Development and performance of manually operated solar sprayer

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Abstract:
India is an agriculture based country. Agriculture has a significant role in the socio-economic fabric of India. An Engineer is always focusing on development and reduction in human efforts. So many inventions and development have been done in different fields including machinery, constructions, nanotechnology etc. It is now important to focus on agriculture field. Machine becomes an integral part of human being. Automation helps to give high production rate than manual production rate in the competition market. Engineer accepts the challenges and makes the design into reality. This paper deals with the development of solar sprayer, the maximum and minimum field efficiency in cashew plot was found at the discharge of 200 ml/min (98.12%) and 100 ml/min (87.09%). The weight of SPV operated sprayer was 11.5 kg with liquid, which provided less drudgery and easy to carry. It was concluded that, the cost of operation of SPV operated weedicide sprayer (189.53 Rs/ha) was economically feasible than manual weeding operation (7740 Rs. /ha) and manually operated knapsack sprayer (359.2Rs. /ha).
***Keywords**: Solar panel, battery, charger, motor and humans and sprayer*

Introduction

Sprayer provides optimum utilization of pesticides or any liquid with minimum efforts. In Indian farms generally two types of spray pumps are used for spraying, they are hand operated and fuel operated, out of which hand operated spray pumps are most popular. Different spraying techniques have been developed suitable for different types of spray equipment. A solar operated sprayer is easy to handle and maintenance free, hence is affordable to the farmers. Therefore, a solar operated sprayer is designed and fabricated. This system can be operated using solar energy or electrical energy. The solar energy is converted into electrical energy and is stored in a storage battery. The main advantages of the present system are the running cost reduces to minimum and consume less time. Solar energy from the sun is harvested on the solar panel. The panel is made up of photovoltaic cells, which converts photon energy to electric energy. These cells are made up of silicon semiconductor. Solar panel is used to generate electric energy and charge the battery. The charged battery is used to operate a DC pump for spraying the pesticide.

Solar power is the most ecofriendly resource mainly because it is free, unlimited and free from pollution. The solar energy is usually harvested through solar panels that are made up of photovoltaic cells. The photovoltaic (PV) or solar cells convert the sun’s energy into the useful energy which is then used to perform work such as for domestic purpose, industrial purpose, agricultural purpose etc. The conventional hand operated sprayer needs lot of effort to push the lever up and down in order to create the pressure to spray. The power operated sprayer requires purchase of fuel which increases the running cost of the sprayer. In order to overcome these difficulties, the sprayer with solar energy as a source of power not only minimizes the drudgery of the work but is also more effective than the conventional ones. The solar sprayer might be the solution for spraying of herbicides for effective weed control with minimum drudgery and saving the conventional fuel. The photovoltaic conversion system to generate electricity from the sunlight may be most appropriate solution for providing the energy for spraying. The photovoltaic conversion system has various advantages over the conventional method. Keeping in view, the paper entitled “Development of manually operated sprayer”

MATERIAL AND METHODS

Development of SPV Operated Solar Sprayer

A solar photovoltaic operated sprayer consisted of different components. viz; photovoltaic panel panels, motor and control system and spray lance with spinning disc. Solar photovoltaic (SPV) panel The Photovoltaic (PV) or solar panel of 6 V, 5 W capacity configured to trap and convert the sun’s energy into the useful power, which is used to operate the sprayer. Solar PV Panel was used for operating the sprayer and for charging a battery.

6 V capacity dc motor was used to operate the spinning disc having 4000-4400 rpm and was fitted at the end of the lance. The spinning disc nozzle was fixed on D.C. motor. A compact size, rust proof, easy to clean and maintain and low electric consumption motor was used to reduce the weight. Liquid enters on spinning disc by rotating spinning disc nozzle used the centrifugal force to add velocity to the liquid and breaks it into fine droplets**.**

Solar photovoltaic (SPV) panel

The photovoltaic (PV) or solar panel of 6 V, 5 W (Fig.1) configured to trap and convert the sun’s energy into the electrical energy which is used to operate sprayer. Solar PV panel was used for operating the sprayer and for charging a battery and is observed that as the rating of solar panel increases, weight increases but the time for charging the battery decreases when solar panel is operating at its maximum rating. Thus, by considering weight and charging time as the criteria, 20W rating solar panel was selected for this sprayer as shown in Table1.

Fig.1. Solar Panel

Table 1. Comparison of solar panels by power rating

S No	Solar Panel Rating (W)	Rating(W)I=P/V(A) (V=12 volts)	T=Ah/I (hr)	Weight (kg)
1	6	6/12=0.5	8/0.5 = 16	0.6
2	8	8/12=0.66	8/0.667 = 12	0.8
3	10	10/12=0.833	8/0.83 = 9.63	1.2
4	15	15/12=1.25	8/1.25 = 6.4	1.5
5	20	20/12=1.66	8/1.67 = 4.79	2.0
6	30	30/12=2.5	8/2.5 = 3.2	3.6
7	40	40/12=3.33	8/3.33 = 2.402	5

DC Motor

A 6 V D.C. motor was used to operate the spinning disc having 4000-4400 rpm. The D.C. motor was fitted at the end of the lance. The spinning disc nozzle was fixed on DC Motor(Fig.2). A compact size, rust proof, easy to clean and maintain and low electric consumption motor was used to reduce the weight. Liquid enters on spinning disc by rotating spinning disc nozzle used the centrifugal force to add velocity to the liquid and breaks it into fine droplets

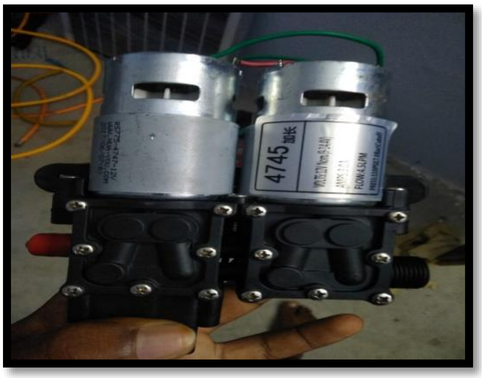

Fig.2. DC Motor

Liquid tank

The 5 liters' capacity tank made up of High density polyethylene material was used and connected to the spray lance pipe with spinning disc nozzle which breaks liquid into fine droplets. The output droplet size depends on flow rate and disc operating speed.

Main frame

The whole unit of sprayer including tank, SPV panel and control unit was framed in metallic frame module of mild steel. The supporting base and entire unit needs to be strong and light weight. It was made of metal, in which solar panel (5 W, 6 V) was mounted on the frame. Solar charge controller was placed at the side of the frame

Battery

The SPV operated weedicide sprayer was provided with 6 V, 4.5 (Fig.3) A sealed lead acid battery which was used as alternative power source during cloudy atmosphere (in rainy season). The battery was charged with the help of SPV panel available on top of the sprayer. The regularized voltage of 6V required for motor operation was supplied by battery.

Fig.3.Battery

Lance

A lance made up of fiber material having extension rod for increasing the lance length was used. Extension rod was made up of mild steel material. The battery casing was made up of HDPE (High Density Polyethylene) material was placed at rare end of lance. The on/off switch was provided on lance. The motor was fitted on front end of lance with spinning disc.

Solar Charge controller

A solar charge controller (Fig.4) regulated the voltage and current from solar panel and was placed between a solar panel and a battery. It was used to maintain the proper charging voltage to the battery and protected it from overcharging and discharging.

Fig.4. Solar Charge Controller

Table 2. Technical specifications of SPV operated weedicide sprayer

S No.	Component	Specification	Material Used
1	Solar Photovoltaic Panel	5 W, 6 V Size: 28 cm*17.5 cm	-
2	D.C. Motor	Voltage : 6 volt	-
3	Spinning Disc Nozzle	RPM:4000-4400,Diameter: 9 cm	HDPE
4	Battery	:6 V Current:4.5 Ah	Sealed Lead Acid Battery
5	Lance	Length :2.1 m Diameter:4 cm	HDPE
6	Frame	Height : 32 cm Breath : 22 cm Width:12 cm	Mild Steel
7	Connecting Rod	Height: 73 cm Bend Pipe length: 40 cm Diameter:2 cm	Galvanized Iron Pipe
8	Switch	1 No. on/off	-
9	Accessories	Two abdomen belt	Nylon
10	Tank	Capacity: 5 liter Height : 10 cm Breadth: 7 cm Width: 4.5 cm	HDPE
11	Weight of Solar Operated Weedicide Sprayer with liquid	11.5 kg	-

Working of SPV operated solar sprayers

SPV solar sprayer with 5 Watt solar panel was used for operating a 6 V DC motor; on the D.C. motor the spinning disc nozzle mounted which was attached at the end of the lance. The motor produced a high speed rotary motion. The weedicide chemical fed to spinning disc nozzle. The spray tank and solar charge controller was mounted on a frame. The 6 V, 4.5Ah battery was fixed on the lance. The spray fluid is fed to high speed rotating spinning disc optimizes spray fluid into fine droplets. The 6V, 5 W SPV panel was mounted on head of operator to charge the battery. The motor rotates the spinning disc, at high speed which resulted in disintegration of spray fluid into fine droplets. The control valve on the pipe adjust desired flow rate as required. The operator directed the discharge hose with lance to the target.

Performance Evaluation of SPV Operated Weedicide Sprayer

The performance evaluation of developed SPV operated sprayer test was carried out in a laboratory and field**.**

Testing of battery discharging of SPV operated solar sprayer

The battery discharging characteristics of SPV operated solar sprayer was used to determine the discharge time and battery voltage reduction. The SPV panel was covered with the black cloth and fully charge battery was discharged by operating the sprayer motor. The various parameters like time, battery voltage, battery current and discharge rate was measured at an interval of 15 minutes. The voltage reduction was noted till the full discharge of battery, which stopped the working of motor. Three replications were conducted and average value was observed.

Testing of battery charging

The battery charging characteristics of SPV operated solar sprayer was used to determine the charging time and battery voltage rise or increase while sprayer was in non -operating condition. The SPV panel was fully exposed in sunlight for battery charging. The various parameters like panel voltage, panel current, battery voltage, solar intensity, ambient temperature was measured at the interval of 30 minutes. The battery was charged till reaches up to 6.4 V. Three replications were conducted and average value was reported.

Testing of simultaneous battery charging and discharging of SPV operated solar sprayer.

The battery charging and discharging characteristics of SPV operated solar sprayer was studied to determine the total operating period of sprayer. The battery was charge by SPV panel which, was fully exposed in sunlight and simultaneously battery was use for operating the SPV sprayer. The various parameter like battery voltage, battery current, panel voltage, panel current, solar intensity, ambient temperature was measured at the interval of 1 hour. The sprayer was operated till the motor stopped working up to 3.3 V. Three replications were conducted and average value was observed.

Spraying Characteristics

The swath width of the SPV operated solar sprayer was measured by spraying on dry floor and wetted diameter of area was measured and discharge rate of sprayer was measured by using measuring cylinder for every 15 minutes interval.

Discharge rate variation test

Discharge rate variation test of SPV operated solar sprayer was carried out by placing the liquid tank with three different heights at three different discharge rates. The discharged volume was collected in measuring cylinder in ml/min. (Awulu 2011).

Spray volume requirement

The liquid volume requirement was carried out by measuring 3 m×3 m open field. The tank (5 liter) was filled up with liquid. The electrical power of the system was turned on and operator walked at 2.52 km/hr through the field. This was replicated thrice for each flow rate i.e. 100 ml/min, 150ml/min and 200 ml/min., by setting the valve at three different positions. The spray volume in liter/ha was recorded. (Awulu 2011).

Spray volume distribution Test Spray

Volume distribution pattern was noted on a patternator of size 160 cm x 110 cm. The patternator has 23 triangular grooves at equal spacing and rack carrying spray- collecting tubes, which was mounted below the collecting end points of the grooves (Plate 3.5). The spinning disc was placed horizontal direction above the patternator, at the height of 5 cm, 10 cm and 15 cm. The sprayer was operated for 15 minutes in each situation was able to obtain a measurable amount of spray from the collecting tubes and this was replicated thrice for each flow rate i.e., 100,150,200 ml/min. Droplet distribution test was carried out by using glossy papers (30 mm x100 mm) to measure spray spots. The glossy papers after deposition of spray droplets were analyzed on Image Analysis System for droplet size in VMD, NMD uniformity coefficient and droplet density.

Field testing of SPV operated solar sprayer

Prior to start of the field test, the field condition i.e. area, shape of field and type of field were recorded. The crop parameters like name of crop, row spacing, height of crop, plant to plant spacing were also recorded. The field test was conducted in cashew plantation at Department of SWCE, CAET, BSKKV, Dapoli. The following field parameters were determined during test.

i. Effective field capacity, ha/hr
ii. Theoretical field capacity, ha/hr
iii. Field efficiency, %
iv. Weed control efficiency, %

Effective field capacity

The effective field capacity is the ratio of total area covered in hectares to the total time required for field operation in hours.

$$E.F.C = \frac{Area}{Time}$$

E.F.C. = Effective Field Capacity, ha/hr

Area = Area of the test plot, ha
Time = Total time, hr

Theoretical Field Capacity

Theoretical Field Capacity is the area covered by implement at its rated width and at rated speed. Theoretical field capacity was determined by the formula,

T F C=$\frac{W \times S}{10}$

T.F.C. = Theoretical Field Capacity, ha/hr
W = Effective working width,
M/ S = Travel Speed, km/hr

Field Efficiency

The field efficiency is the ratio of effective field capacity to the theoretical field capacity

F.C=$\frac{E.F.C}{T.F.C} \times 100$

Weed Control Efficiency

Weed control efficiency was calculated by using following formula.

W E=$\frac{W_1 - W_2}{W_1} \times 100$

Where W.E. = Weed Control Efficiency, %
W1 = No. of weed in the field before weeding
W2 = No. of weed in the field after weeding

Economics of SPV operated weedicide sprayer

Fixed Cost consist following items

1. Cost of sprayers is denoted as (C) in Rs.
2. Depreciation rate (Rs. /hr) =$\frac{C-X}{L \times H}$.
3. Interest rate (Rs./hr)=$\frac{(C+S)}{2} \times \frac{I}{X}$
4. Total fixed cost = Depreciation + Interest.

Variable Cost

1. Total Chemical cost (Rs.hr) = Chemical consumed (lit/hr) X Chemical Cost (Rs. /lit).
2. Operating cost of labour (Rs. /hr) = Wage of operator / Working Hours.
3. Repair and maintenance (Rs. /hr) = 5 % of initial cost.
4. Total Variable cost = Chemical cost (Rs.hr) + Operators cost (Rs./hr) + Repair and maintenance (Rs. /hr)

Total operating cost = Fixed Cost + Variable Cost
Where, C = Initial cost or cost of machine, Rs.
H= Annual use of machine, hr
I = Interest rate, %
L = Total life of machine, yr
S = Salvage value, Rs.

Fig.5.SPV operated solar sprayer

RESULTS AND DISCUSSIONS

The battery discharging characteristics of SPV operated weedicide sprayer was studied to determine the discharge time of battery. The variation of battery voltage with time and corresponding discharge of weedicide sprayer is shown in fig.6.

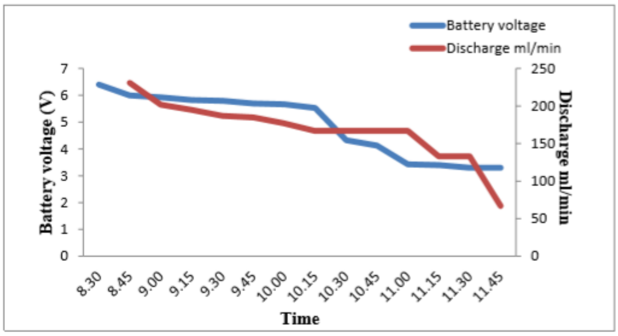

Fig.6. Battery discharging characteristics during solar spraying

Battery Charging with SPV panel of SPV operated solar sprayer

The battery charging characteristics of SPV operated weedicide sprayer was studied to determine the charging time and battery voltage rise while sprayer was in non- operating condition. The SPV panel was fully exposed to sunlight for battery charging. The various parameters like panel voltage, panel current, battery voltage, solar intensity, ambient temperature, discharge of liquid were measured.The variation of battery voltage, panel voltage corresponding solar intensity with time is shown in fig.7.

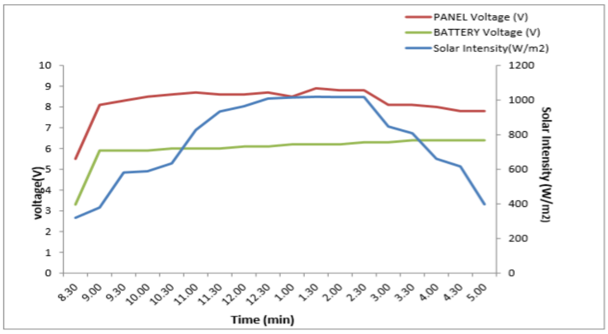

Fig.7. Battery Charging with SPV Panel of SPV operated solar sprayer

Battery charging-discharging of SPV operated solar Sprayer

The battery charging and discharging characteristics of SPV operated weedicide sprayer was studied to determine the total operating period of sprayer. The battery was charge by SPV panel which, was fully exposed in sunlight and simultaneously battery was use for operating the SPV sprayer. The various parameters like battery voltage, battery current, panel voltage, panel current, solar intensity, discharge of liquid was measured .The variation of battery voltage with solar intensity and variation in discharge of sprayer with corresponding voltage is shown in fig.7 and fig. 8 respectively.

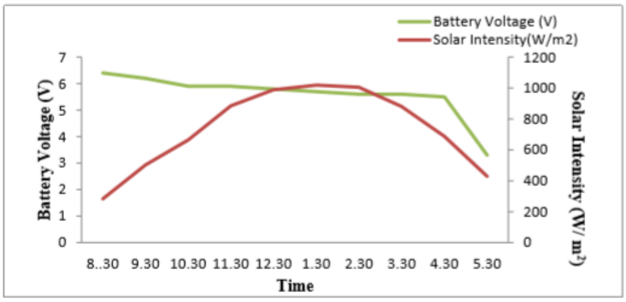

Fig.8. Battery charging-discharging of SPV operated solar Sprayer

The SPV operated weedicide sprayer worked continuously for 8 hours (8.30 a.m. to 4.30 p.m.) without interruption due to availability of power from solar panel. The battery voltage varied from 6.4 to 5.5 volt during the operating period. The discharge of SPV operated weedicide sprayer was varied from 176 ml/min to 231 ml/min during the testing. The SPV operated weedicide sprayer hours continuously operated 3 hours 15 min. only without SPV panel and with SPV panel it could be operated for 8 hours continuously shown in fig. 8.

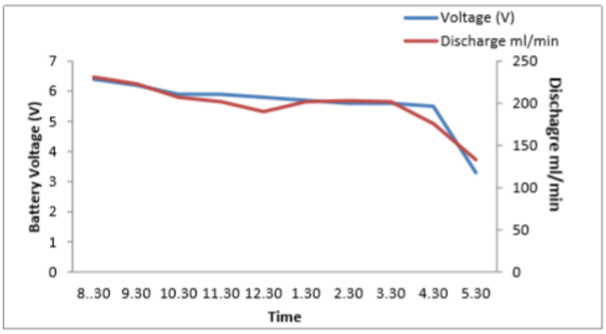

Fig.9. Battery charging- discharging with SPV Panel

It was observed that discharge rate of SPV operated weedicide sprayer was decreased from 231 ml/min (6.4 V) to 133 ml/min (3.3 V).

After completion of a fabrication of a solar sprayer we tested it on a selected area of a weed.The measurement of weed count is shown in fig: 10

Fig: 10 Measurement of weed count by 0.5 m x 0.5 m square frame

We tested the developed solar sprayer for different spray droplet discharge rate which is shown in below fig

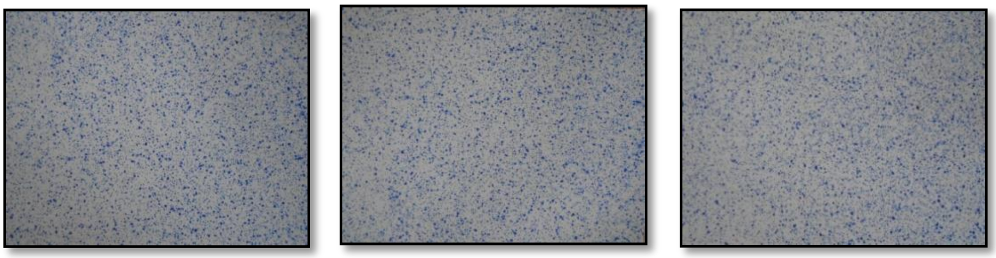

Fig: 11 Distribution of spray droplet at 100ml/min discharge rate

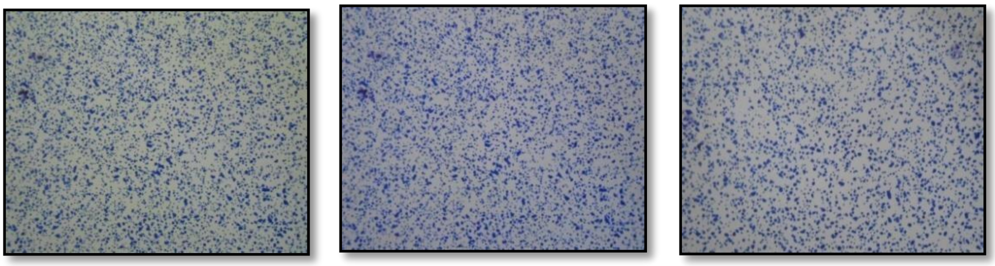

Fig: 12 Distribution of spray droplet at 150ml/min discharge rate

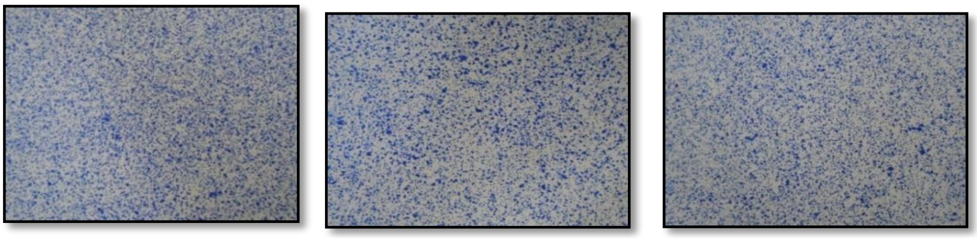

Fig: 13 Distribution of spray droplet at 200ml/min discharge rate

Before spraying After 3 days of spraying After 6 days of spraying

Fig: 14 Effect of spraying (100 ml/min)

Before spraying After 3 days of spraying After 6 days of spraying

Fig:15 Effect of spraying (150 ml/min)

Before spraying After 3 days of spraying After 6 days of spraying

Fig: 16 Effect of spraying (200 ml/min)

Field performance of SPV operated weedicide sprayer in cashew nut plantation I. Weed control Efficiency (After 3 days)

Sr.no.	W1 No. of weeds before spraying			W2 No. of weeds after spraying			Weed efficiency $WE=\frac{W_1-W_2}{W_1}\times 100$ (%)		
	100 ml/min	150 ml/min	200 ml/min	100 ml/min	150 ml/min	200 ml/min	100 ml/min	150 ml/min	200 ml/min
1	261	351	227	29	29	6	88.88	91.73	97.35
2	331	175	315	42	21	5	87.31	88	98.41
3	302	190	290	45	18	4	85.09	90.52	98.62
						Average	**87.09**	**90.08**	**98.12**

II. Weed control Efficiency (After 6 days)

Sr.no.	W1 No. of weeds before spraying			W2 No. of weeds after spraying			Weed efficiency $WE=\frac{W_1-W_2}{W_1}\times 100$ (%)		
	100 ml/min	150 ml/min	200 ml/min	100 ml/min	150 ml/min	200 ml/min	100 ml/min	150 ml/min	200 ml/min
1	261	351	227	0	0	0	100	100	100
2	331	175	315	0	0	0	100	100	100
3	302	190	290	0	0	0	100	100	100
						Average	100	100	100

CONCLUSIONS

1. It was concluded that the addition of SPV panel to sprayer, the operation period was increases from 3 hours 15 minutes to 8 hours.
2. The results obtained from the spray characteristics of SPV operated weedicide sprayer, revealed that, for getting maximum swath width with least variation in discharge rate with respect to variation in different heights, 150 ml/min discharge rate was suitable.
3. It was revealed that for getting maximum field efficiency of SPV operated weedicide sprayer 200 ml/min discharge rate was suitable.
4. The maximum field efficiency of SPV operated weedicide sprayer in cashew plot was found at the discharge of 200 ml/min (98.12%) and minimum field efficiency was found at the discharge rate 100 ml/min (87.09%).
5. The weight of SPV operated weedicide sprayer was found to be 11.5 kg with liquid, which provided less drudgery and easy to carry.

6. It was concluded that, the cost of operation of SPV operated weedicide sprayer (189.53 Rs/ha) was economically feasible than manual weeding operation (7740 Rs./ha) and manually operated knapsack sprayer (359.2Rs./ha).

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