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Performance analysis of a developed self-propelled mini rotary weeder under field conditions

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Abstract

The performance evaluation of a self-propelled mini rotary weeder was conducted to assess its suitability for inter-row weed control in agricultural fields. The machine, powered by a 2.0 hp two-stroke petrol engine and equipped with a centrally driven rotary blade mechanism, was tested under field conditions to evaluate its operational efficiency, weed removal effectiveness, field capacity, and maneuverability. The developed weeder was operated in row crops with varying row spacings, and observations were recorded for weeding efficiency, plant damage, fuel consumption, and time required for operation. The test results indicated that the rotary weeder effectively uprooted and buried weeds while maintaining proper soil pulverization around the crop rows. The adjustable working width ranging from 140 mm to 250 mm enabled the machine to operate efficiently under different crop spacing conditions. The self-propelled feature reduced operator fatigue and improved ease of operation compared with conventional hand weeding methods. The rotating blades operating at approximately 176 rpm provided satisfactory soil stirring and weed-cutting action without causing significant crop damage. The machine demonstrated higher field capacity and lower labor requirements than traditional manual weeding practices. The evaluation confirmed that the developed self-propelled mini rotary weeder is a reliable and economical solution for small and medium-scale farming operations. Its compact design, low weight, and efficient power transmission system contribute to improved field performance and reduced weeding costs. The machine has significant potential to enhance farm productivity by reducing labor dependency and increasing the timeliness of weed management operations.

Keywords: Performance evaluation, self-propelled mini rotary weeder, weeding efficiency, field capacity, agricultural mechanization, weed control, rotary blades

1. Introduction

In tillage, rotary tiller blades may be rotated on vertical-axis rotor shifts. The resulting texture of rotary tiller tilled soil is a function of the soil condition, blade kinematics and soil flow dynamics (Kinzel, Holmes & Huber). The soil flow dynamics depends on whether the rotor axis of the cultivator is horizontal or vertical and on the direction of rotation of the blades. For the horizontal rotor axis, the blades may be rotated in down-cut or up-cut direction; while for the vertical axis, the direction of rotation may be clockwise or anticlockwise. In general, rotary tillers work on the horizontal axis rotor; and seldom on a vertical series of vertical axis rotors (Bukhari, Leghari & Memon).

In addition to the aforementioned advantages, the rotary tiller is used for weeding, weeding is an important but equally labour-intensive agricultural unit operation. Today the agricultural sector requires non-chemical weed control that ensures food safety. Consumers demand high quality food products and pay special attention to food safety. Through the technical development of mechanisms for physical weed control, it might be possible to control weeds in a way that meets consumer and environmental demands.

In spite of these advantages, the rotary tiller also mixes and pulverizes the tilled soil well; resulting in a good clod size distribution. The number of tillage passes required to achieve an acceptable tillage quality, using rotary tiller, is also significantly reduced (Destan & Houmy) in comparison to the series of operation that would result in the same tillage quality with the use of passive tools.

1.1 Weeds

Weeds are nothing but those unwanted plants which grow with the crop and they compete with the growing crop for light, nutrients and water. For the controlling of weed it is essential to know about the weeds for the experimental study to fulfil the purpose of design and development of women friendly weeder. Smith (1964) stated that inter cultivation is an operation that required some kind of tool that stir the surface of the soil to a shallow depth in such a manner that young weeds could be destroyed and crop growth promoted. Agrawal and Singh (1968) listed the common weeds of agricultural land with their scientific and common names. Biswas (1984) reviewed and reported about weeds in Bhopal region. Weeds classified in different ways as per their place of occurrence or habitat, duration of life cycle, plant family etc. Devnani (1988) and D Singh (1996) reported that the aim of inter cultivation is to provide best opportunity for the crop to established and grow vigorously, up to the time of harvest. The purpose of inter cultivation is to control the weed growth, improve the soil conditions by reducing evaporation from the soil surface, improve infiltration of rain or surface water, and to maintain ridges or beds on which the crop is grown. The control of weed is major objective as they compete with the crop for light, nutrient and water. Most of the work on weeding therefore emphasizes the need for timeliness of weeding operation. The underlines the need for farmers to have operation control over power and machinery. Since timeliness in weeding is virtually impossible to achieve if one is to rely on the traditional manually operated hand tools such hoe, khurpi and family labours. Duff and Oricno (1971) reported that the timing rather than the frequency of weeding was a major determination of effective weed control for crop. Recommendation have been made for the first weeding to be done 2-3 weeks after sowing, followed by a second weeding three weeks later and if necessary.

1.2 Loses due to weeds

Smith (1961) reported that the weed competition is a serious problem in almost all rainy seasons' crops causing the losses in yield ranging from 9 to 60 % or more. Grist (1976) has reported that the weeds affected the microclimate around the plants harbour diseases and pests, increases the cost of

production, plug irrigation and drainage canals and lower the quantity and quality of crop and showed that the competition of one grass plant (*Echinochloa crusgalli*) per square foot reduced yield of rice by 25%. Moorthy and manna (1989) [28] weeds compete severely with upland rice for light, nutrients, moisture and space. The yield losses are colossal ranging from 50-97%. Chandrakar and chandraker (1992) reported that the weeds compete severely for nutrients and depending upon the intensity of weeds growth, deletion of nutrients may be up to 86.5Kg N, 12.4Kg P and 134.5 Kg K per ha. Moorthy (1996) reported that the percent yield losses due to weed competition for the first one month, two month and entire crop season were 23.7, 35.4 and 40.8 respectively.

1.3 Methods of weed control

Weed control is the process of limiting weed infestation so that crops could be growth profitably and other activities of man conducted efficiently. Researchers with varied degree of success have tried many methods of weed control. Knowing the several of weed control and applying some of them systematically, based on the requirements and the situations, the problem of weeds in the agricultural farm may be kept under control. Agarwal and singh (1968) study the important methods of weed control. Biswas (1984) gave the detailed account of various important weed control methods.

2. Methodology

The testing of the developed single row power weeder involves various factors like operation safety, light weight of machine, overcomes man power scarcity, saves time and cost, easiness in fabrication are taken into account for its design procedure. The operation and adjustment were made simple so that a village artisan can fabricate, repair the weeder and farmer can operate the weeder easily.

2.1 Assembling of power weeder

After finalizing the dimensions of manufactured parts, assembling of all parts together was done and located in suitable frame, which carry the different units without baulking the performance of the engine and the weeder.



Fig 1: Development and Installation of Power Weeder

2.2 Testing and Performance Evaluation

Field testing was done by following the testing criteria and

aspects mentioned by test codes. Testing of developed power weeder was tested as per IS: 1976:1976 test code and

the following observations were recorded. Fig. shows testing and performance evaluation of different treatments.



Fig 2: Field Testing of Power Weeder

3. Weeding efficiency

It is the ratio between the numbers of weeds removed by power weeder to the number of weeds present in a unit area and is expressed as a percentage. The samplings were done by quadrant method, by randomly selection of spots by a square quadrant of 1 square meter (Tajuddin, 2006).

$$\text{Weeding efficiency (\%)} = \frac{W_1 - W_2}{W_1}$$

Where;

- W_1 = Number of weeds counted per unit area before weeding operation
- W_2 ; = Number of weeds counted in same unit area after weeding operation

3.1 Plant damaged

It is the ratio of the number of plants damaged after operation in a row to the number of plants present in that row before operation. It is expressed in percentage.

$$\text{Plant damage (\%)} = \left(1 - \frac{q}{p}\right) \times 100$$

Where,

- p = Number of plants in a 10 m row length of field before weeding.
- q = Number of plants in a 10 m row length of field after weeding.

3.2 Effective field capacity

Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of the

travel and the amount of field time lost during the operation. Effective field capacity is usually expressed as hectare per hour.

$$\text{EFC} = \frac{A}{T_p + T_i}$$

Where,

- EFC = Effective field capacity, ha/h
- A = Actual area covered, ha
- T_p = Productive time, h
- T_i = Non-productive time, h

3.3 Theoretical field efficiency

Theoretical field capacity of the machine is the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width. It is expressed as hectare per hour and determined as follows.

$$\text{TFC} = \frac{W \times S}{10}$$

TFC = Theoretical field capacity, ha/h

- W = Width of cut, m
- S = Speed of operation, Km/h

3.4 Field efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage. It includes the effect of time lost in the field and of failure to utilize the full width of the machine.

$$\eta_e = \left(\frac{\text{EFC}}{\text{TFC}}\right) \times 100$$

Where,

- η_e = Field efficiency %,
- EFC = Effective field capacity, ha/h.
- TFC = Theoretical field capacity, ha/h.

3.5 Fuel consumption

The fuel consumption has direct effect the economics of the power weeder. It was measured by top fill method The fuel tank was filled to full capacity before the testing at levelled surface After completion of test operation, amount of fuel required to top fill again is the fuel consumption for the test duration. It was expressed in litre per hour.

4. Techno- Economic Feasibility

4.1 Cost of Weeding Operation

The cost of weeding operation for all treatments was estimated based on the prevailing market price of inputs, fabrication cost of the implement, rental charges of machinery, and wages of operators and labourers, wherever applicable. The operational cost of the power weeder was categorized into two components, namely fixed cost and operating (variable) cost, following the methodology suggested by Kamboj *et al.*, 2012^[22].

Fixed costs are independent of the extent of machine use, whereas operating costs vary proportionally with machine utilization. The fixed cost components included depreciation, interest on investment, taxes and insurance, and housing cost. The operating cost comprised fuel consumption, lubricants, repair and maintenance, and labour wages. The total cost of operation was expressed in Indian Rupees per hectare (Rs ha⁻¹).

4.2 Operation cost

Cost of weeding operation performed for all treatments was worked out on the basis of the prevailing input and fabrication price of the implements, machinery and rental wages of operator and labours if required. The cost of operation of power weeder is divided into two heads known as fixed cost and operation cost, where fixed cost is independent of operational use while variable cost varies proportionally with the amount of use (Kamboj *et al.*, 2012) [22].

4.2.1 Repair and maintenance cost

The repair and maintenance cost is a product of machines cost price and repair and maintenance percentage factor (Kamboj *et al.*, 2012) [22].

RM = 2.5% × purchase price or capital investment per year

4.2.2 Fuel cost

Fuel cost is calculated based on actual fuel consumption for the operation.

4.2.3 Lubricants

It can be determined depending upon the maintenance cost or depending upon the oil price or oil consumption. Average lubrication cost is taken as 1.5% of fuel cost in Rs. /h. (Kamboj *et al.*, 2012) [22]

4.2.4 Wages of operator

Wages are calculated based on actual wages of workers per hour.

4.3 Fixed cost

4.3.1 Depreciation

It was a measure of the amount by which value of the machine decreased with the passage of the time. According

to the annual depreciation was calculated as follow:

$$D = \frac{C-S}{L \times H}$$

Where,

- D = Depreciation per hours
- C = Capital investments
- S = salvage value, 10% of capital investments (Rs.)
- L = Life of machine in hours or years.

4.3.2 Interest

Interest is calculated on the average investment of the machine taking into consideration the value of the machine in the first and last year. These are usually calculated on yearly basis. The annual interest on the investment can be calculated as.

$$I = \frac{C+S}{2} \times \frac{i}{H}$$

Where,

I = Interest per hours
i = 10% per year.

4.3.3 Taxes and insurance

Insurance charge is taken based on the actual payment to the insurance, it may be taken as 1 % of the initial cost of the machine per year.

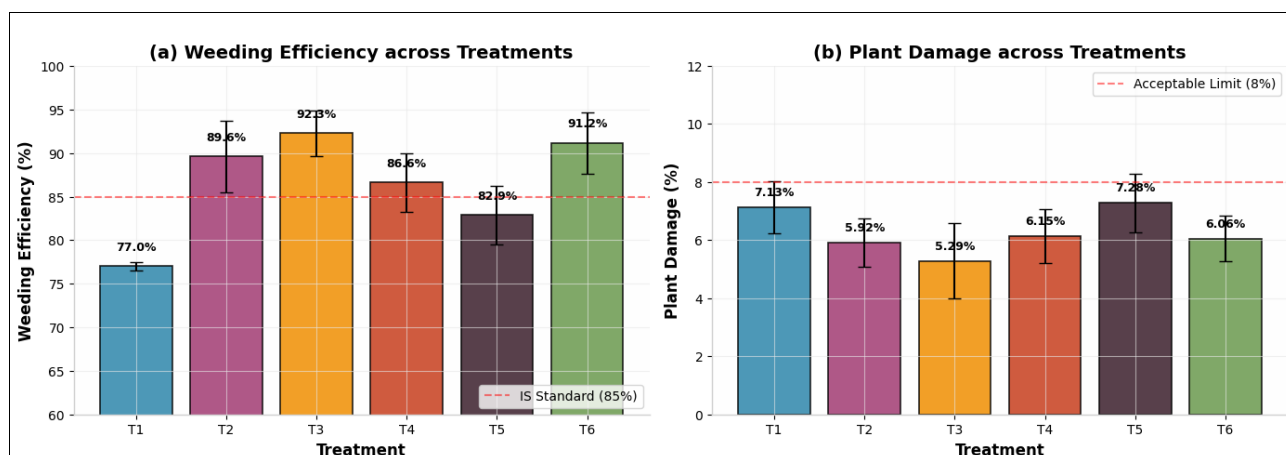
4.3.4 Housing

Housing cost is calculated on the basis of the prevailing rates of the locality, but roughly, the housing cost may be taken as 1% of the initial cost of the machine per year.

5. Results and Discussion

5.1 Weeding Efficiency

The performance evaluation of the power weeder under different treatments revealed significant variation in weeding efficiency (Fig.3a). Among the treatments, T₃ recorded the highest mean weeding efficiency of 92.3%, followed by T₆ (91.2%) and T₂ (89.6%). Treatments T₄ and T₅ achieved efficiencies of 86.6% and 82.9%, respectively, whereas the lowest efficiency was observed in T₁ (77.0%).



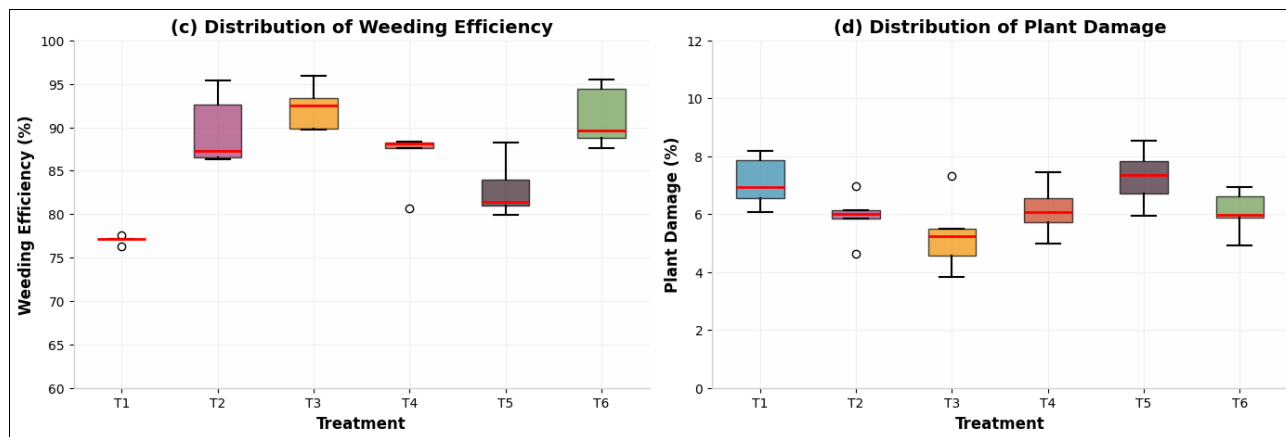


Fig 3: Performance Evaluation of Power Weeder

The results indicated that treatments T₂, T₃, T₄, and T₆ satisfied the Indian Standard (IS: 1976:1976) minimum requirement of 85% weeding efficiency, as represented by the reference line in Fig. 3a. In contrast, T₁ and T₅ failed to meet the prescribed standard. The superior performance of T₃ and T₆ may be attributed to improved soil-tool interaction, effective uprooting of weeds, and better field coverage during operation. Lower efficiency in T₁ could be due to inadequate penetration depth or improper operational parameters, resulting in incomplete weed removal.

The box plot distribution (Fig. 3c) further demonstrated that T₃ exhibited consistently high efficiency with comparatively lower variability, indicating stable performance under varying field conditions. Although T₆ also achieved high efficiency, a relatively wider spread suggested moderate variability in operational performance. T₅ displayed lower median efficiency and greater dispersion, indicating inconsistent weeding effectiveness.

5.2 Plant Damage Analysis

Plant damage caused during weeding operations varied among treatments (Fig. 3b). The highest plant damage was recorded in T₅ (7.28%), followed by T₁ (7.13%), while the lowest damage was observed in T₃ (5.29%). Treatments T₂, T₄, and T₆ resulted in plant damage of 5.92%, 6.15%, and 6.06%, respectively.

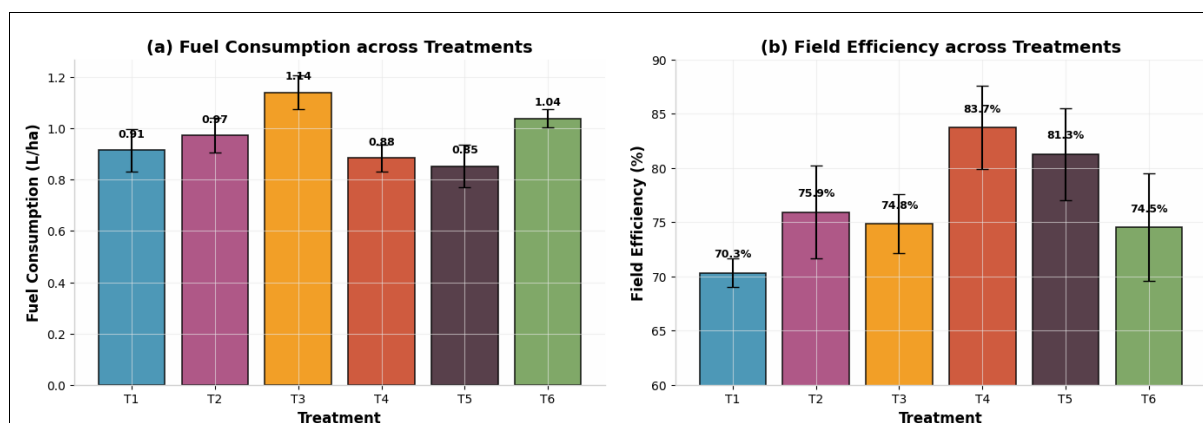
All treatments remained within the acceptable plant damage limit of 8% specified under IS standards, indicating the suitability of the developed power weeder for intercultural operations without causing excessive crop injury. The lower

plant damage observed in T₃ suggests that the treatment maintained an optimum balance between effective weed removal and crop safety. Conversely, higher damage in T₅ and T₁ may be associated with excessive blade aggressiveness, improper alignment, or inadequate maneuverability during operation. The distribution of plant damage shown in Fig. 3d, revealed relatively consistent performance for T₂, T₄, and T₆, whereas T₅ exhibited higher variability with a broader interquartile range. The presence of outliers in some treatments indicated occasional instances of increased crop injury, possibly due to field heterogeneity or operator handling differences.

5.3 Operational Performance of Power Weeder

The figure presents the operational performance of a power weeder across six treatments (T₁-T₆), focusing on fuel consumption, field efficiency, field capacity, and their interrelationship. Overall, the results highlight clear differences among treatments, indicating variations in operational effectiveness and energy utilization.

Fuel consumption varies across treatments, with T₃ recording the highest value (1.14 L/ha), indicating comparatively higher energy requirement and lower fuel efficiency. In contrast, T₅ shows the lowest fuel consumption (0.85 L/ha), followed closely by T₄ (0.88 L/ha), suggesting better fuel efficiency in these treatments. T₁, T₂, and T₆ fall in the intermediate range, with T₆ showing relatively higher fuel use (1.04 L/ha) compared to most treatments except T₃.



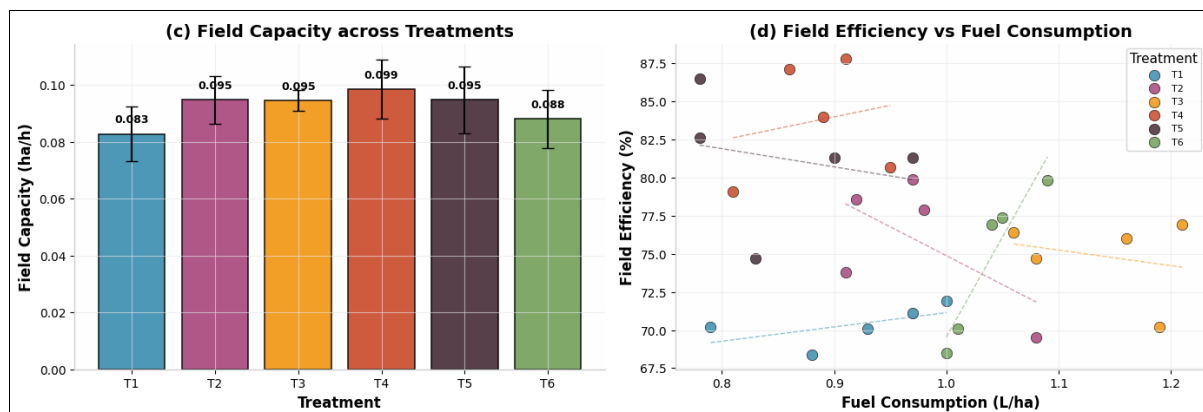


Fig 4: Operational Performance of Power weeder (Fuel, Efficiency and Capacity)

Field efficiency also differs significantly among treatments. T₄ demonstrates the highest field efficiency (83.7%), closely followed by T₅ (81.3%), indicating better utilization of machine time with minimal losses during operation. T₁ records the lowest field efficiency (70.3%), while T₂, T₃, and T₆ show moderate and comparable performance ranging between approximately 74% and 76%.

Field capacity shows a similar trend, with T₄ achieving the highest value (0.099 ha/h), indicating superior area coverage per unit time. Treatments T₂, T₃, and T₅ show similar intermediate capacities around 0.095 ha/h, whereas T₆ (0.088 ha/h) and T₁ (0.083 ha/h) exhibit lower performance, reflecting reduced operational throughput.

The relationship between field efficiency and fuel consumption shows a general tendency where improved efficiency is often associated with lower or moderate fuel use, although the relationship is not strictly linear. Treatments T₄ and T₅ appear to offer the best balance between high field efficiency and lower fuel consumption, making them the most operationally efficient options. In contrast, T₃ combines high fuel consumption with relatively lower efficiency, indicating poorer overall performance.

Overall, T₄ emerges as the most effective treatment due to its combination of highest field efficiency, maximum field capacity, and low fuel consumption. T₅ also performs well, particularly in terms of fuel economy, but is slightly lower in efficiency compared to T₄. Treatments T₁ and T₃ show comparatively weaker performance, with T₁ limited by low efficiency and capacity, and T₃ by excessive fuel consumption.

6. Conclusions

The field testing and performance evaluation of the developed single-row self-propelled mini rotary power weeder was conducted as per IS: 1976:1976 test code under six treatment combinations of weeding depth and row spacing, with five replications each. The overall results clearly demonstrated that both weeding depth and row spacing significantly influenced machine performance in terms of agronomic effectiveness, field efficiency, and energy requirement. Among all the tested parameters, treatment T₄ (5.0 cm weeding depth and 20 cm row spacing) emerged as the most balanced and practically suitable combination, delivering an optimum performance across multiple indicators.

The weeding efficiency of the machine varied from 77.04% to 92.28%, with the highest value observed in treatment T₃

(7.5 cm depth, 15 cm spacing). Although deeper operation improved weed removal efficiency, it also increased draft requirement and fuel consumption. In contrast, treatment T₁ showed the lowest performance due to insufficient soil penetration. Overall, it was observed that increasing weeding depth improved weed removal effectiveness, but beyond an optimum level it resulted in higher energy demand and operational load. Plant damage remained within acceptable limits in all treatments (5.29% to 7.28%), confirming that the machine design ensured safe operation around crop rows. Notably, even at higher depths, plant damage remained low, indicating effective blade configuration and proper crop clearance.

Fuel consumption ranged between 0.85 and 1.14 L/ha, increasing with greater weeding depth due to higher soil resistance and draft requirement. Wider row spacing contributed to reduced operational resistance and improved fuel economy. Field efficiency varied from 70.30% to 83.70%, with the highest value recorded in T₄, where moderate depth and spacing minimized turning losses and improved operational continuity. Similarly, field capacity ranged from 0.083 to 0.099 ha/h, with T₄ again performing best due to its superior balance of working width and field efficiency. Draft requirement, slip percentage, vibration levels, and noise levels all remained within acceptable operational limits, confirming the machine's suitability for field conditions typical of loam soil.

Overall performance assessment indicated that T₄ provided the most desirable combination of high field efficiency, satisfactory weeding efficiency, low plant damage, and relatively low fuel consumption, making it the most practical operational setting for real-field applications. While T₃ achieved the highest weeding efficiency and lowest plant damage, it was associated with higher energy demand, making it less economical for routine use. Therefore, T₄ is recommended as the optimum operational treatment for the developed mini rotary power weeder.

Economically, the machine demonstrated strong potential for small and marginal farmers, with an estimated operational cost of approximately Rs. 1,434 per hectare, which is significantly lower than manual weeding and competitive with other mechanical weed control methods. The reduced dependence on manual labour, improved field capacity, and adaptability to varying row spacings further enhance its suitability for Indian farming systems, particularly where labour shortages and small landholdings are major constraints. Overall, the developed self-propelled mini rotary power weeder successfully meets the design

objectives of efficient weed control, minimal crop damage, operational economy, and field adaptability, making it a viable and practical solution for modern agricultural weed management.

Declaration of Generative AI and AI-assisted technologies

The authors take complete responsibility of the information present in the manuscript. They did not use any kind of AI tools or related technologies in drafting the review paper.

Author statement

Myself (Krishna) gathered relevant research articles, participated in the sequence alignment, and drafted the manuscript. Other authors, created the diagrammatic representation and conceptualised the data. Also, provided additional information about systems. Finally, validated and visualized the information in the manuscript for final submission.

Declaration of competing interest

The authors declare that they have no financial interests or personal relationships that could have appeared to influence the information reported in this paper.

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