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Development of battery operated walk behind type sprayer

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Abstract
Proper technique of application of pesticide and the equipment's used for applying pesticide are vital for the success of pest control operations. Farmers generally use lever operated knapsack sprayer which is manually operated equipment. While operating the knapsack sprayer, the body is in awkward posture which creates the lot of discomfort on operator head, neck clavicle and shoulder regions. Therefore, a battery operated walk behind type sprayer was developed, to reduce discomfort and time required for sprayer. Walk behind type sprayer is economical, more efficient and spray theta faster rate. It is helpful for small-scale farmer and unskilled labour who can also operate it without any difficulties. Based upon review of literature and data, design a walk behind type sprayer was done. Based upon design, CAD model of walk behind type sprayer was developed. The operating hours of pump using 8AM or 12AH batteries was expected to be 2-3 hours or 5-6 hours, respectively. The total cost of per year battery operated walk behind type sprayer was Rs 19165.80.Thebreak even point (BEP) calculated on area basis for battery operated walk behind type sprayer was 171 ha. The breakeven point (BEP) calculated on year basis for battery operated walk behind type sprayer was 2.21 years.

Keywords: Battery operated, walk behind type sprayer, BEP

Introduction
World crop yields are reducing every year between 20 to 40% due to the damage wrought by plant pests and disease (FAO, 2015) [14]. About 30-35% of the annual crop yields in India get wasted because of pests (Chakrabarty, 2017) [41]. Crop protection is essential to reduce losses of yield. At present, the plant protection methods are chemical, mechanical, biological, agronomical and biophysical types. Among these, most preferable one is chemical method of plant protection. India has a large and diverse agricultural sector which requires quite effective methods for spraying pesticides at a desired rate, in minimal time for reducing yield losses. Chemical protection plays a major role in agricultural production because effective control of pest, disease and weed with minimal time expenditure. As the cropping pattern is becoming more intensive, use of these pesticides is also increasing. Consumption of insecticide in agriculture has been increased more than 100% from 1971 to 1994-95. For instance, consumption of insecticide in India, which was to the tune of 22013 tones, has increased to 51755 tons by 1994-95 (Anon. 2020, a) [3]. Consumption of all these pesticides in same duration has increased more than two times, that is from 24305 tons to 61357 tones. But in recent past changes has been observed in trends of pesticides consumption. Singh and Kaul (1972) [33] reported energy expenditure of manual knapsack sprayer as 0.49 l/min. Nag *et al*. (1980) [28] studied the physiological workload of spraying operation. The heart rate and oxygen consumption were found to be 125.5 beats/min and 0.653 l/min. The mean overall discomfort rating were 3.4, 5.0 and 5.7 on an eight point discomfort scale (0- no discomfort, 7- extreme discomfort) and the mean body part discomfort score were 65.8, 93.8 and 89.1 and the end of first, second and third fill of sprayer, respectively. The maximum discomfort was experienced at the left clavicle region followed by lower back, neck, left thigh and right clavicle. Due to this reason, for overcome of this problem with these sprayers there is need to develop the battery operated walk behind type. Bretthauer *et al*. (2009) [11] they found that management of foliar soybean diseases such as Asian Soybean Rust requires good canopy penetration and thorough spray coverage. The purpose of this study was to examine how spray application rate and spray droplet size affect the efficacy of rust applications in wide-row (36 inch) soybean plantings. The VC spray quality treatment at 15 gpa had the highest coverage and deposition in both the upper and lower canopy.

No significant differences in rust severity or yield were observed between the treatments. These results demonstrated that a larger droplet spectrum application, while reducing spray drift, could also potentially provide effective control of rust in wide row soybean plantings. Johnstone (1973) [22] studied that if an efficient pesticide is selected, requiring less than 10 nano gram/insect, than no more than 10% active ingredient should be in the spray with droplets of 60 micro m, in order to achieve a kill with the impact of one droplet on the insect. Bhanutej *et al*. (2015) [43] they are reported that In India, agriculture crops that come as yield decides the total production, adds to the economy of our country. The yield decreases due to the presence of pests, insects in the farms. To kill the pests, insect's pesticides, fertilizers are sprayed either manually or by using sprayers. Earlier, the pesticides and fertilizers were sprinkled manually, but they will result in harmful effects on farmers. In order to overcome this problem, This Sprayer works on Bernoulli's principle, in which the spraying action of the sprayer is due to the head developed and mechanical linkage. The model is developed mathematically for the major components like tank, required head and the spring mechanism Shivraja *et al*. (2014) [32]. They are suggested that conventional sprayer having the difficulties such as it needs lot of effort to push the liver up and down in order to create the pressure to spray. Another difficulty of petrol sprayer is to need to purchase the fuel, which increases the running cost of the sprayer. In order to overcome these difficulties, I have proposed a wheel driven sprayer, it is a portable device and no need of any fuel to operate, which is easy to move and sprays the pesticide by moving the wheel. Singh *et al*. (2002) [42] studied the spray distribution pattern of different nozzles namely: hollow cone, solid cone, adjustable and fan type mainly used for agricultural purpose at three different pressures (0.75, 3.0 and 6.0 kg/cm') and three angular settings of the nozzles. The discharge rate of adjustable and fan type nozzle was higher than solid cone and hollow cone nozzle. It was concluded that uniform spray at 3.0 kg/cm2 would be obtained if the nozzle spacing for hollow cone, solid cone, adjustable and fan type nozzles are 48, 42, 42, and 30 cm, respectively. Gavali (2018) [17] reported that in current pesticide spraying technologies for specialty crops frequently result in over-application and excessive off-target losses and spray drift, primarily due to large variations in canopy sizes and densities, plant spacing, and constant pesticide delivery rate offered by conventional sprayers. Existing Works by researches has given an idea about on the pesticides sprayers are related to Fluid injection metering, advancement in Nozzle and electrostatic sprayers. Sagar (2017) [9] suggested that ANSYS is the very effective and powerful tool in determining the stress and strains (deformation) in the components. The design is simple and compact with minimum fabrication cost. The fabricated model is affordable for middle and lower class farmers through Government Subsidies. Compared to other types of spraying mechanisms, the crank- slotted lever spraying mechanism incorporated in present project is more efficient and is with low maintenance. Rajashekargoud (2017) [2] As suggested model has more number of nozzles which will cover maximum area of spraying in minimum time & at maximum rate. Proper adjustment facility in the model with respect to crop helps to avoid excessive use of pesticides which result into less pollution. Abhishek (2017) [16] suggested the model has removed the problem of back pain, since there is no need to carry the pesticide tank on the back. Health problems from the pesticide during the spray will be zero. This model has more number of nozzles which will cover maximum area of spraying in minimum time & at maximum rate. The regulators can also be applied which helps in reducing the change of pressure fluctuation and regulator Valves helps to maintain pressure. Guo (1996) [18] studied deposition and distribution of droplets emitted by a low volume sprayer (LVS) and high volume sprayer (HVS) on cauliflower leaves. Results showed that both sprayers gave more deposition on middle layer leaves than leaves at the inner and outer layers. The deposition from LVS on middle and inner layer's leaves was 21.3 and 64.3% higher than that by using HVS. Deposition on upper and lower surface of leaves at middle layer was 0.0210 and 0.0066 µg/cm2respectively from LVS. On the other hand, they were 0.0151 and 0.0017µg/cm2from HVS. Kaul *et al*. (1996) [24] reported that the drift or loss of chemicals to the air was influenced by evaporation, drop size spectrum, wind speed, height of nozzles, forward speed, crop height, atmospheric stability, working width and boom height, in this order. Willam (1997) [39] reported that most of the paddy farmers in Philippines spray by placing the nozzle 30cm or more from the leaf surface and spraying their crop until the leaf is wet but not yet dripping, causing pollution to the soil, and finally to the water. The main aim of our research is to design and developed battery operated walk behind type sprayer, which can overcome the limitation of a knapsack sprayer.

2. Material and Methods

The develop machine will be suitable for spraying in dry field conditioner. The various factors involved in design were, strength and durability, operational safety and easiness in fabrication. The fabrication, operation and adjustment were made simple so that a local artisan can fabricate, repair and farmer can operate the sprayer. The implement was design and developed at the Workshop of MCAET Ambedkar nagar (ANDUAT, Ayodhya). The frame are used support the all body parts and it is also called as cheesy the frame material is mild steel. The Conceptual CAD view of developed walked behind type of sprayer. The main frame is used to support the all body parts. It is also called as chassis which is made by mil steel. The main mounted on the axle shaft with single traction wheel and carries above the spray tank and below wheels, pump integration, and a boom assembly of 0.9 m length with hollow cone type nozzles. The spray tank was connected to the boom with the aid of distributing flexible rubber hose via the integrated piston pump. The boom frame is bolted at the front end of the main frame. The boom frame was designed in the way that the boom height could be adjusted as per the crop height between 30 cm -120 cm above the ground. The chemical in the spray tank is pumped to the flexible hose by the piston pump integrated with the tank. The pump was actuated by motor, which gets the power from the battery. During the operation the operator simply kept the boom in a horizontal position and pushes the spirit (with the help of handle) into the rows of the crop. Handle of machine is not adjustable there are two grip in the handle through which whole machine will be operated. The distance between both the grip are 460 mm (Fig. 1).

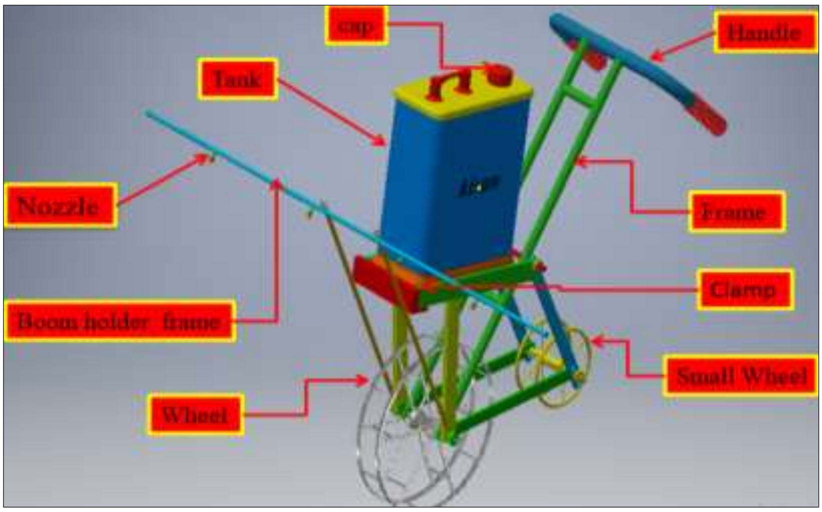

Fig 1: A view of walk behind type sprayer

For calculating actual field capacity and theoretical field capacity the time consumed for real work and that lost for other activities such as tuning, filling of tank were taken into consideration. The time required for actual operation and time lost measured by stopwatch. Actual field capacity (Sharma, *et al*. 2010) [44] and Theoretical field capacity (Sahay, 2008) [45] was calculated. Cost analysis is very important for a new technology Operational cost of the total of fixed cost and variable cost of the machine. The total cost of the walk behind type sprayer was determined by knowing the cost of the material and fabricating cost of the walk behind type sprayer. The operational cost (tk. /ha) was used in equation 1 to 07 to calculate all the parameters.

$$\text{Actual field capacity} = \frac{\text{area covered, ha}}{\text{total time taken, h}} \quad 01$$

$$\text{total} = \text{time for turning} + \text{time for refilling} + \text{time for calculated work} \quad 02$$

$$\text{Actual field capacity} = \frac{\text{width} \times \text{speed}, \frac{\text{km}}{\text{Hr}} . \times \text{boom}}{10} \quad 03$$

$$\text{Field efficiency} = \frac{\text{Actual field capacity}}{\text{theoretical field capacity}} \times 100 \quad 04$$

$$\text{Depreciation}, \frac{\text{Tk}}{\text{yr}} = \frac{\text{Purchase price, Tk} - \text{Salvage value, Tk}}{\text{life of machine, yrs}} \quad 05$$

$$\text{Interest on investment} = \frac{\text{Purchase price, Tk} + \text{Salvage value, Tk}}{2} \times \text{Rate of interest} \quad 06$$

$$\text{Total fixed cost per year} = 2\% \text{ of purchase of machine} + \text{Rate of interest} + \text{Depreciation}$$

$$\text{Total variable cost per year} = \text{Labour cost per hour} + \text{Repair and maintenance cost per year} \quad 07$$

3. Results and Discussion

The fabricated walk behind sprayer details of components and their specification and the material required for fabrication. The important drawing of main frame, handle, nozzle boom, transport wheel and small wheel shown in Fig. 2, 3, 4, 5 and 6 respectively.

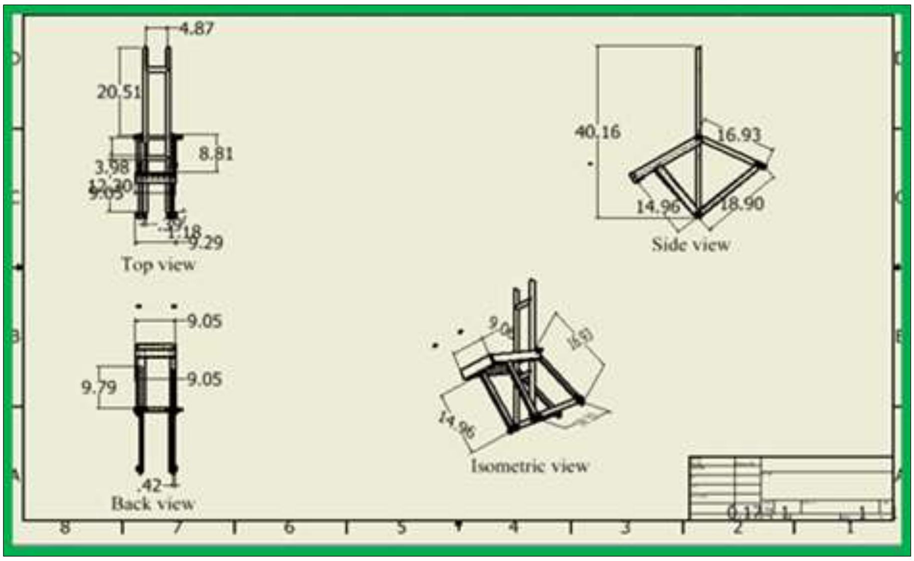

Fig 2: A drawing of Main frame

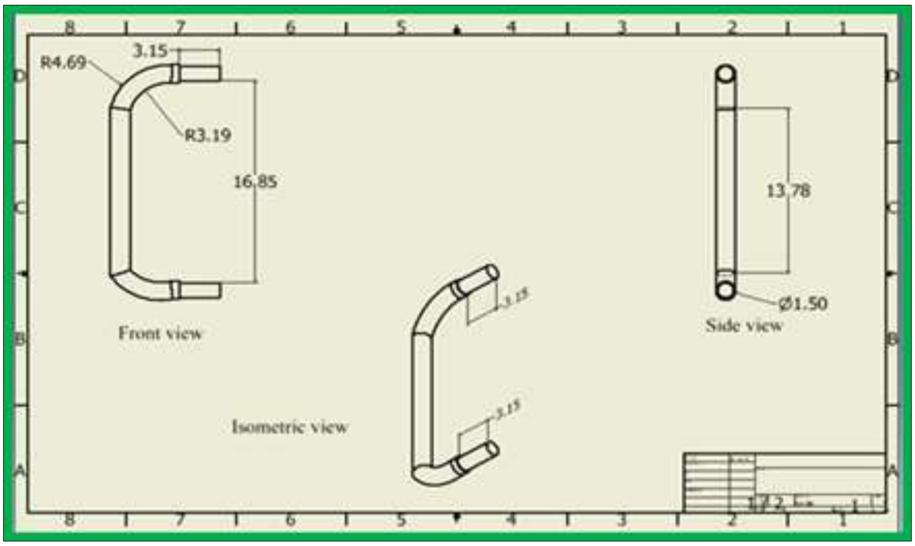

Fig 3: A drawing of handle

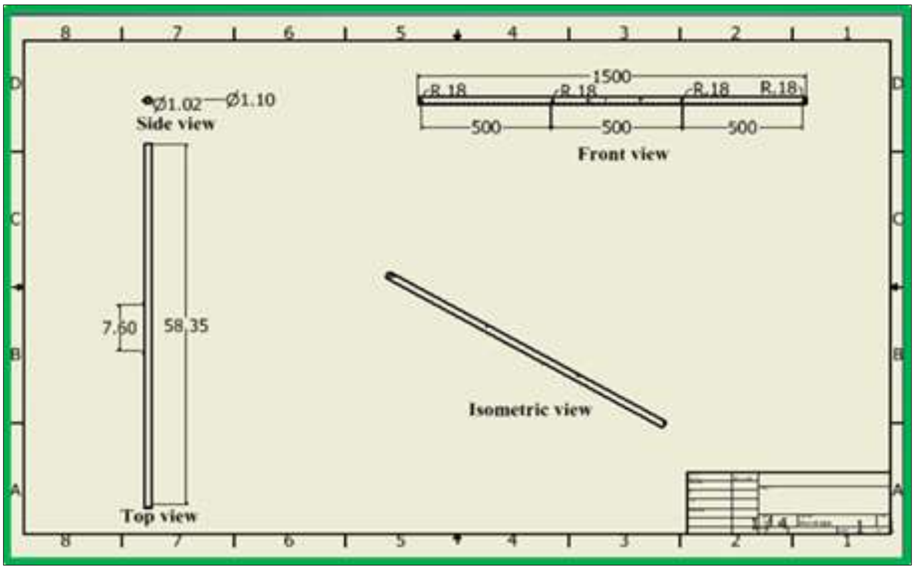

Fig 4: A drawing of nozzle boom

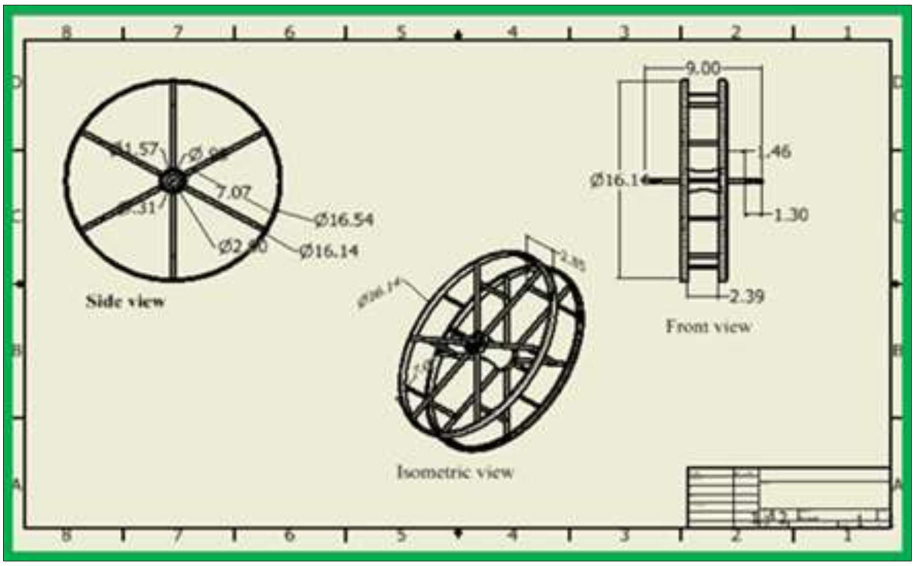

Fig 5: A drawing of transport wheel

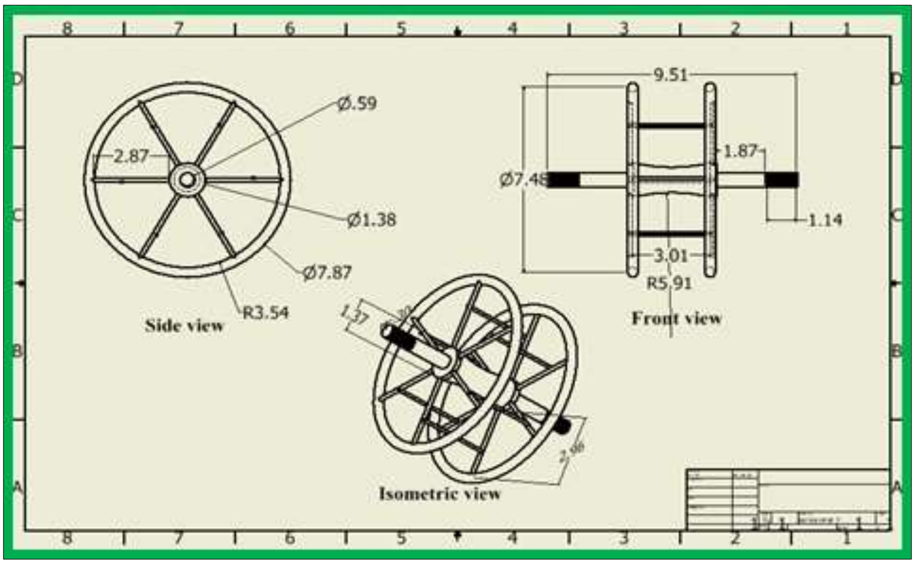

Fig 6: A drawing of small wheel

Operational parameter of developed battery operated walk behind type sprayer A 16 litre capacity tank was filled up with a liquid and the volume marked. The tank was mounted at the implement of the tank frame. The knapsack sprayer system was wheel power operates with crank mounted on the implement and the liquid was sprayed using the pressuring of the normal knapsack sprayer pump. The effective performance of the developed power operated knapsack sprayer was determined by practical trials on the field. The field test was an open field measuring in one minute. The operated walked within a space of 1.08 m per minute through the test field the discharged volume in litre per minute was recorded on the 1 kg capacity local available plastic tank material at different height. This procedure was taken under four nozzle fit on boom frame and collect discharged volume in litre per minute and the mean value determined showing in Table 1.

Table 1: Performance parameter of sprayer.

Sr. No	Parameter	Details
1	Forward Speed	1.4 km/ h
2	Nozzle discharge rate	37.6 litre/ h
3	Rate of application	710.06lh^{-1}
4	Field Capacity	0.21ha/h
5	Field Efficiency	80%
6	Actual field capacity	0.168 ha/h

Cost analysis of the walk behind type sprayer Materials required to construct the machine were procured from the local market. Most of the parts of the machine were designed and fabricated in the workshop of the Department of Farm Power & Machinery, MCAET, Akbarpur, (Ambedkar Nagar).The price and amount of walking behind type sprayer is given below Table 2.

Table 2: Total cost of the walk behind type sprayer

Materials	Amount	Rate	Total Cost
Front wheel	1	200	200
Supported wheel	1	100	100
Handle with cover	1	150	150
M.S. bar (3suti)	2	45	90
Solid aluminium shaft of 2.5 cm Diameter	2	10	20
M.S. flat bar (2 cm wide X 3 mm)	2	45	90
M.S. nut bolts	8	6	48
M.S. pipe (Outer diameter 0.65 cm & inner diameter 0.125cm	5	10	50
Making charge of nozzle holder	4	100	400
Making charge of hose connector	1	100	100
Making charge of frame to hold the Sprayer	1	150	150
Cost of the sprayer tank, batter and pump etc.			3000
Total cost of the walking behind type sprayer with tank			4,398

The cost of ownership of battery operated walk behind type sprayer is depicted in Table 3. The depreciation, interest, insurance + tax and housing cost per year of battery operated walk behind type sprayer was Rs 396, 217.8, 88and 44respectively. The total fixed and variable cost per year of battery operated walk behind type sprayer was Rs 745.8and 18420respectively. The total cost of per year battery operated walk behind type sprayer was Rs 19165.80. The total area covered annually was calculated 80.64 ha by assuming spraying window in a year for Kharif and Rabi season of60days and actual field capacity of 0.168 ha/h. The breakeven point (BEP) calculated on area basis for battery operated walk behind type sprayer was 171 ha. The breakeven point (BEP) calculated on year basis for battery operated walk behind type sprayer was 2.21 years.

Table 3: Cost of ownership of battery operated walk behind type sprayer

Sr. No	Description	Unit	Sprayer	
			Value	Cost Per year
1	Cost of Machine	Rs.	4400	
2	Life in years	years	10	
3	Depreciation	Rs.	396	396.00
4	Total interest	Rs.	217.8	217.80
5	Insurance + Tax	Rs.	88	88.00
6	Housing Cost	Rs.	44	44.00
7	Fixed Cost	Rs.		745.80
8	Maintenance/year	Rs.	220	220.00
9	Total working days per year	days	60	
10	Total hours of harvest	h	480	
11	labour charges	Rs./day	300	18000.00
12	Electricity cost per year	Rs.	200	200.00
13	Variable Cost			18420.00
14	Total Cost Per Year	Rs.		19165.80
15	Total area covered per year	ha	80.64	
16	Harvesting Rate Rs/ha	Rs.	350	
17	Total Earning Per Year	Rs.		28224
18	Profit / Loss per year	Rs.		9058
19	Running cost per ha	Rs.		238
20	Profit / Loss per ha	Rs.		112
21	Break -Even Point (area wise)	ha		171
22	Break -Even Point (Year wise)	years		2.12

Based on the study on walk behind type sprayer was developed for spraying in most of field and horticultural crops. The operating hours of pump using 8AM or 12AH batteries was expected to be 2-3 hours or 5-6 hours, respectively. The distance b/w two nozzle of battery operated walk behind type sprayer was 0.468 m The nozzle discharge rate of battery operated walk behind type sprayer was 37.6 liter/h On an average field capacity of battery operated walk behind type sprayer was 0.21 ha/h. The total cost of per year battery operated walk behind type sprayer was Rs 19165.80. The breakeven point (BEP) calculated on area basis for battery operated walk behind type sprayer was 171 ha. The breakeven point (BEP) calculated on year basis for battery operated walk behind type sprayer was 2.21 years

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