Bullock Drawn Solar Powered High Clearance Sprayer

Introduction

In Raichur district, cotton and pigeon pea crops are predominantly grown by the farmers. In order to control pest and diseases, generally farmers carry out 4 - 5 times spraying operation. Normally, many of the farmers use locally available manual operated Knapsack/motorized power sprayers and HTP power operated gun sprayers mounted on bullock cart. However, it is observed that the uniformity in spraying operation cannot be effectively achieved by using locally available sprayers. In the present context, labour shortage is a severe problem during spraying operation and demand more price. An economical and feasibility solution for spraying operation is required for cotton and pigeon pea crops in Karnataka.

Renewable energy source like solar energy is available abundantly, so by utilizing solar energy using solar panels a sprayer can be powered. In order to cover large area and to overcome the scarcity of labour, the bullock drawn solar powered high clearance sprayer was developed to utilize the available solar energy. The sprayer also can be used for spraying tall field crops due to its high clearance. The solar energy was used as power source for the operation of sprayer unit and bullock power will be used for pulling the cart. This will save save fossil fuels like diesel and petrol. Thus, solar energy is a promising solution and need to be utilized for spraying operation. The practical utility of solar powered bullock drawn sprayer has wide scope in Karnataka. The development and popularization of solar powered bullock drawn high clearance sprayer for cotton and red gram crops is essential and has wide scope in Karnataka. The entrepreneurship among farmers/users can also be created by conducting frontline demonstrations in farmers field. The revenue generation can also be done by the adoption of custom hiring service centre in villages. Hence, solar powered bullock drawn high clearance has more scope in Karnataka.

Constructional Details and Specifications

The sprayer consists of the working components namely Solar photovoltaic modules, Spray tank, DC motor Pump, Battery, Wheel, Seat, Spray boom, Nozzle and Pressure control device. The individual components were procured, fabricated, assembled and developed in the College of Agricultural Engineering, Raichur.

Solar pv modules

The solar pv modules were selected based on the power requirement of the motor and the pump. The discharge rate and the operating pressure influence the selection of the solar pv modules. The main parameter which influence the solar pv module is the temperature of the region and maximum sunshine hours. According to the requirement the capacity of solar pv modules selected was 500 W. The specification of single PV module is presented in Table 1.

Table 1: Specification of single pv module

Particulars	Details
Module area	1.64 m^2
Panel capacity	251.9 W
Irradiance	1000 W/m^2
Ambient temp.	27.2 °C
Current	6.99 A
Voltage	36 V
Module efficiency	15.3 per cent

Selection of motor

The selection of dc motor involves the discharge rate and the operating pressure required for the sprayer. The actual power required to pump the liquid and the power available from the solar pv modules should be matched with the motor. The dc motor is getting power from the pv modules directly and is coupled with the pump. The platform is made for both the pump and motor for uniform rotation of shafts. The specifications of selected motor are presented in Table 2.

Table 2: Specification of selected motor

Particulars	Details
Type	Permanent magnet DC motor
Capacity	0.5 hp
Current	15.5 A
Speed	1500 rpm

Pump

The gear pump was selected based on the power requirement for operating the sprayer. The selected gear pump is coupled with dc motor to pump the liquid. The speed of both the pump and motor should match with each other. The pumps used are of two sizes namely, 25 l/min and 50 l/min. The pump was connected to tank through the suction pipe. The specification of the selected rotary pump is presented in the Table 3.

Table 3: Specification of selected pump

Particulars	Details
Type	Rotary positive displacement pump
Speed	1500 rpm
Head	10 m
Discharge	25 and 50 l/min

a) Suction pipe

The suction pipe is used to suck the liquid from the tank with the help of four way nipple.

b) Delivery pipe

The delivery pipe was selected according to discharge and capacity to withstand the pressure. The flexible hose pipe was selected to deliver the water to spray boom. Tee joint with two sizes of 19.05 mm and 25.4 mm ball valves (flow control valves) were provided in the delivery pipe for diverting the flow. One of the ball valve remains closed during the operation.

c) Battery

The batteries used are lead acid dry type. Two batteries of 12 V capacities

were used. The pv modules produces 72 V as each panel will produce 36 V. The batteries were kept besides the tank. The current from the pv modules is continuously stored into the batteries in the sunshine hours. The switchboard is provided for batteries and pv modules. The batteries give constant power to the motor due to stored electricity. The pv modules give intermittent power to the motor because of variation in the solar intensity. Because of the higher voltage, the capacity of the pv modules is limited to 500 W. The specification of battery is presented in Table 4.

Table 4: Specification of selected battery

Particulars	Details
Type	Dry lead acid type
Voltage	12 V
Capacity	100 Ah

The line diagram and front, side & top view of bullock drawn solar powered high clearance sprayer is presented in Fig. 1 and 2. The complete view of developed solar powered high clearance sprayer ready for field trials is shown in Fig. 3.

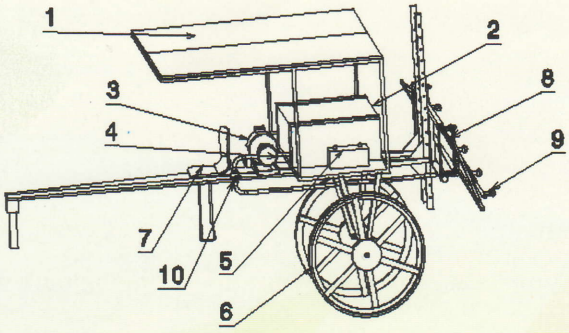

Fig. 1: Line diagram of bullock drawn solar powered high clearance sprayer

Components of sprayer

1. Solar photovoltaic modules
2. Spray tank
3. DC motor
4. Pump
5. Battery
6. Wheel
7. Seat
8. Spray boom

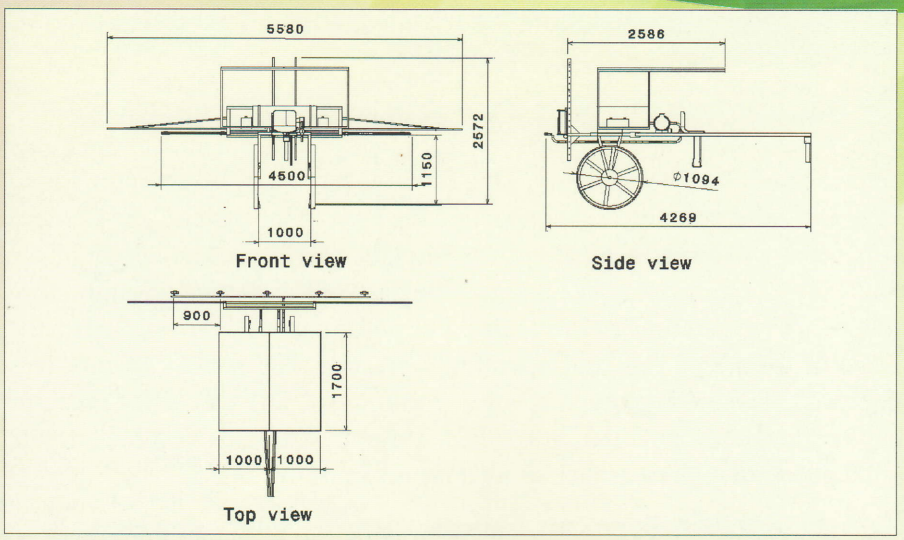

Fig. 2: Front, side and top view of bullock drawn solar powered high clearance sprayer

Fig. 3: A view of bullock drawn solar powered high clearance sprayer

Fabrication of sprayer

A solar powered spraying system has been developed for field crops. The spraying system consists of 5 hollow cone nozzles having discharge of 25 l/min and 50 l/min. The sprayer is provided with 500 W solar panels having 5 nozzles for spraying five plant rows. The solar sprayer is provided with DC pump of 0.5 hp and operating pressure of 10 kg/cm^2. The pump is

coupled with 24 V DC motor having an rpm of 1500. The sprayer is provided with water tank of 275 l capacity.

The two solar panels of 250 W are fixed on the frame through nut and bolt. The frame is made up of mild steel angles. The length and with of the frame are 1.70 and 2 m, respectively. This frame is having 5.08 cm angled mild steel and mild steel flats for supporting the base of the panels. The frame is supported by four angled steel from the tank platform. The length of the angles is 92 cm and size is 2.54 cm. The base of the frame and supporting angles are welded for rigid structure. The pump capacity is designed on the basis of discharge rate and operating pressure. The panel capacity was decided based on the pump capacity requirement. The seat of the operator is placed at the front end of the panels. The specification of bullock drawn solar powered high clearance sprayer is presented in Table 5.

Table 5: Specifications of bullock drawn solar powered high clearance sprayer

S. No.	Parameters	Value
1	Source of power	Solar pv modules
2	Pump	25 l/min and 50 l/min of 1500 rpm speed and 10 kg/cm^2 operating pressure.
3	Motor	0.5 hp capacity, 1500 rpm speed and 24 V, DC.
4	Power transmission	Panel-motor-pump
5	Number of nozzles	5
6	Pressure control device	Pressure relief valve
7	Boom length, mm	4500
8	Wheel, mm	Diameter 1000, width 100
9	Ground clearance, mm	1200
10	Tank capacity, l	275

Calibration of bullock drawn solar powered high clearance sprayer

The laboratory tests were conducted to assess the different machine parameters such as discharge rate at different operating pressure, uniformity of the spray, droplet size and spray angle. The different types of nozzles were tested at different operating pressure and different pump capacity at different levels of discharge rate, uniformity co-efficient, droplet size and spray angles.

Performance evaluation of bullock drawn solar powered high clearance sprayer

The performance evaluation of bullock drawn solar powered high clearance sprayer on cotton and red gram crops have been carried out at research farm of University of Agricultural Sciences, Raichur. During field trials, the biometric data pertaining to cotton such as row to row spacing, plant to plant distance and height of crop were noted. Before spraying operation, the wheels tread of the machine and spray boom height were adjusted according to row spacing and the height of crop. For spraying operation the recommended chemical solution as per the plant requirement was prepared separately in the tank. The chemical solution was thoroughly mixed and the same solution was poured into the chemical tank of the sprayer. In order to provide protection for operator the protective clothes, hand gloves and face cover glass were utilized to avoid any harmful effects for the operator during the field trials. The data on speed of operation, swath width, discharge rate, efficacy, power output and time losses were measured and noted for the cotton and red gram crop. The biological efficacy was also measured and the number of the insects present before spraying and after spraying was noted. The biometric parameters of cotton and red gram crop were noted during field trials. The data pertaining to machine parameters were recorded and analysed.

Efficacy

a) Cotton: The biological efficacy was measured for cotton. The chemical used for spraying cotton crop was dinotefuran (osheen). The chemical was mixed with water at a proportion of 0.2 gm/l. The main sucking pests for cotton were aphids and leaf hopper. The efficacy was measured by taking the number of insects present before the spraying and number of insects present 3 days, 5 days and 10 days after spraying.

b) Red gram: The efficacy of red gram crop was also measured during the field test. The chemical used for spraying the red gram crop was chlorantriniprole. The chemical was mixed with water at a proportion of 0.2 ml/l. The main insect present in the crop was Pod borer and Helicoverpa armigera. The efficacy was measured by taking the number of insects present 1 day before spraying and number of insects present 5 and 10 days after spraying.

Economics of bullock drawn solar powered high clearance sprayer

The cost of operation of the sprayer was calculated based on the fixed and variable cost. The cost of operation for spraying and its labour requirement for cotton crop has been worked out based on the fixed cost, variable cost, labour charges and bullock hiring charges and other prevailing wages.

The cost of operation for spraying has been estimated and the payback period for the sprayer unit has been worked out based on facts and assumptions. The breakeven point and payback period for bullock drawn solar powered high clearance sprayer was also calculated.

Results and Discussion

The laboratory and field tests were conducted to assess the performance of the sprayer. The solar radiation intensity and discharge rate at different time intervals is given in Table 6.

Table 6: Solar radiation intensity and discharge rate at different time intervals

Time	Intensity, W/m^2	Discharge, l/min (Single nozzle)
9am	650	2.3
10am	748	2.7
11am	952	2.9
12noon	991	3.2
1pm	980	3.0
2pm	860	2.6
3pm	854	2.5
4pm	763	2.5
5pm	580	2.1

The solar power output is measured for different time intervals from morning to evening. Since the spraying operation can be done any time in a day, the test was conducted from 9 am to 5 pm at 1 hour interval. The solar radiation intensity is normally high in bright sunshine hours and varied between 580 to 952 W/m^2 during the test period. The maximum power obtained directly from pv modules is at the afternoon. The biometric parameters of cotton and red gram are presented in Table 7 and 8, respectively.

Table 7: Biometric parameters of cotton crop

S. No	Particulars	Details
1	Variety	*Bt* (MRC 7351)
2	Average height of crop, mm	1150
3	Stage of crop, days	120
4	Row to row spacing, mm	900
5	Plant to plant spacing, mm	450

Table 8: Biometric parameters of red gram crop

S. No.	Particulars	Details
1	Variety	Maruthi ICP 8863
2	Average height of crop, mm	1560
3	Stage of crop, days	120-150
4	Row to row spacing, mm	600
5	Plant to plant spacing, mm	200

The performance results of bullock drawn solar powered high clearance sprayer on cotton and red gram crop are presented in Table 9 and 10, respectively.

Table 9: Field performance of bullock drawn solar powered high clearance sprayer on cotton crop

S. No.	Parameters	Values
1	Variety	B*t* Cotton MRC7351
2	Row spacing, mm	900
3	Plant to plant, mm	450
4	No. of rows covered, No.	5
5	Swath width, mm	4500
6	Total boom length, mm	5580
7	Operating pressure, kg/cm2	7
8	Discharge rate, l/min	36.5-44.5
9	Speed of travel, km/h	2.7
10	Draft, N	802.65
11	Size of field, ha	2
12	Field capacity, ha/h	0.945
13	Power output, kW	0.65
14	Quantity of chemical solution, l/ha	1840.47

Table 10: Field performance of bullock drawn solar powered high clearance sprayer on red gram crop

S. No.	Parameters	Values
1	Variety	Maruthi ICP 8863
2	Row spacing, mm	600
3	Plant to plant, mm	200
4	No. of rows covered, No.	7
5	Swath width, mm	4500
6	Total boom length, mm	5580
7	Operating pressure, kg/cm2	7
8	Discharge rate, l/min	36.5-44.5
9	Speed of travel, km/h	3.0
10	Draft, N	804.38
11	Size of field, ha	2
12	Field capacity, ha/h	1.012
13	Power output, kW	0.68
14	Quantity of chemical solution, l/ha	1717.7

The field trials carried out on cotton crop using solar powered high clearance sprayer is shown in Fig. 4. Bio-efficacy of spraying against leafhopper in cotton, Bio-efficacy of spraying against aphids in cotton and Bio-efficacy of spraying against *Helicoverpa armigera* in red gram are presented in Tables 11, 12 and 13 respectively.

Fig. 5: Spraying operation on cotton crop using bullock drawn solar powered high clearance sprayer

Table 11: Bio-efficacy of spraying against leafhopper in cotton

Treatments	Population of leaf hopper (No. of hoppers/leaf)			
	Pre count	3 DAS	5 DAS	10 DAS
T1	5.76	3.7	3.56	4.5
T2	5.46	1.66	1.53	2.46
T3	5.53	4.5	4.43	4.83
T4	5.46	4	4	4.46
T5	5.7	1.3	1	2.76

DAS: Days after spraying

Table 12: Bio-efficacy of spraying against aphids in cotton

Treatments	Population of aphids (No. of aphids /leaf)			
	Pre count	3 DAS	5 DAS	10 DAS
T1	27	13.66	12.66	11.33
T2	27.33	6.2	5.86	5.9
T3	30	14	13	12.76
T4	27.66	6.2	5.73	5.36
T5	28.66	5.8	5.53	15.86

DAS: Days after spraying

Table 13: Bio-efficacy of spraying against *Helicoverpa armigera* in red gram

Treatments	Population of *Helicoverpa armigera* (No. of *Helicoverpa armigera* /plant)			
	% pod damage	1 DBS	5 DAS	10 DAS
T1	27	2.1	1.0	0.5
T2	28	2.5	0.6	0.3
T3	30	2.9	1.5	0.4
T4	18	3.1	1.2	0.3
T5	21	3.0	0.9	0.3

DAS: Days after spraying
DBS: Days before spraying

Economics of bullock drawn solar powered high clearance sprayer for selected field crops

The cost of operation and the savings are presented in the Table 14.

Table14: Cost of operation and savings for bullock drawn solar powered high clearance sprayer for cotton and redgram crop

S. No.	Parameters	Cotton	Redgram
1	A) Total fixed cost, Rs/h	22.74	22.74
2	B) Total operating cost, Rs/h	98.36	98.36
3	Total cost (A + B), Rs/h	121.1	121.1
4	Total cost, Rs/ha	128.14	119.66
5	Breakeven point, h/annum	123.61	123.61
6	Payback period, years	3.6	3.6
7	Per cent of financial saving over the manual knapsack sprayer, per cent	56	67.14
8	Per cent of labour saving over the manual knapsack sprayer, per cent	56.6	59.48

The economics of bullock drawn solar powered high clearance sprayer were calculated. It was observed that, the cost of operation of bullock drawn solar powered high clearance sprayer was Rs.121.1/h and Rs. 128.14/ha for cotton and Rs. 119.66/ha for redgram crop. Breakeven point and payback period were 123.61 h/annum and 3.6 years. Per cent of financial saving over the manual knapsack sprayer was 56 per cent for cotton and 67.1 per cent for redgram crop. Per cent of labour saving over the manual knapsack sprayer was 56.6 and 59.48 per cent in cotton and redgram crop respectively.

In order to create awareness among the users, training programmes and demonstrations were conducted for the farmers, commercial manufacturers, village artisans and the other users. For fabrication, sale and service of bullock drawn engine operated sprayer for the farming community, the commercial manufacturers in this region have been identified for further popularization. The safety aspects to be followed for sprayer have been educated by conducting frontline demonstrations in villages.