International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(8): 575-579
Received: 25-05-2025
Accepted: 27-06-2025

RK Naik
Professor (FMPE), SVCAET&RS, IGKV, Raipur, Chhattisgarh, India

Meesha Lahre
M. Tech, (FMPE), SVCAET&RS, IGKV, Raipur, Chhattisgarh, India

Sourabh Kumar Dewangan
Ph. D Scholar, (FMPE), SVCAET&RS, IGKV, Raipur, Chhattisgarh, India

Corresponding Author:
RK Naik
Professor (FMPE), SVCAET&RS, IGKV, Raipur, Chhattisgarh, India

Development of a battery-supported sprayer- cum-weeder

RK Naik, Meesha Lahre and Sourabh Kumar Dewangan

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i8Sh.3683

Abstract
In India, insects, diseases and weeds cause major losses in crop yield. Weed control with hand tools is labor-intensive and inefficient, highlighting the need for mechanical weeders to improve productivity. Similarly, pest and disease management requires frequent pesticide and fungicide spraying, which adds labor and cost. Since ineffective weed management is a major hurdle in crop and vegetable production, mechanical weeders are essential to boost yield and efficiency. A machine that integrates both weeding and spraying can reduce effort, save time and enhance crop yield sustainably. Therefore, a new machine that functions as both a sprayer and a weeder was developed and tested in a study. It was intended to manage particular crop parameters such as row spacing and plant height for different horticultural crops. The machine is mounted on a strong frame (1109 mm × 600 mm × 1000 mm) and is powered by a 650 W PMDC motor supplied by 42 V LifePo4 lithium -Ferro phosphate battery, while the spraying unit operates with a 12 V lead-acid battery. For weeding, interchangeable blades (B_1 weeder blade and B_2 tiller blade) are attached using nuts and bolts, with B1 weighing 4.34 kg and B2 weighing 7 kg. The sprayer system consists of a double motor diaphragm pump (7 bar pressure), a brass hollow cone nozzle assembly with four nozzles (each with six holes) and a 1.8 m wide boom mounted 700 mm above the ground, connected to a 25 L tank through a 1.8 m hose pipe of 20 mm diameter. The machine can operate at a speed of 2-2.5 km/h with a ground clearance of 370 mm, supported by wheels and a chain-sprocket transmission system. The overall machine weight is 77 kg for the weeder and 102 kg when equipped with the sprayer tank. The total cost of fabrication was ₹60,350, with an operating cost of ₹75.26 per hour or ₹242.77 per hectare. Economic analysis indicated a payback period of just over three years, confirming the machine's viability for small and marginal farmers.

Keywords: Weed management, pest control, mechanical weederC

Introduction
Weeds are a major threat to crops, often causing more economic damage than insects or diseases. They are responsible for about one-third of crop losses, and controlling them makes up roughly 16% of farming costs. (Chandrakanth, 2022) [2]. Farm mechanization improves the daily lives of farmers by reducing hard labor and the need for manual workers. Countries with higher levels of mechanization can increase their crop production, making them better prepared to meet current and future food demands. (Tiwari *et al*., 2019) [9].

On small farms, weeding and spraying are often done by hand, which is slow, tiring, and can be inconsistent. Combining these two tasks into a single pass would save time and money. Both effective weed control and precise crop protection are essential for growing healthy horticultural crops, ensuring high yields, and lowering labor costs. Traditionally, farmers perform these two critical jobs-spraying agrochemicals and weeding between and within rows-as separate operations. This traditional approach increases both the time and cost for farmers. An effective substitute for fossil fuels when it comes to powering moving equipment has been found in batteries. In the realm of agriculture, a battery-operated sprayer with a DC pump that utilizes accumulated electrical energy presents numerous benefits (Chandrakar *et al*., 2024) [3].

Design calculations and parts selection: The design process for this project started with a series of calculations. We determined the power needed for the weeder by looking at key factors like soil resistance, the speed of operation, and the width of the cut.

These calculations were essential to ensure the final machine would be both efficient and effective.

Selection of motor power

The power a weeder needs is greatly affected by soil resistance, as well as the rotor shaft design and the speed of operation. Since the weeding operation offer less soil resistance due to soil moisture and tilled condition soil resistance were kept as 0.0056 kg/mm^2. Since operator has to walk behind the weeder, so speed of operation of the weeder was considered as 0.4 ms^{-1} to 0.7 m/s. Most of horticultural crops (bitter gourd) the spacing between rows between 1540-1620 mm and hence width of operation was considered 350-400mm. The depth of operation was considered as 35 to 40 mm and transmission efficiency is 82%. Power requirement for battery operated weeder was calculated using the formula (Sahay, 2010) [6].

$$P = \frac{SR \times d \times w \times v}{75}$$

where,
SR = soil resistance, kg/mm^2
d = depth of cut, mm
w = effective width of cut, mm
v = speed of operation, ms^{-1}
Hence, power requirement is estimated as

$$P = \frac{0.0056 \times 40 \times 350 \times 0.6}{75}$$

P = 0.627 hp
= 0.467 kW
The total power required is estimated as follows

$$Pt = \frac{P}{\eta}$$

$$= \frac{0.467}{0.82} = 0.569 \text{ kW}$$

where,
P = Power required for digging the soil, kW
η = Transmission efficiency, %
A DC motor with a power output of at least 0.569 kW recommended. Based on market availability, a 650W DC motor would be a suitable choice for this weeder.

Selection of motor torque

The formula is used for the calculation of the torque transmitted though the shaft. (Khurmi, 2005) [4].

$$T = \frac{P \times 10^3 \times 60}{2 \times \pi \times N}$$

Where,
P = power, kW
T = torque transmitted by the shaft, N-m
N = revolutions per minute, rpm
Considering the motor speed as 2500 and motor power be 0.569 kW, we get torque

T = 2.17
Thus, the torque of 2.17N-m was obtained.

Design of rotor shaft

A shaft is a rotating machine element which is used to transmit the power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) setup within the shaft permits the power to be transferred machine or components linked up to the shaft. In designing process, the maximum tangential force which can be induced by the rotor should be considered. The maximum tangential force occurs at the minimum of blades tangential speed is calculated by the following (Bernacki *et al.*, 1972) [1].

$$Ks = \frac{Cs \times 75 \times Nc \times \eta c \times \eta z}{u}$$

Where,
Ks = Maximum tangential force, kg
Cs = Reliability factor (1.5 for non-rocky soils and 2 for rocky soils)
Nc = Power of motor, hp
ηc = Traction efficiency for the forward rotation of rotor shaft (0.9)
ηz = Coefficient of reservation of engine power (0.7)
u = Minimum tangential speed of blades

$$Ks = \frac{1.5 \times 75 \times 0.87 \times 0.9 \times 0.7}{2.07} = 29.78 \text{kg}$$

Tangential peripheral speed, u is calculated using the following equation:

$$u = \frac{2 \times \pi \times 132 \times 150}{60 \times 1000} = 2.07 \text{ ms}^{-1}$$

Where,
N = revolution of rotor, rpm
R = radius of rotor wheel, mm

$$u = \frac{2 \times \pi \times 132 \times 150}{60 \times 1000} = 2.07 \text{ ms}^{-1}$$

After substituting the value of revolution of rotor shaft (132 rpm) and its radius as 150mm in the equation we get the tangential peripheral speed (u) to be 2.07 m/s. Substituting the value of tangential peripheral speed (u) in the equation of maximum tangential force and thus value determined equals to 29.78 kg. The maximum moment on the rotor shaft (Ms) is obtained by the following (Bernacki *et al.*, 1972) [1].
Ms=Ks× R
Ms= 29.78 × 150
Ms = 4467 kg-mm
The allowable stress on the rotor (π_{all}) was calculated by following the equation (Mott, 1985) [5]:

$$\pi_{all} = \frac{0.577 \times k \times \sigma_y}{f}$$

Where,
π_{all} = allowable stress on rotor shaft, Mpa
k = Coefficient of stress concentration (0.75)
f = Coefficient of safety (1.5)
σ_y = Yield stress, 520 MPa (Yield stress of rolled steel (AISI 302)

$$\pi_{all} = \frac{0.577 \times 0.75 \times 520}{1.5} = 150.02 \text{ Mpa}$$

By substituting above values in the following equation, rotor shaft diameter was calculated as:

$$D = \sqrt[3]{\frac{16 \times M_s}{\tau_{all} \times \pi}}$$

Where,
τ_{all} = Allowable stress on rotor shaft, kg/cm$^{2.}$
D = Rotor shaft diameter, mm;
M_s = Maximum moment on the rotor shaft, kg-cm;

$$D = \sqrt[3]{\frac{16 \times 446.7}{1530.6 \times \pi}} = 11.41\text{mm}$$

In order take into account fluctuating load during the operation, diameter of the rotor shaft was selected higher than the calculated value as 20 mm.

Design of blade

Different parameters used in the study and have been in consideration to give safe strength and bending values for manufactured blades during weeding operation. The calculation and assumptions are based on standard handbook of machine design were followed. Assumption was made as follows; Number of blades in one working set = 6; Length of blade = 70 mm; Width of blade = 30 mm. To calculate the design strength of blade; revolution per minute of rotor shaft (N) = 132 rpm; radius of output rotor (R) = 150 mm.

For cutter blade design, number of blade, cutting width and thickness were important parameters. During cutting, blades would be subjected to shearing as well as bending stresses. Total working width of the weeder was 350 mm having rotor shaft of length of 480 mm. Total of 12 blades were provided with cutting width of 30 mm. Therefore, four blades were provided on each flange and two flanges were mounted on rotor shaft. The soil force acting on the blade (Ke) was calculated by the following.

$$Ke = \frac{\text{Ks} \times \text{Cp}}{\text{i} \times \text{Ze} \times \text{ne}}$$

Where,
Ke = Soil force acting on the blade, kg;
Cp = Coefficient of tangential force as 0.8,
i = Number of flanges is 2,
Ze = Number of blades on each side of the flanges is 6, and
Ne = Number of blades which act jointly on the soil by total number of blades.

$$\text{Ke} = \frac{29.78 \times 0.8}{2 \times 6 \times 2/12} = 11.91\text{kg}$$

The soil force acting on the blade (Ke) was determined as 11.91 kg.

The values of be, he, S, S_1were equal to 0.2, 2, 7 and 1.5 cm Considering the shape of the blades, the bending stress (σ_{zg}), shear stress (τ_{skt}), and equivalent stress (σzt) can be calculated by the following equations (Bernacki *et al.*, 1972) [1]:

$$\sigma_{zg} = \frac{6 \times Ke \times S}{be \times he^2}$$

Where,
σ_{zg} = Bending stress, MPa;
Ke = Soil force acting on blade, kg;
S = Blade length, mm;
be = Blade thickness, mm; and
he = Width of blade, mm.

$$= \frac{6 \times 11.91 \times 70}{3 \times 30^2} = 1.8526\text{kg/mm}^2 = 18.2\text{Mpa}$$

$$\tau_{skt} = \frac{3 \times \text{Ke} \times \text{S}^1}{(\frac{he^1}{be} - 0.63) \times \text{be}^3}$$

where,
τ_{skt} = Shear stress, MPa;
K_e = Soil force acting on blade, kg;
S^1 = Distance from the shank, mm;
b_e = Blade thickness, mm; and
h_e = Width of blade, mm.

$$\tau_{skt} = \frac{3 \times 11.91 \times 15}{(\frac{20^1}{2} - 0.63) \times 2^3}$$

= 7.1498kg/mm^2 = 70.11 Mpa

$$\sigma_{zt} = \sqrt{\sigma_{zg}^{\ 2} + 4\tau_{skt}^{\ 2}}$$

Where,
σ_{zt} = Equivalent stress, MPa;
σ_{zg} = Bending stress, MPa; and
τ_{skt} = Shear stress, MPa.

$$= \sqrt{18.2 \times 18.2 + (4 \times 70.11 \times 70.11)}$$

=2.8102kg/mm^2 =27.5Mpa

The bending stress, shear stress and equivalent stress were determined as 18.2MPa, 70.11MPa and 27.5MPa, respectively.

Speed reduction

Speed reduction of motor consists of spur gears received the mechanical power from the DC motor by a coupling. It consists of set of speed reduction gears having number of teeth as 10 and 45, respectively. The input shaft to the gear box was rotating at the speed of 595 rpm by the motor. The speed of output shaft of the gear box was 132 rpm. The calculations of the same are given below (Sharma and Mukesh., 2010) [7]:

N_1 = 595 rpm, T_1 = 10 teeth, T_2 = 45

$$N_2 = \frac{N_1 \times T_1}{T_2}$$

N_2 = 595× 10/ 14

N_2 = 132 rpm

The speed reduction ratio was found to be 1:4.1.

Battery

A battery can be defined as an electrochemical device (consisting of one or more electrochemical cells) which can be charged with an electric current and discharged whenever required. Batteries are usually devices that are made up of multiple electrochemical cells that are connected to external inputs and outputs.

Consumption of battery

A battery can be defined as an electrochemical device (consisting of one or more electrochemical cells) which can be charged with an electric current and discharged whenever required. Batteries are usually devices that are made up of multiple electrochemical cells that are connected to external inputs and outputs. The battery capacity is directly proportional to days of autonomy and inversely to discharge rate.

$$\text{Battery capacity, (Ah)} = \frac{\text{Total Watt hours per day used by appliance} \times \text{Days of autonomy}}{\text{Discharge rate of battery} \times \text{nominal battery voltage}}$$

Where,

Total watt hours per day = Total power used by appliance in one day

= 650 x 4 = 2600

Days of autonomy is defined as the number of days that the battery can supply the site's loads without any support from generation sources.

Discharge rate is defined as the steady current in amperes (A) that can be taken from a battery of defined capacity (Ah) over a defined period (h) =18/3 = 6

Nominal battery voltage = the total battery voltage on full charged condition = 42

Assumption,

For 1 hour application and for single day storage

Nominal voltage = 42V

$$\text{Battery capacity} = \frac{2600 \times 1}{6 \times 42} = 16.04$$

Battery capacity = 10.31 Ah (No-load)

Size of battery

Single battery of 42 V and 18 Ah.

Equivalent voltage = 42 V

Equivalent charge = 18 Ah

Charging time of battery

Charging time of battery = Battery Ah / Charging Current

= 18/6 = 3 h.

Discharging time of battery when connected to motor

Fully charged deep cycle battery, could up to 95% discharge

$$\text{Discharging time, h} = \frac{\text{Battery amp delivered}}{\text{amp required by PMDC motor}}$$

= (18 × 0.95) / 2.2

= 17.1/2.2

= 7.77 h (No-load condition).

Developed prototype battery supported sprayer cum weeder

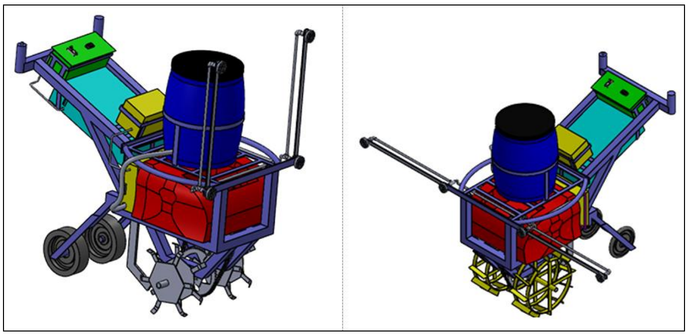

Fig 1: Developed prototype of sprayer cum weeder

Table 1: Components of sprayer cum weeder

S. No.	Components	Particular	Specifications
1.	Handle	Height from ground	1m
		Length of handle	490mm
2.	Battery	Type	LifePo4
		Voltage	42v
3.	Main frame	L×W×H	1109mm×600mm×1000mm
		Attachment	Weeder and sprayer
4.	Motor	Power (watt)	650watt
		Type	PMDC
5.	Blade	Type	B1(weeder wheel blade), B2(tiller blade)
		Attachments	Nut and bold is used
		Weight	B_1= 4.34kg; B_2=7kg
6.	Panel box	Placement	Front end
Details of sprayer			
7.	Nozzle	No. of holes	6
		No. of nozzle	4
		Material	Brass
		Type	Hollow cone type
8.	Hose pipe	Length	1.8m
		Diameter	20mm

9.	Pump	Type	Double motor diaphragm pump
		Pressure	7 bar
10.	Boom	Width	1.8m
		Height from ground	700mm
11.	Battery	Type	Lead acid
		Voltage	12V
12.	Tank	Capacity	25L
13.	Wheels	Type	W_1= transportation wheel, W_2= support wheel
		Diameter	W_1=305mm; W_2=199mm
Additional overall specifications			
14.	Power source		Battery operated
15.	Power transmission		Chain and sprocket
16.	Overall dimensions		1065mm×1700mm×1086mm
17.	Bearing		UPC bearing
18.	Speed of operation		km/h
19.	Wheel track		490 mm
20.	Wheel base		1065 mm
21.	Total weight of weeder		77 kg (without tank)
22.	Overall total weight		102kg (with sprayer tank)
23.	Ground clearance		370mm

Conclusion

The developed sprayer-cum-weeder effectively combines weeding and spraying operations, addressing two major challenges in crop production-weed control and pest/disease management. Powered by a 650 W PMDC motor with a 42 V lithium battery and supported by a 12 V lead-acid battery for spraying, the machine ensures efficient field operations. It operates at a speed of 2–2.5 km/h with a ground clearance of 370 mm and provides flexibility through interchangeable blades and a 4-nozzle boom sprayer. With a total fabrication cost of ₹60,350 and an operating cost of ₹242.77 per hectare, the machine is economically viable, showing a payback period of just over three years. Its integrated design reduces labor, saves time, and enhances crop yield, making it a sustainable solution for small and marginal farmers

Acknowledgements

The authors would like to thank the All India Coordinated Research Project on Farm Implements and Machinery (AICRP-FIM) for funding this research. They are also grateful to the Department of Farm Machinery and Power Engineering at SV College of Agricultural Engineering and Technology and Research Station Indira Gandhi Krishi Vishwavidyalaya, Raipur, India, for providing the necessary facilities for machine testing and for their support in the field evaluation of the sprayer cum weeder.

References

1. Bernacki H, Haman J, Kanafojski CZ. Agricultural machines, theory and construction. Washington, D.C: US Department of Agriculture and National Science Foundation; 1972.
2. Chandrakanth MG. Herbicide usage in agriculture reading to loss of weed and wealth as most weeds are medicinal, Economic policy 24 march 2022, Times of India. 2022.
3. Chandraker A, Victor VM, Jogdand SV, Khalkho D. Battery Powered Agricultural Sprayers: A Review. Current Journal of Applied Science and Technology. 2024;43(6):101-8.
4. Khurmi RS, Gupta GK. A text book of machine design. New Delhi: Eurasia Publication House Pvt. Ltd., Ram Nagar; 2005.
5. Mott R. Machine Elements in Mechanical Design. Columbus, Ohio: Merill Publishing Company; 1985. p. 198.
6. Sahay J. Text book of Element of Agricultural Engineering. 4th ed. New Delhi: A. K. Jain standard publications distributors; 2010. p. 80.
7. Sharma DN, Mukesh S. Farm machinery design, principles and problems. New Delhi, India: Jain Brothers publishers; 2010. p. 56.
8. Sighley JE. Standard handbook of machine design. Tata McGraw- Hill Education; 2011.
9. Tiwari PS, Singh KK, Sahni RK, Kumar V. Farm mechanization − trends and policy for its promotion in India. Indian Journal of Agricultural Sciences. 2019;89(10):1555-62.