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Development of Solar Cum Hand Operated Hybrid Knapsack Sprayer for Vegetable Crops

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ABSTRACT

Sprayer is use as plant protection equipment for spraying of pesticides, herbicides, weedicides, etc. In India most of the farmers are marginal land holders and traditionally they use hand lever operated knapsack sprayer for spraying, but this involves fatigue due to continuous hand lever operation results in the low efficiency. Now a days the power operated knapsack sprayers are available in the market and farmers are using it to fulfill the requirements of spraying operation in production agriculture but the vibrations, noise levels causes the high level of fatigue in the operation. Due to this problem labor relucted to use this type of sprayer. As we consider the remote area there is unavailability of abundant amount of fuel and electricity there were lot of problems occurs in the agricultural operation all this problems motivated us to develop a Solar cum Hand operated Hybrid Knapsack Sprayer by using modern development techniques. Under this study design and selection of components of sprayer was carried out by using modern design techniques. Actual field capacity, field efficiency and cost of operation per hour are 0.275, 86.38% and Rs. 92.63. The cost of developed sprayer is Rs. 5320. The farmer can save 1.32 times money in spraying operation as compared to hand operated knapsack sprayer.

Key words: *Knapsack sprayers, Design parameters, Nozzles, Solar module, Cost economics*

INTRODUCTION

In Indian scenario near about 70,000 million rupees crops worth is lost every year from which near about 52 percent losses are caused by insects and diseases, 33 percent by weeds and 15 percent by rodents, birds and nematodes. Spraying is one of the most important operations in crop production. The need of chemical application arises from man's desire to protect his crop from attack of various pests and diseases. Spray application is a complex process and can be influenced by many variables. The magnitude and uniformity of spray deposition depend on the canopy geometry, pesticide properties; spray equipment design, application parameters and weather conditions. Various type of knapsack sprayers are generally used for spraying. The most prevalent types of knapsack sprayer in India are hand operated, mechanical and battery operated type.

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Mechanical and hand operated sprayer requires to operator to move their hand continuously in order to spray liquid which ultimately cause fatigue on the operator back, shoulder and the muscles of the hand.

Power sprayer requires fuel and Battery operated sprayer requires electricity for charging the battery. The application will be limited if fuel and electricity is not available[9]. "Energy - demand" is one of the major threads for our country. Finding solutions, to meet the "energy demand" is the great challenge for social scientist, engineers, entrepreneurs and industrialist of our country. According to them, applications of non-conventional energy are the only alternate solution for conventional energy demand. As we consider the remote area there is unavailability of abundant amount of fuel and electricity there were lot of problems occurs in the agricultural operation all this problems motivated us to develop a Solar cum Hand operated hybrid Knapsack Sprayer by using modern development techniques. Solar charge, Battery cum Hand operated sprayer can use in remote areas by using solar energy, when solar and electrical energy not available hand operated lever can be used for spraying operation without creating pollution and noise.

MATERIAL AND METHODS

This deals with the materials and methods used for development of "SPV, battery cum hand operated knapsack sprayer". The main part of the equipment are SPV module, Charge controller, DC Battery, Frame, Sprayer tank, Hose pipe, Lance, Nozzle, Cut-off device, Hand lever, Piston pump, Diaphragm pump etc. The materials and methodology used for research work is discussed in following sections.

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2.1 Design of sprayer components:

2.1.1 Determination of nozzle discharge (hollow cone):

$$P_1 = \frac{1 \times \rho \times V_2^{\,2}}{2} \quad V_2 = 2\sqrt{\frac{2 \times P_1}{\rho}}$$

$$Q = A \times 2\sqrt{\frac{2 \times P_1}{\rho}} \quad 0.34 \times 10^{-5} \times 2\sqrt{\frac{2 \times 2.04 \times 10^{13}}{1000}} = 1.37 \text{Lit/min} \ldots\ldots\ldots (1)$$

Where,

P_1= Differential pressure in respect of atmospheric pressure

P_2 = Atmospheric pressure

Q = Discharge rate of nozzle

A = cross section area of orifice$\left(\frac{\pi \times D^2}{4}\right)$

D = Diameter of orifice

2.1.2 Design of sprayer tank:

The tank of manually operated sprayer should be such a size that it can supply liquid for about 10 -15 minutes of continuous spraying. The minimum capacity of manually operated sprayer tank was estimated as under

$$Q_t = D \times t = 1.37 \times 15 = 20 \quad \ldots\ldots\ldots (2)$$

2.1.3 Pump

A pump moves a specific volume of liquid with each stroke or revolution. The pump output is proportional to speed and virtually independent of pressure

1. Diaphragm pump

The theoretical pump discharge (Q_{th}) is given by

$$Q_{th} = D_p \times N$$

= 2.8 lpm

Where,

Q_{th}= Theoretical flow, lpm

D_p = Volume of displacement of pump in one revolution, l/rev

2. Plunger barrel pump

The theoretical pump discharge (Q_{th}) for plunger barrel type pump is given by

$$Q_{th} = \text{A.L.N.} \times 10^{-3}$$

Where,

A= area of plunger, cm^2

L= Length of stroke, cm

N= Pump speed, rpm

Pressure discharge relationship of pump

Hydraulic head and pressure of the of the calculated by following formula

$$P = \rho \times g \times h \quad \text{..... (5)}$$

Pa = 1000 × 9.81 × 56.226= 551.58 kPa

PSI = 62.42796 (lb/ft^3) × 1.28148 (ft.) = 80 PSI

2.1.4 Determination of strength of strap assembly (Belt)

Back pack tank exerts a force when loaded thus,

Weight of empty tank (W) = m × g =4.65 × 9.81= 45.62 N..... (3)

Where,

W = weight of unloaded tank

M= mass of unloaded tank

G = acceleration due to gravity

Note: 1 litre = 1 kg

Capacity of tank = 16 litre = 16 kg

Mass of complete filled tank = 20.65 kg

W' = 20.65 × 9.81 = 202.58 N

Belt is subjected to tension when tank is loaded with spray mixture.

Maximum tensional stress (ϕ_{max}):

$$\phi \max = \frac{F}{A} \text{ ..... (4)}$$

Where,

F = Weight of loaded tank acting on the one belt

A = Effective cross-sectional area of the belt

$$F = \frac{W'}{2} = \frac{202.58}{2} = 101.29 \text{ N}$$

$$A = \text{length} \times \text{Breadth} = 800 \times 40 \text{ mm}^2 = 3200 \text{ mm}^2$$

Tension acting on the belt,

$$\phi = \frac{101.29}{32000} = 0.00317 \text{ N/mm}^2$$

Average power consumption by diaphragm pump:

$$P_r = \frac{E_p}{T} \times 60 = \frac{19.2}{60} \times 60 = 19.2 \text{ Wh} \text{ ..... (6)}$$

Where,

E_p = Energy consumption, Wh

T= Time period, min

Load Estimation:

Total Wattage,

$$P_{rt} = q \times P_r = 1 \times 19.2 = 19.2 \text{ Wh} \text{ ..... (7)}$$

Where,

P_r= Wattage of diaphragm pump

q = quantity

Energy demand:

E_d (Wh) = P_{rt} × H = 19.2 × 5 = 96.0 Wh..... (8)

Where,

H = operating hours

Load demand:

E_d (Ah) = $\frac{E_d(Wh)}{V_{nsv}} = \frac{96}{12}$ = 8 Ah..... (9)

Where,

V_{nsv} = nominal system voltage

Corrected load, $E_{c\,(}$Ah) = $\frac{E_d(Ah)}{\eta_b} = \frac{8}{0.95}$ = 8.421 Ah

Where, η_b = Battery efficiency

Battery sizing

The size of battery required for SPV operated DC diaphragm pump was given by,

Battery capacity = $\frac{E_d(Wh)}{\text{system voltage}} = \frac{96}{12}$ = 8 Ah..... (10)

PV array sizing

The PV array sizing required for 12 V DC diaphragm pump was determined by, Corrected current load, $I_d = \frac{E_c(Ah)}{G} = \frac{8.421}{8}$ = 1.0526 Ah..... (11)

Where,

G = Lowest daily sunshine hours.

Rated design current,

$I_{DE} = \frac{I_d}{n_m} = \frac{1.0526}{0.90}$ = 1.17 Ah..... (12)

Where,

n_m = module derate factor

Charge controller sizing

Maximum current, $I_t = N_p \times I_p = 1 \times 1.2$ = 1.2 Ah..... (13)

Where,

N_p= no. of solar panel in parallel

I_p = Peak current of selected solar panel

Electrical power

Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start or operate a load for one second. Electrical power is measured in watts (W).

W = V x A..... (14)

Where, V = voltage (V), I = current (A), W = Power (Watt)

Efficiency of solar cells: Efficiency of a solar cell is defined as the ratio of the energy output to the energy input from the sun.

$$\text{PV efficiency } \% = \frac{\text{Output Power (watt)}}{\text{Input Power(watt)}} \times 100 = \frac{V \times I}{I_s \times A} \times 100 \text{ ..... (15)}$$

Where,

V= Voltage Produced, Volt I_s = Solar intensity $\left(\frac{\text{watt}}{m^2}\right)$

I = Current developed A= area of array(m^2)

Pumping efficiency: Pumping efficiency is defined as the ratio of power needed to deliver water to the power supplied by the array

$$\text{P.E. } \% = \frac{\text{Power needed(watt)}}{\text{power supplied (watt)}} \times 100 \text{..... (16)}$$

Economics of solar cum hand operated hybrid knapsack sprayer:

For economic evaluation of solar cum hand operated hybrid knapsack sprayer straight line method was used.

RESULTS AND DISCUSSION

Scheme of developed Solar cum hand operated hybrid knapsack sprayer system has following steps:

1. DC (Direct current) voltage are generated by solar panel, as per requirement of power solar panel was selected. In absence of solar energy battery can charge by electrical energy.
2. Charge control unit is provided between battery and solar panel preventing reverse flow of battery towards panel and preventing from overcharging of battery.
3. DC voltage generated in the battery is used to run DC motor pump connected between spray tank and cut-off device.
4. Hand operated lever is provided to operate the sprayer in absence of solar and electrical energy.
5. Outlet of pump and cut-off device (Trigger) is connected by hose pipe for supply spray liquid to spray lance. Cut-off device is use for cut-off the supply of spray liquid to the lance and prevents wastage of liquid. Nozzles are fitted on the lance for atomizing the liquid.

The Solar cum hand operated hybrid knapsack sprayer was developed by utilizing various components available in the market by the process of development design over the traditional methods as shown in Fig. 2

Fig. 1: Flow diagram for Scheme of developed Solar cum hand operated hybrid knapsack sprayer

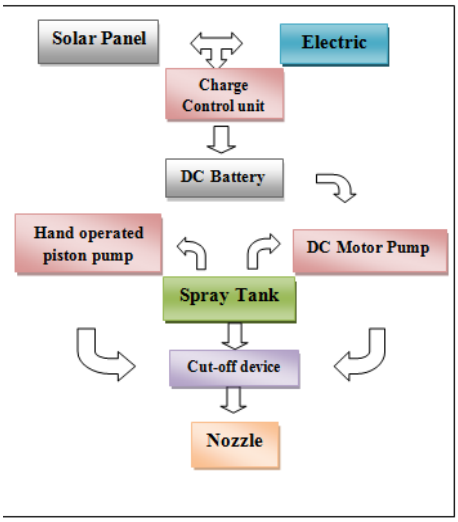

Fig. 2: Solar cum hand operated hybrid knapsack sprayer

The performance and evaluation trial of Sprayer had carried out as per testing procedure mentioned given in Indian Standard. The width of spraying affects effective field capacity of sprayer. The average observed width was 0.53 m at operation speed of 1.78 km/h. It was observed that the working on these speeds was convenient for field operations without any obstacle. The theoretical and actual field capacity of the sprayer for insecticides application in the field was found to be 0.094 ha/h and 0.082 ha/h. The field capacity and field efficiency of the sprayer depends upon size of plot, swath width, speed and skill of operator. The field efficiency of the Sprayer was found to be 88.24 %. The average application rate of the Solar Charge, Battery cum Hand Operated Knapsack Sprayer was 495 lit/ha.

Table 1. Comparative points between SPV, battery cum hand operated knapsack sprayer and Hand lever operated knapsack sprayer

S.N.	Parameters	SPV, battery cum hand operated knapsack sprayer	Hand lever operated knapsack sprayer
01	Time for Spray(h/ha)	4.22	8.20
02	Swath width (m)	1.09	0.95
03	Speed of operation (km/h)	2.52	1.61
04	Theoretical field capacity (ha/h)	0.275	0.154
05	Actual Field Capacity (ha/h)	0.237	0.122
06	Field Efficiency (%)	86.38	79.16
07	Solution required (lit/ha)	495	508
08	Cost of Sprayer (Rs.)	5320	1400

Battery charging-discharging of SPV cum hand operated vegetable knapsack sprayer

The battery charging and discharging characteristics of SPV cum hand operated knapsack 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 was measured.

Table 2. Battery charging with SPV cum hand operated hybrid knapsack sprayer

Sr. No.	Time	Solar Intensity	Temp ℃	Voltage (V)		Current(A)	Wind speed(m/s)
				Panel	Battery		
1	8:30	339	35	5.7	3.4	0.8	0.7
2	9:00	382	35.8	8.2	5.6	0.6	0.2
3	9:30	593	36.2	8.3	5.6	0.6	0.9
4	10:00	625	36.9	8.4	5.6	0.6	0.6
5	10:30	639	38.1	8.6	5.8	0.8	0.7
6	11:00	825	38.5	8.6	5.9	0.7	0.8
7	11:30	936	38.1	8.6	5.9	0.7	1.1
8	12:00	968	37.9	8.7	6.1	0.6	1.2
9	12:30	1001	37.7	8.7	6.1	0.6	2.1
10	13:00	1009	38.2	8.7	6.1	0.6	1.8
11	13:30	1024	37.3	8.8	6.3	0.6	1
12	14:00	1037	37.3	8.8	6.3	0.4	1.2
13	14:30	968	37.2	8.9	6.3	0.5	0.5
14	15:00	877	37.7	8.7	6.4	0.5	0.9
15	15:30	842	36.4	8.5	6.4	0.4	0.2
16	16:00	672	36.2	8.9	6.4	0.4	1.9
17	16:30	617	35.2	7.8	6.4	0.4	0.7
18	17:00	389	34.3	7.7	6.4	0.4	0.4

The variation of battery voltage with solar intensity and variation in discharge of sprayer with corresponding voltage is shown in fig. 3

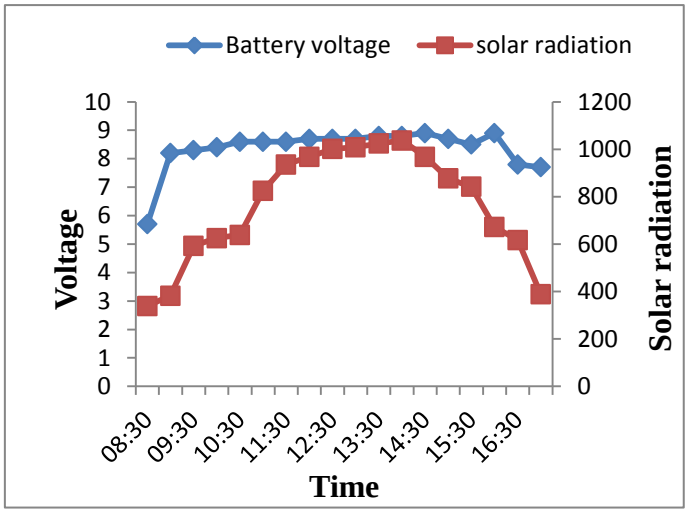

Fig. 3: Battery charging-discharging of SPV cum hand operated hybrid knapsack sprayer

It was observed that the SPV operated sprayer worked continuously for 8 hours without interruption due to availability of power from solar panel. The battery voltage varied from 6.4 volt to 3.4 volt during operating period. It was revealed that SPV cum hand operated knapsack sprayer operated 4 hour 30 min. without panel and 8 hour with panel continuously.

Economics of solar cum Hand operated hybrid knapsack sprayer:

The economic evaluation of solar cum hand operated hybrid knapsack sprayer for the discharge rate of 1350 ml/min and hand operated knapsack sprayer was calculated and result obtained are summarized in table.

Table 2. Economics of solar cum Hand operated hybrid knapsack sprayer

Sr No.	Description	Solar cum hand operated hybrid knapsack sprayer	Manually operated Knapsack sprayer
I	**Fixed cost**		
i	Cost of sprayer, Rs./h	5320	1400
ii	Depreciation, Rs./h	1.995	0.525
iii	Interest, Rs./h	0.798	0.21
	Total fixed cost Rs./h	**2.793**	**0.735**
II	**Variable cost, Rs./h**		
iv	Cost of chemical, Rs./h	**53.76**	**29.71**
v	Operator cost, Rs./h	**30**	**30**
vi	Repair and maintenance cost, Rs./h	**8.87**	**2.33**
	Total variable cost, Rs./h	**92.63**	**62.04**
	Total operating cost	**95.423**	**62.78**
vii	No. of labour @ 240 Rs./day	**1**	**1**
viii	Operating time of spraying, h/ha	**4.22**	**8.20**
ix	Field capacity, ha/h	**0.237**	**0.122**
X	Operational cost, Rs/h	390.89	514.78

Table 3: Specification of SPV, battery cum hand operated knapsack sprayer

Sr. No.	Components	Specifications	Materials
01	Solar photovoltaic module No of modules Dimension No of solar cells Short circuit current (Isc) Open circuit voltage Maximum power Weight	 1 Rectangular 48.5 × 32 cm2 36 1.14 A 22.08 V 20 Watt	Silicon Cell
02	Charge control unit Capacity	 5A	
03	Battery Type Voltage Capacity	Sealed Lead Acid Battery 12V8Ah	Lead Acid
04	Pump Type of pump Discharge Pressure	Diaphragm pump & piston pump 2.8 lit/min 80 PSI	
05	Hose pipe Length Diameter Pressure bearing capacity	 130cm 10mm 300 kpa	 Rubber
06	Cut-off device Type	Trigger	Plastic
07	Spray lance Type Length Diameter	Straight type 550mm - 900 mm 6mm	 Stainless steel
08	Type of nozzle	Hollow cone nozzle Twin nozzle	Plastic
09	Frame Weight	 1.6kg	 Mild steel
10	Tank Capacity Height Width Weight (empty tank)	 20 lit 400mm 300mm 4.65kg	 Plastic
11	Strap Length Thickness Width	 800mm 20mm 40mm	 Plastic coated fabric, rexin etc.
12	Pressure gauge Range	700 kpa	
13	Weight of sprayer without liquid	6.45kg	
14	Weight of sprayer with liquid	22.45kg	

CONCLUSIONS

This research work was undertaken for development of Solar cum hand operated Vegetable knapsack sprayer for vegetable crop spraying. The developed sprayer was tested for its feasibility of operation. Following conclusions are made from the present research study.

The Speed of operation of Solar cum hand operated Hybrid knapsack sprayer for Vegetable crops and Hand operated knapsack sprayer were observed as 2.52 km/h and 1.61km/h respectively, that means Solar cum hand operated knapsack sprayer has operating velocity 1.57times as compared to Hand operated knapsack sprayer because hand

operated knapsack sprayer requires more manual power for operating hand lever and fatigue is occurred in operator due which speed of spraying was reduces.

The operational cost of solar cum hand operated hybrid knapsack sprayer and hand operated knapsack sprayer is 390.89 and 514.78 respectively. It was concluded that hand operated knapsack sprayer require 1.32 times operational cost as that of solar cum hand operated hybrid knapsack sprayer.

Thus Solar cum hand operated hybrid knapsack sprayer will help the farmers of those remote areas of country where fuel is not available easily. They can perform their regular work as well as saves fuel up to large extent. At the same time, they can do their pesticide spraying work with very less environment pollution. Thus, indirectly saving revenue of government and also most demanded fuel, during cloudy atmosphere and unavailability of electricity for battery charging Spraying operation can be done by using hand operated lever provided in sprayer.

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