in comparison to the traditional method (Rs/ha)	B-C ratio
	(1)	(2)	(3)=(1+2)	Grain (4)	Straw (5)	Total 6=(4+5)	(7)	(8)=(7/3)
T_1	16800	2974.57	19774.57	82608.2	7499.95	90108.15	70333.58	**3.56**
T_2	16800	2604.73	19404.73	83448.0	7576.20	91024.20	71619.47	**3.69**
T_3	16800	2326.30	19126.30	82239.6	7466.49	89706.09	70579.79	**3.69**
T_4	16800	9000.00	25800.00	81795.0	7426.12	89221.12	63421.12	**2.46**

From perusal of the data presented in the Table 7, it is evident that the benefit-cost ratio was in higher range (3.56 to 3.69) in weeding by machine from treatment T_1 to T_3, as compared to the manual weeding, by *Khurpi* (2.46). The B-C ratio was maximum in treatment T_2 and T_3 (3.69) and minimum (3.56) in treatment T_1, when the weeding was done by the use of power weeder. The weeding by *Khurpi* was found least economical on account of lowest B-C ratio among all the treatments.

The highest grain and straw yield were recorded in the paddy crop when weeding was done using a power weeder. This was probably due to the fact that the rotating blades pulverized the soil, leading to better aeration in the root zone and improved nutrient availability for plant growth and development (*Deshmukh & Tiwari, 2019; Singh et al., 2021*). In weeding by *Khurpi*, although the weeding efficiency was higher, the lower yield of the crop in comparison to machine weeding (treatments T_2 and T1) may be attributed to less soil pulverization, resulting in restricted aeration near the root zone of the plants (*Patel et al., 2020*). The highest B–C ratio in treatment T2, over treatments T1 and T3, was due to the higher yield of grain and straw in T1 compared to other machine operations. The lowest B–C ratio in the control treatment (T4) was mainly due to the reduced grain and straw yield and the higher cost of cultivation associated with *Khurpi* weeding, which required a large amount of manual labour for operation (*Kumar & Singh, 2022*).

CONCLUSIONS

The study evaluated the effect of forward speed of a rotary power weeder on field performance, crop yield and economic efficiency in paddy cultivation. Results revealed that an increase in forward speed enhanced the actual field capacity but led to higher plant damage, power requirement and a decline in field efficiency. The treatment operated at a moderate speed of 1.27 km h^{-1} (T_2) exhibited the most desirable combination of performance indicators, with superior weeding efficiency, lower crop damage and a balance between time efficiency and operational cost. Consequently, T_2 also recorded the highest grain and straw yields, resulting in the maximum benefit–cost ratio among all treatments. The findings suggest that maintaining an optimum forward speed of approximately 1.27 km h^{-1} ensures effective weed control, improved soil conditions and enhanced profitability in paddy cultivation. Adoption of rotary power weeders at this operational speed can significantly reduce labour dependency and promote sustainable mechanization in wetland paddy farming.

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