The Pharma Innovation Journal 2022; SP-11(11): 836-843

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(11): 836-843

www.thepharmajournal.com
Received: 16-09-2022
Accepted: 21-10-2022

Sudhir Kumar Singh
Department of Farm Machinery & Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

RK Kathiria
Associate Professor, Department of Farm Machinery & Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

Km Sheetal Banga
Assistant Professor, Department of Agricultural Engineering, Janta Vedic College, Baraut Baghpat, Uttar Pradesh, India

AL Vadher
Assistant Professor, Department of Farm Machinery & Power Engineering, Junagadh Agricultural University, Junagadh, Gujarat, India

Corresponding Author:
Sudhir Kumar Singh
Department of Farm Machinery & Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, India

Design and development of walking type battery operated boom sprayer cum weeder

Sudhir Kumar Singh, RK Kathiria, Km Sheetal Banga and AL Vadher

Abstract
Aimed at issues associated with low capacity, more spraying time, fatigue of operator with use of knapsack sprayer, noise pollution of engine operated commercial existing sprayers and the depleting resources of fuel, a walking type battery operated boom sprayer cum weeder was developed. Similarly traditional weeding operation requires more labour and scarcity of labour leads to more time requirement for weeding operation. A need of combined sprayer cum weeder machine at an affordable price was developed to fulfil the need of farmers. The objective of this study was to design and develop a walking type battery operated boom sprayer cum weeder. The developed machine had an mechanism to do both weeding and spraying at the same time and individually. The horizontal motion and spraying by machine was controlled by electric power train. The electric power train consisted of differential, gearbox, and motor. The motor was connected to the driven wheel by an appropriate teeth ratio to provide the required speed and torque. Four 12 volt batteries were connected in series to achieve 48 volts. The machine was equipped with a throttle speed controller. The gearbox designed had driving and driven helical gears in which driving gear have 16 no of teeth, outer diameter is 2.5 cm and gear width 1 cm similarly in driven gear have 53 teeth, outer diameter 7 cm and width 2 cm. The uniformity of deposition and penetration of chemical droplets to the plant canopy was increased by designed a new construction of the frame, and a uniform field distribution is realised simultaneously while weeding is done with minimal plant harm. The forged ball valve is used to control the flow of discharge when the target is identified, and the spacing between the nozzles and height from above the plant canopy is adjusted. It was observed that the pesticide droplets sprayed by the developed spraying machine had better penetration ability and good uniformity, which eliminates the runoff of chemical through the plant canopy to soil and solidification issues caused by chemical absorption into the soil. The facility of weeding system was also provided in a single machine to overcome the operational cost of weeding.

Keywords: Knapsack, boom sprayer, weeder, electric, walking type, controller

1. Introduction

The economic and environmental costs arising from the use of agrochemicals, research on application strategies of Plant Protection Products (PPP), has progressed dramatically in recent decades. In response to increased public concern about the possible harm caused by chemical inputs in agricultural production systems, industry has been compelled to create new and more effective pest management and control methods for insect pests, illnesses, and weeds. These new technologies must be less hazardous to the environment than chemical-based methods already in use, while also protecting the health of farm workers and customers. Many people believe that bio pesticides should be used with existing spray technologies; however their success has been restricted due to equipment inadequacy, formulation efficacy, or a combination of the two. Farmers suffer financial issues when they purchase separate equipment for each type of pesticide, according to the logic for using current conventional equipment. Pests and diseases are decreasing crop production every year. Crop protection is critical for reducing output losses. Chemical, mechanical, biological, agronomical, and biophysical strategies are currently used to protect plants. The chemical method of plant protection is the most preferred of them. India's agricultural sector is enormous and diverse, necessitating efficient ways for spraying pesticides at a specified rate and in a short amount of time to reduce production losses. Chemical protection is vital in agricultural production because it provides for efficient insect, disease, and weeds control with little effort and price. It also decreases human drudgery by lowering the number of field workers necessary. Pesticides are applied to the crop by sprayers to give chemical protection. Insects, plant diseases, and weeds in field reduce plant growth, decrease yield and quality.

2. Material and Methods

Many species of crops are grown in different regions, according to prior reviews. Some crop varieties have a lower canopy, while others have a higher canopy closure. Spraying procedures are essentially the same, with the exception of crop structure and chemical types. Therefore, the spraying equipment proposed in this research was suited for any row crop with a planting row spacing of 120 cm and anything between plant spacing.

2.1 Developed machine structure

The walking type battery operated boom sprayer cum weeder mainly consist of BLDC motor, gearbox, motor controller, differential, pump, battery and weeding attachment. Its structure is shown in Fig 1.

The main components of the above developed machine are as given below:

Fig 1: Snapshot of the prototype of a developed machine

2.1.1 Motor

An electric motor is a device that converts electrical energy into mechanical energy. Direct current (DC) sources such as batteries can be used to power electric motors. Motor was selected based on the speed and power requirement. The motor supplies the required power to move the machine. Motor was placed on the front of the differential of developed machine. For accurate motion and speed control, a BLDC motor is utilised in combination with a controller. At no load condition, the rated speed of 1kW motor is 3000rpm.

2.1.2 Design of motor selection

Assume total soil load controlled by motor = 300 kg

Force acting due to weight of soil controlled by motor (w) = 300×9.8 = 2940 N

Required torque (T):

Assumed coefficient of friction b/w soil and tyre (μ) = 0.6

Radius of wheel (r) = 27.5 cm = 0.275 m

T = μ×w×r

= 0.6×2940×0.275

= 485.1 N-m

Linear velocity = Angular velocity × radius of wheel

Considering required speed = 2km/h

= 0.55 m/s

Angular velocity = Linear velocity/radius of wheel

= 0.55/0.275

= 2 rad/s

Angular velocity = 2πN/60

N = Angular velocity×60/2π

= 2×60/2×3.14

= 19.1 rpm

Hence required power = 2πNT/60

= 2×3.14×19.1×485.1/60

= 969.78 W

Hence 1000 watt motor was selected.

2.1.3 Gear box

Gearboxes come in variety of load capacities and ratios. The function of gear box was to change the speed of a vehicle. The developed gear box and gears are shown in Fig 2. and Fig 3. Respectively. The output rpm of Gearbox is given by the basic formula-

$$\frac{N1}{N2} = \frac{T2}{T1}$$

Where,

T_2: T_1 is gear ratio

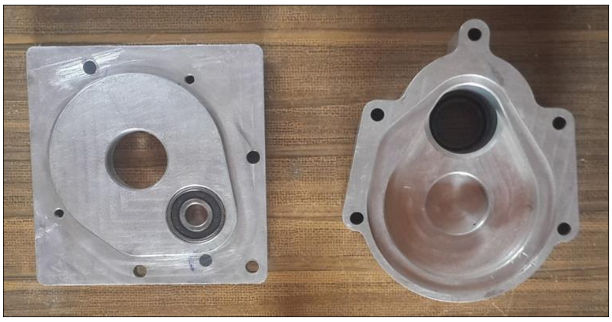


Fig 2: Developed Gearbox

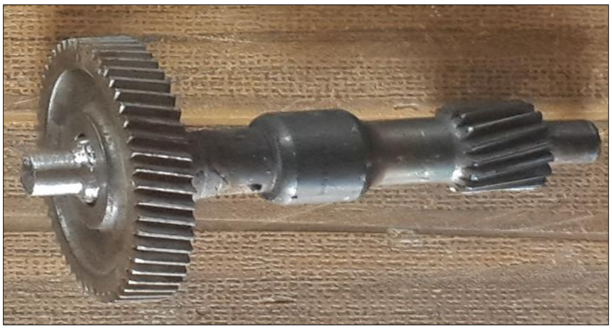


Fig 3: Designed Gear

2.1.4 Motor Controller

The motor is powered by the controller, which draws power from the batteries. A brushless DC motor controller controls the motor's speed and torque by regulating the current and voltage delivered into it. Motor controllers can perform a variety of tasks, including starting, stopping, overcurrent protection, overload protection, reversing, and changing the speed.

2.1.5 Differential

The 33-inch differential drives two wheels at distinct speeds. Between the left and right wheels, the differential generates proportional RPMs. During a turn, the differential permits the outer drive wheel to rotate faster than the inner drive wheel.

2.1.6 Battery

The battery is the primary source of electrical energy in a machine. Battery is selected based on power requirement of motor. 42 Ah lead acid batteries were used in the machine. It supplied the required power for the motor to run, while the battery serves as the machine's power source. Lead acid batteries are less expensive and have an efficiency of 80-85%. Batteries are mounted on the front side of the frame and welded to the differential shaft. The batteries are connected in series to provide a voltage of 48 volts, which is needed to run the motor. The Snapshot of the developed machine is shown in Fig 5.The main technical parameters of the walking type battery operated boom sprayer cum weeder are shown in Table 1.

Table 1: Main technical parameters of the prototype

Parameters	Values
Overall dimension, mm	1720×965×1910
Weight of machine (kg)	171
Travel speed (km/h)	1-2
Battery (Ah)	42
Motor power (kW)	1
Motor controller	1
Differential, Inch	33
Diaphragm Pump	Volts: 12V Amps: 6 A Working pressure: 200 PSI Open flow: 9 LPM
Spraying power (W)	72
Effective spraying width (m)	3.6
Theoretical spraying volume (L /min)	7.2-7.5
Blades	Sweep type, Duck foot type and blade type

2.2 Working principle

A developed machine's power train consisted of an electric driving system and battery acted as an energy storage system. DC motor connected to the wheel shaft via a gearbox and a differential. The power train of developed machine is shown in Fig 4. A differential was attached between the wheels to regulate the left and right traction wheels to spin at slightly different rates during turning. The speed of motor was very high. Therefore a gearbox was designed to reduce the speed of wheel. When the operator actuated the throttle, power controller drew current from battery how much power it is supposed to deliver. The controller read the hand throttle setting, adjusted the power, drew power from the batteries, and provided it to the motor. The controller provided power (voltage) to the motor, which was used to rotate the transmission. The transmission then drives the produced machine forward or backward by turning the wheels. When the throttle is fully rotated, the controller sends the full battery voltage to the motor. The controller sends zero volts to the motor if the operator takes his or her hand off the throttle. The controller takes current from the battery according to the load on the motor at any setting in between. The snapshot of the developed walking type battery operated boom sprayer cum weeder are shown in Fig 5.

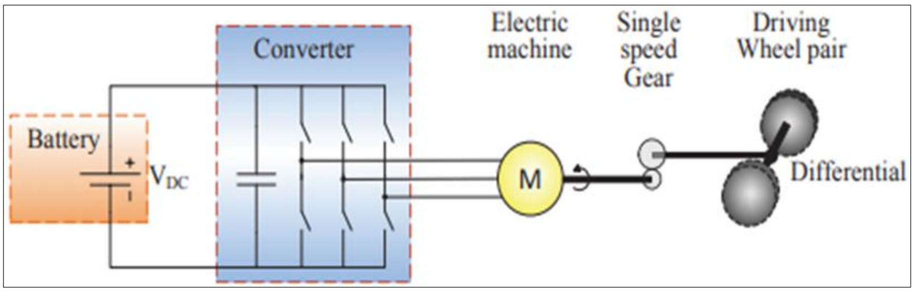


Fig 4: Power train in developed machine

Fig 5: Snapshot of the developed machine with weeding attachment

2.3 Design of power unit
2.3.1 Design for motor power requirement

Soil resistance = 0.7 kg/cm^2
Maximum width of cut = 38 cm
Depth of cut = 5 cm
Speed of operation = 2 km/h (0.55 m/s)
Draft = Width of cut × Depth of cut ×
Soil resistance = 38 × 5 ×0.7= 133 kg

Power requirement for weeding operation was calculated as following expression:

Power (P) = voltage × ampere = 716.87 W

Power requirement for spraying operation = voltage × ampere = 12 × 6 = 72 w

Power requirement to propel the machine = total tractive effort of a vehicle × speed

Total tractive effort of a vehicle (T_{TE})
$T_{TE} = RR + F_A + GR + F_D$

Where
RR = Rolling Resistance,
F_A = Acceleration force,
GR = Grade Resistance,
F_D = Drag force due to air resistance

2.3.2 Calculation of rolling resistance (RR)
The opposing force that the vehicle must overcome as a result of the rolling motion between both the wheels and the vehicle's surface of motion is known as rolling resistance which is calculated as given expression (Saurabh chauhan, 2015) [2].

$RR = W_T \text{ X } Cr$

Where,
W_T = Total machine weight, kg
Cr = coefficient of rolling resistance

Consider coefficient of rolling resistance 0.1 as suggested (Bawden, 2015) [6]

= 171.5 x 0.1 = 17.15 kg = 168.07 N

2.3.3 Calculation of acceleration force (F_A)-
The acceleration force is the force that assisted the vehicle in reaching a predetermined speed from a standstill in a given amount of time. Acceleration force was calculated by given expression (Saurabh chauhan, 2015) [2].

$F_A = ma$

Where,
m = mass of the developed machine, kg
a = required acceleration, m/s^2

$m = \frac{W_T}{g}$

Where,
W_T = Total machine weight, kg
g = Acceleration due to gravity, m/s^2

$m = \frac{171.5}{9.8} = 17.5 \text{ kg} = 171.5 \text{ N}$

Since 2 km/h speed achieved in 2 sec

So $a = \frac{2 \times 5/18}{2} = 0.28 \text{ m/s}^2$

$F_A = 17.5 \times 0.28 = 4.9 \text{ N}$

2.3.3 Calculation of gradient resistance (GR)
When a machine climbs an inclined surface, this is the force that tends to draw it back. The machine’s grade resistance can be determined as follows (Saurabh chauhan, 2015) [2].

$GR = W_T \times \text{Sin}Ø$

Where,
GR = Grade resistance and
Ø = Grade angle
Consider ground slope 2%
(Since 2% slope is equivalent to 1.15 in degree)
GR = 171.5 × sin 1.15°= 3.44kg= 33.71 N

2.3.4 Calculation of drag force due to air resistance
The drag force due to air resistance is considered negligible because the forward speed is too low.

Now total tractive effort (T_{TE}) = RR + F_A + GR = 168.07+ 4.9+ 33.71 = 206.68 N

Hence power required to propel the machine calculated as
Power = total tractive force x speed

$= 206.68 \times 2 \times \frac{5}{18}$ since vehicle is operated 2 km/h = 114.82W

Total motor power requirement for weeding operation
Total power requirement = propelling power of machine + power required for weeding

= 114.82 + 716.87 = 831.69 w

Total motor power requirement for spraying operation
Total power requirement = propelling power of machine + power required for spraying
= 114.82 + 72
= 186.82w

2.3.5 Calculation of torque required on the drive wheel of developed machine
The required wheel motor torque based on the tractive efforts as given below:

$\text{Torque} = R_f \times T_{TE} \times R_w$

Where,
R_f = Friction factor
T_{TE} = Total tractive effort
R_w = Radius of wheel

The typical value of friction factor is 0.6
Torque = 0.6 × 206.68× 0.275 = 34.10 Nm

The total machine load multiplied by the friction coefficient between the wheel and the soil and the radius of the driving wheel equals the maximum tractive torque a wheel can transmit, and it is calculated as (Saurabh chauhan, 2015) [2].

Max Torque = $\mu \times W_T \times R_W$

Where,
μ = coefficient of friction between the wheel and soil
W_T = Total machine weight, kg
R_W = Radius of wheel, m
Max Torque = 0.6×171.5×9.8×0.275
= 277.31Nm

For satisfactory performance of the vehicle we have
Max torque > motor Torque

2.4 Design of spraying operation department

There are different kinds of sprayers available for cotton and pigeon pea but the rows and spacing of these plants are not same while row spacing varies between 1~1.5 m. To fulfil the spraying needs of different types of cotton and pigeon pea crops, battery operated boom sprayer cum weeder developed in which six nozzles had been attached perpendicular to the ground. The geometric layout, liquid path transmission and different parts of developed machine are depicted in Fig 6.

The power source is a battery for sprayer. When the working pressure is 2.5 kg/cm^2, the designed sprayer can meet the spraying operation department's requirements, as shown in the Table 2.The effective spray rate is Q_w = 78 L/h under the working pressure of 2.5 kg/cm^2. When the nozzle is fully opened, then the high pressure flow velocity v_h and Reynolds number Re in the tube are, respectively, calculated as:

Flow velocity (v_h) = $\frac{Q}{A}$

Flow velocity (v_h) = $\frac{2.16\times10^{-5}}{5.02\times10^{-5}}$m/s

= 0.43 m/s

Reynolds number (Re) = $\frac{V_h \times d}{\gamma}$

= $\frac{0.43\times0.008}{0.897\times10^{-6}}$ = 3835> 2300

Since the Reynolds number is more than 2300, the pipe flow in the spraying operation is turbulent. When pesticide solution passes through the hose pressure pipe and the nozzle, some local pressure loss took place due to head. For the calculation of pressure loss in the hose pipe, the local head loss coefficient ζ the local head loss h, and the local pressure loss P_L are, calculated respectively as given below:

Local head loss coefficient
(ζ) =0.5 × (1 - $\frac{A_a}{A_h}$)

= 0.5× (1 - $\frac{2.0096}{50.24}$) = 0.48

Local head loss (h) = $\frac{\zeta \times V_h}{2g}$

= $\frac{0.48\times0.43}{2\times9.8}$ = 0.01m

Local pressure loss (P_L) =$\rho g h$

= 1000×9.8×0.01

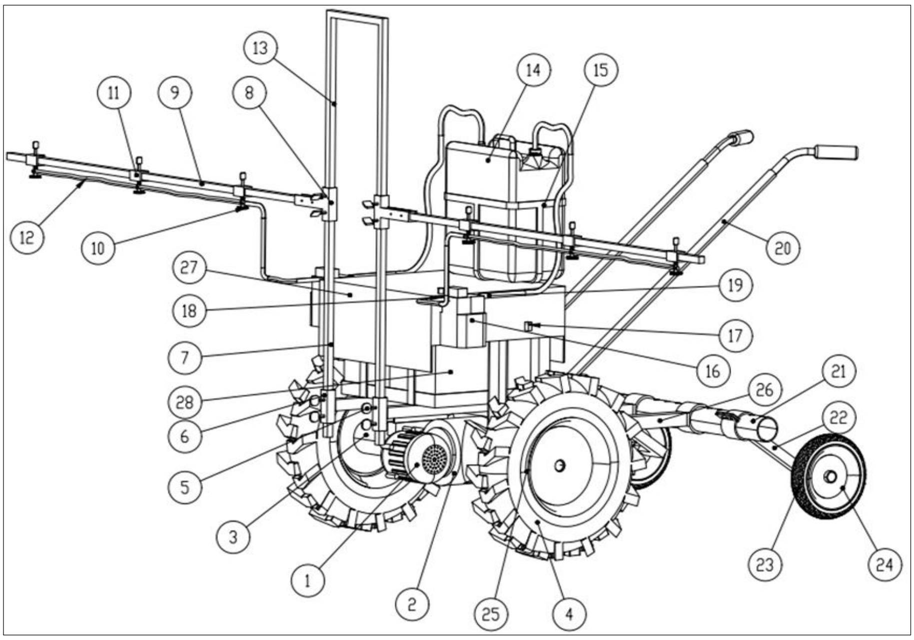
= 98 Pa
= 0.001 kg/cm^2

In the above formula
A_h = cross-sectional area of the inner hole of the hose pipe in mm^2
A_a= cross-sectional area of the nozzle hole in mm^2.
In conclusion, the local pressure loss at the hose pipe-nozzle connection is much less than the working pressure has no impact on the spraying effect, and the spraying operation department can continue to run normally. The main technical parameters of the spraying operation are given below in table 2.

Table 2: Main technical parameters of the spraying operation unit

Part Name	Technical index	Values
Diaphragm pump	Pressure range (kg/cm^2)	14
	Flow range (L/min)	9
High pressure pipe	Inner diameter (mm)	8
Hollow cone nozzle	Maximum flow (L/min)	1.5
	Spray angle (°)	60
	Nozzle aperture, mm	1.6
Forged ball Control valve	Diameter of valve &	DN8 1/4 inch
	pressure(inch & kg/cm^2)	PN25
Pressure gauge	Pressure (kg/cm^2)	0-35

Fig 6: Different parts of developed machine



1. Motor	11. Nozzle sliding attachment	21. Headpiece
2. Gearbox	12. Hose pipe	22. Attachment of rear tyre
3 Differential	13. Vertical pipe	23. Rear tyre
4. Front tyre	14. Tank	24. Rear rim
5. Rear attachment of boom	15. Tank stand	25. Front rim
6. Rotating knob	16. Pump	26. Weeder attachment
7. Boom frame	17. Switch	27. Cover
8. Boom holder	18. Output pipe of pump	28. Battery
9. Boom	19. Input pipe of pump	
10. Nozzle fixer	20. Handle	

2.5 Design of the manual positioning adjustment and targeting system

On a walking type battery operated boom sprayer cum weeder machine, targeting and orientation adjustment system detects the spatial orientation of the crop canopy, adjusts the distance between the nozzle and the canopy, and controls the opening and closing of the forged ball valve manually because for the same crop and the same period, the age and height of the crops were basically the same. Therefore, this study used manual adjustment of the nozzle height from the canopy otherwise in case of automatic system it becomes costly as compared to manual system and small & marginal farmers could not buy this developed machine.

The spraying system on both sides of the spraying machine is a separate unit that must be regulated manually from the plant canopy. Both sides, each single boom consisted of three nozzles and connected to the individual pump. Both the boom bar manually adjusted according to the crop canopy requirement. The chain was attached individually on both sides of the boom to provide angle according to requirement. The nozzle adjustment from the plant canopy is shown in below Fig 7.

Fig 7: Nozzle adjustment from the plant canopy

2.6 Design of weeding operation department

Weeding attachment was also provided in this developed machine to destroy weeds which is shown in Fig 5. The 30×30cm square shape frame was attached to the headpiece and main frame. The blades were made of high carbon steel. Three blades with 250 mm long and 8 mm thickness were used. The distance between the blades adjusted on the headpiece according to the requirement. The circular shape headpiece is used to attach the blades whose length 150 cm and diameter is 7.5 cm and it provides support and rigidity to the blades. The distance between hole to hole was 5 cm and diameter of hole was 1.5 cm. At rear end two support wheels were mounted as shown in Fig 5.The blades were 8 mm wide and thick to give them strength. Depth of weeding could be controlled by rotating the headpiece. The overall specification of developed machine is given below in Table 3.

Table 3: Technical specifications of different components of the developed walking type battery operated boom sprayer cum weeder

Components	Specification
Type	Walking type battery operated boom sprayer cum weeder
Diaphragm pump	Volts: 12V, Amps: 6 A, Working pressure: 200, PSI Open flow: 9 LPM
Battery	Brand: Amaron, Model:12AL042, Battery series: Quanta, Nominal voltage: 12V, Battery rating: 42Ah, Output power: 504Wh, Dimensions (L×W×H): 199 mm × 167 mm × 175 mm, Weight of the battery: 14 kgs
Battery charger	48V 20AH
Power controller	Power: 1000W, Volts: 48V
Throttle	Volts:48V, Type-motor control, Battery type-Lead acid
Motor	Power:1000 W, Volts:48V, Rated RPM:3000
Front tyre, Inch	5-12
Rear tyre, Inch	3-10
Wheel rim, inch	12
Differential, inch	33
Gearbox	Driving gear: Teeth = 16, Ø = 25 mm, Driven gear: Teeth = 53, Ø = 70 mm
Type of Nozzle	Hollow cone, Discharge rate: 1.5 LPM, Spray angle: 60°
Boom length (each side), m	1.56
Height of the boom	Adjustable as per requirements
No. of nozzles in the sprayer	6
Nozzle spacing, mm	500 (Adjustable)
Swath width of boom, m	3.4
Boom discharge, lt/min	7.8
Pressure gauge, kg/cm2	35
Forged ball control valve	DN8 1/4 inch PN25
Hose pipe dia, mm	8
Material used for pesticides tank	PVC
Tank capacity, L	30
Working speed, Km/hr	1-2
Weight, Kg	171.5
Stage of speed reduction	Two (1^{st} stage in differential and 2^{nd} through designed gearbox)
Speed reduction ratio from motor to drive wheel	37.5
Wheel track, cm	84
Wheel base, cm	106
Size of frame (L×W×H), cm	45×39×41
Handle type and size (diameter and width), mm	L type (35, 100)
Length of handle, m	1.1
Handle mounting	Adjustable according to person height
Mast height for mounting weeding tool, cm	15
Type of blade	Sweep, duck foot and T type
Headpiece, cm	97
Cutting width, cm	25
Weeding depth, cm	5
Maximum and minimum turning radius, m	2.1 @ 2 km/h and 1.68 @ 2 km/h
Overall dimensions (L×W×H), mm	1720×965×1910

3. Conclusions

In this study, sprayer cum weeder machine was developed to apply pesticide on plant canopy and remove weeds in the spaces between plant rows simultaneously. The overall dimensions of developed sprayer were 1720×965×1910 mm and the weight of machine was 171.5 kg and worked satisfactorily. This research fulfilled the basic requirement of manual spraying different row crops, uniformity and deposition of spray in the field and also removing weeds while spraying. The prototype had been analysed through field trials. The tests included laboratory tests and field tests. Field trials were done to collect data, and the sprayer structure was improved to increase the spraying quality and weeds were also uprooted with the weeding attachment in a same machine. Hence spraying and weeding operations have completed from single machine, which saves money, time and solve the labour problem.

4. References

1. Karale DS, Thakre SH, Khambalkar VP, Deshmukh MM, Walke RD. Design Considerations in Battery Electric Vehicle. International Journal of Engineering and Creative Science. 2020;3(6):2581-6667.
2. Chauhan S. Motor torque calculations for electric vehicle. International journal of scientific & technology research. 2015;4(8):126-127.
3. Ma C, Li G, Peng Q. Design and Test of a Jet Remote Control Spraying Machine for Orchards. Agri

Engineering. 2021;3(4):797-814.
4. Patil RS, Bharambe RS, Pawar VY, Sugandhi S, Thakare KS. Analysis of Electric Vehicle Drive Train. International Research Journal of Engineering and Technology. 2018;5(4):2395-0072.
5. Ayyagari ST, Erakkat SK, Neerati M. Design and fabrication of solar powered remote controlled all terrain sprayer and mower robot. ar Xiv preprint arXiv:2106-05236; c2021.
6. Bawden Owen John. Design of a lightweight, modular robotic vehicle. For the sustainable intensification of broad acre agriculture. Unpublished thesis, School of Electrical Engineering and Computer Science and Engineering Faculty, Queensland University of Technology; c2015.
7. Netam A, Patel KK, Naik RK. Design of pedal operated maize sheller. The Pharma Innovation Journal, SP. 2022;11(1):1095-1099.