The Pharma Innovation Journal 2022; 11(12): 5306-5310

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 5306-5310

www.thepharmajournal.com
Received: 20-10-2022
Accepted: 24-11-2022

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Design and cost economics of low cost solar powered weeder

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Abstract
Energy is the basic need of human being. Most of the innovation depends upon conventional energy sources affecting environment and human health. There is a need to turn science into green science by using non – conventional energy sources. Sun is a source of renewable energy which emits solar radiation, by using solar panel, which can easily convert electricity and do any mechanical work. The farmers are incurring huge expenditure towards weeding operation in ground nut crop. Commercially, numbers of mechanical operated weeders are available, which are costly and consume more fuel, which is expensive and availability of fuel at rural areas is difficult. In view of this, design and development of a low cost powered weeder for suitable in ground nut crop is highly essential, as the farmer is the heart of Indian economy and our new invention gives support to the farmer to use user friendly weeder. In review of this a low cost solar powered weeder suitable for groundnut was designed, fabricated and evaluated at college of agricultural engineering, Madakasira. The weeder consists of one solar panel, dc motor, two batteries, rotary blades, chain and sprocket mechanism and bevel gear mechanism. The solar panels make up most (upto 40%) of the systems cost. The size of PV system is directly dependent on the power consumption by the weeder, size of motor and the solar irradiance available. The cost for the fabrication of the machine is Rs.10,600/- and operating cost is Rs.76/hr. The machine was evaluated for charging and discharging time and cost economics.

Keywords: Solar powered weeder, battery, solar panel, solar irradiance

1. Introduction
Agriculture and its allied sectors are a prominent sector of economic development in India which amounts to 20.2% in the financial year 2020-21 (NSO). It has been the back bone of Indian economy and culture. One of the reasons behind reduction in the productivity in agriculture is weeds. Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost involved in agriculture production. A weed can be any plant growing in the wrong place at the wrong time and doing more harm than good (Parish, 1990) [6]. More than 33 percent of the cost incurred in cultivation is diverted to weeding operations there by reducing the profit share of farmers (Aditya Sirmour, 2018) [7]. Weeds waste excessive proportions of farmer's time, thereby acting as a brake on development (Lavabre, 1991) [5]. Weeds cause up to one-third of the total losses in yield, besides impairing produce quality and raising cost of production (NRCWS, 2007 & Thorat, 2014) [1, 8]. A study undertaken at DWSR suggests that proper weed management technologies, if adopted, can result in an additional national income of Rs.1, 05,036 crore per annum (NRCWS, 2007) [1].
Weed control methods in India are chemical, mechanical and biological. Manual weeding is laborious, ineffective and uneconomical due to decrease in agricultural labours. Mechanical weed control is one of the best methods for weed control. Fuel operated weeder requires fuel which is expensive and is a non-renewable energy and availability of fuel at rural areas is difficult. Another drawback of fuel operated weeder is the need of fuel which increases the running cost of the weeder also. Consumption of crude oil in 2014-2015 is 223.24 Million Metric Tons (MMT) to 232.87 MMT in 2015-2016 which shows that increase in consumption about 4.31%. (Source: Energy statistics-2017, Ministry of statistics and program implementation). The quantum of energy India's land area receive from sun is equivalent to 15,000 times its consumption requirement (500 billion kWh) as projected for 2004 (Amrutesh et.al, 2014) [2]. In order to overcome these difficulties, two objectives were selected in the research area 1. To design and develop a low cost solar powered weeder for groundnut crop and 2. To determine the cost economics of solar power weeder.

2. Material and Methods

The design and development of solar photovoltaic weeder and performance evaluation of weeder, step by step procedure of design and evaluation is given in detail. The present experiment was carried out at college of Agricultural Engineering, Madakasira. Madakasira is located at latitude of 13°54'N and longitude of 77°18'E. It has an average elevation of 676 meters MSL (2,221ft). The system was designed and fabricated by considering parameters like desired weeding capacity, low weight, low cost, user-friendly nature, high operating time and for faster coverage of area. Thus, the solar weeder was fabricated to be a value for money product in the agricultural sector. The system was fabricated according to the design parameters.

2.1 Design of Solar Photovoltaic Weeder

Solar power weeder is designed to remove the unwanted weeds that cause severe damage to the crop yield. Solar panel converts solar radiation into electrical power. The designed solar weeder mainly consists of a photovoltaic panel, charge controller, battery, DC motor, and roller. Panel converts solar beam radiation into DC electricity during the day. Battery is charged by PV panel and the electricity is stored in this device. In order to supply reduced voltage from battery to weeder, a charge controller is implied.

2.1.1 Determination of power requirement: The first step in designing a solar photo voltaic system is to find out the total power and the energy consumption of all loads that need to be supplied to solar weeder by the solar photo voltaic system.

2.1.2 Considerations of power requirements for design of weeder: Length= 0.2m (spacing of crop), Width of the blade = 0.04 m Radius of the weeder = 0.1 m. Soil cohesion (c) for compacted sandy loam soils is 50 to 75 Kpa (Cohesion (geotechdata.info)). Angle of internal friction (ϕ) for compacted sandy loam soils is 25 to 40° (consider 40^0 for maximum shear force). Weight acting (w) = Approx. 9 Kg (including frame weight, battery and motor and all accessories weight) taken for normal load.

2.1.3 The shear force requirement can be calculated from Mohr-coulomb criterion

Soil Shear Force F = AC + W tan ϕ, Soil shear force is 675N. Torque is 67.5 N-m. Considering the average speed of walking for agricultural field work as 1 km/h, the angular speed for the weeder is 2.77 rad/s. The total power required for the weeder is 187 W.

2.1.4 Sizing of the solar PV panel: Total energy needed by the PV panel is 215 W (considering 15% losses).

$$\text{Watt power requirement for solar panel} = \frac{\text{Total power}}{\text{Panel factor}} \text{ ... Eq.(2.2)}$$

Panel factor for solar panels is 4.32, hence 50 Wp solar panel as shown in fig.1 is selected.

2.1.5 Specifications of panel are as follows

V_{oc} = 21 V; I_{sc} = 2.48 A; V_{max} = 17.5 V; I_{mp} = 2.56A; P_{max} = 50Wp

Fig 1: Solar Panel

Fig 2: Battery

2.1.2 Sizing of battery

Two 12V batteries are used to supply the energy to the motor while they are in operational conditions. Connections of these batteries made in series and are placed in the frame. The capacity of the battery was selected by considering the following data: Total load =120 Wh/day

Nominal battery voltage = 12 V (two)

Battery capacity = 7A-h × 24 V = 168 W- h.

Two Storage batteries as shown in fig.2 of 7Ah, 12V is sufficient to run the system.

2.1.3 Sizing of charger controller: According to standard practice, the size of solar charge controller is to take the short circuit current (I_{sc}) of the PV array, and multiply it by 1.3.
Solar charge controller rating = Total short circuit current of PV array × 1.3 = 2.98 × 1.3 = 3.874 A Hence the solar charge controller rated 6A at 12V is selected which was available in market and is presented in Fig. 3.

Fig 3: Charge controller

Fig 4: DC Motor

2.1.4 Sizing of DC motor: A DC motor with the following specifications were selected for the solar powered weeder as shown in Fig. 4

Current – 13.4 A; Rpm: 2750 rpm; Voltage: 24 V; Torque: 4 N-m

2.1.5 Frame: It is designed in such a way that it should carry all the loads acted by the parts i.e., battery, solar panel, DC motor, Charge controller etc., A 4 mm thick MS flat bars were used for the supporting frame of a solar panel. The main frame to support and connect the roller, motor and panel supporting frame was made of Aluminum hollow pipes of 12 mm diameter. A container was fabricated to fix battery, charge controller and a DC motor on the frame. Gear system (bevel gears 1:1.5 ratio) and chain and sprocket (1:2 ratio) is fixed in between roller and DC motor, by that the speed reduction is done upto 1:3 ratio. The complete frame is as shown in Fig. 5. The developed solar power weeder is shown in Fig. 6.

Fig 5: Frame

Fig 6: Developed solar powered weeder

3. Results and Discussions

The results obtained in this study are presented and evaluated under the following headings:

1. Laboratory Testing of SPV weeder
2. Economics of SPV weeder

3.2 Laboratory testing of SPV weeder

Laboratory testing of SPV weeder was conducted at College of Agricultural Engineering, Madakasira to test different operating parameters like battery charging and discharging characteristics.

3.1.1 Battery charging with a SPV Panel of SPV weeder

The battery charging characteristics of SPV operated weeder was studied to determine the charging time and rise in battery voltage while weeder was in non- operating condition. The SPV panel was fully exposed to sunlight for battery charging. The various parameters like panel voltage, battery voltage, solar intensity was measured. The variation of battery voltage, panel volt age corresponding solar intensity with time is shown in Fig. 7 (a) to (d).

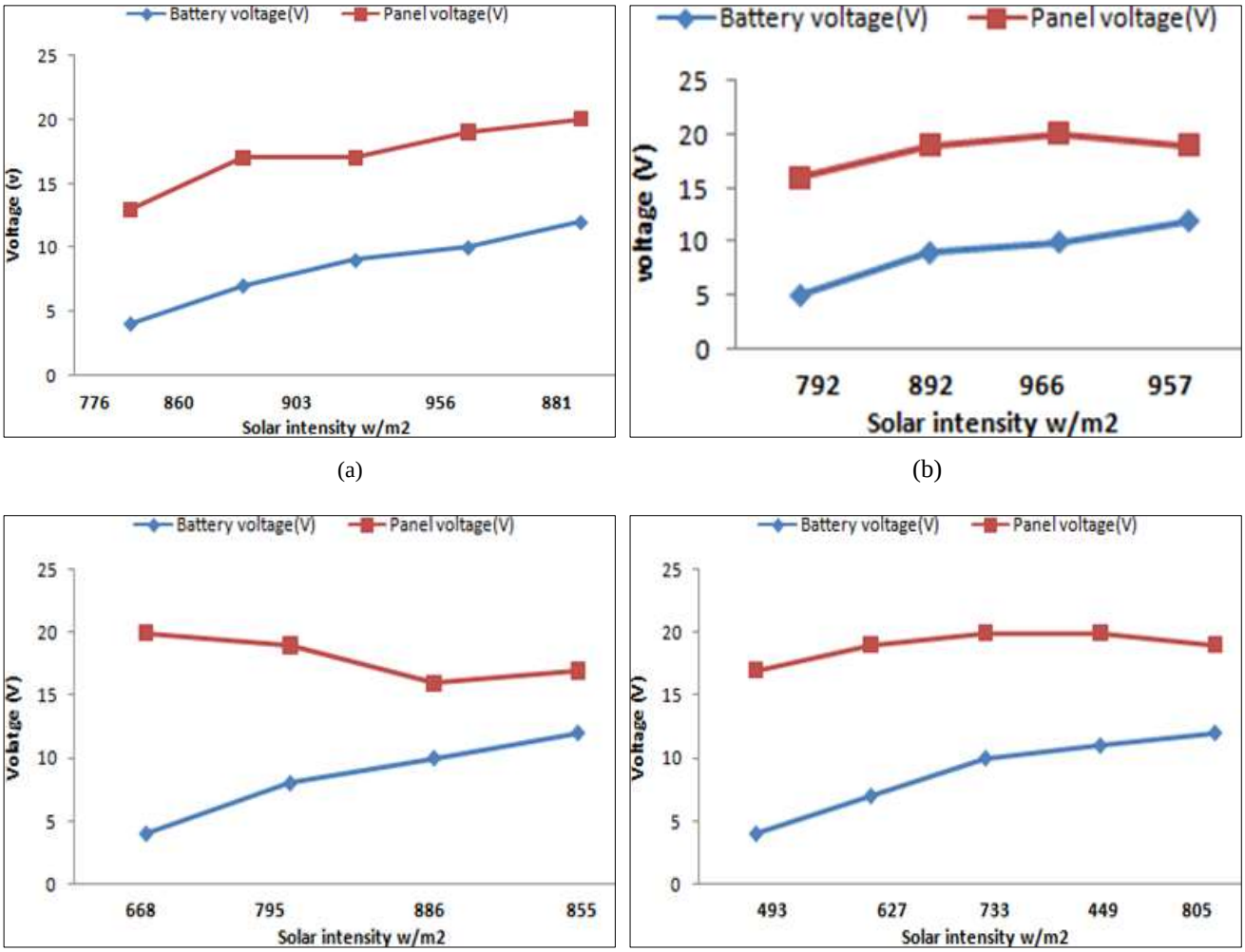

Fig 7: Graphs between battery voltages (V), Panel voltage (V) to that solar intensity (W/m^2)

It was observed that the time required for charging of battery starting at 10 AM (4 V) was found to be 5 hours to achieve full voltage of 12 V. The average charging time at 4.5 h solar intensity is found to be 900 w/m$^{2.}$

3.1.2 Battery discharging of SPV weeder

The battery discharging characteristics of SPV weeder was studied to determine the discharge time of battery. The various parameter recorded during the testing is found to be 6.5 hours without load conditions.

3.2 Economics of solar photo voltaic weeder

The installation of solar photovoltaic system consists of various components such as solar panel, storage battery, D.C. Motor, charge controller, frame and other accessories.

The total cost of newly developed solar photovoltaic weeder as per the prevailing rate was found to be Rs.10,600.00 is presented in Table 1 and cost economics of solar powered weeder is presented in Table 2.

Table 1: Total Cost for fabrication of Solar Powered weeder

Sl. No.	Description	Specification	Cost (Rs.)
1.	Solar panel	50 WP Voc=21V Isc=2.48 A	3200
2.	Solar charge controller	4A/12V	1000
3.	Battery	7AH/12V (two)	2000
4.	Motor	24V DC 2750 rpm	2500
6.	Frame	4 mm thickness flat, 12 mm hallow pipe	900
7.	Production cost		1000
Total Cost			10,600

Table 2: Cost economics of solar powered weeder

Sl. No.	Description	Solar Powered weeder
I	**Fixed cost**	
1.	Initial cost of weeder	10,600
2.	Depreciation, Rs/hr	1.27
	Interest, Rs/hr	1.16
	Total fixed cost	2.43
II	**Variable cost**	
3.	Operators cost, Rs/hr	62.5
4.	Repair and maintenance	10.6
	Total variable cost	73.1
5.	Total operating cost, Rs./hr	76

From the above table it is observed that the total operating cost of solar powered weeder is found to be Rs.76 per hour.

4. Conclusions

The present experiment was carried out at college of agricultural engineering, Madakasira, Anantapur district. The photovoltaic panel of 50 W capacity configured to trap the suns energy into the useful power and was used to perform the weeding. Solar panel was used for operating the weeder and for charging a battery. The DC motor is used for the running of solar photovoltaic weeder, connected with 12V, 7 Ah lead acid batteries which are used as an alternative power source during cloudy atmosphere and the points may be concluded is as follows:

1. The time required for fully charging a discharged battery using solar panel was found to be 5 hours at average solar intensity of 900W/m^2
2. It was observed that the SPV operated weeder worked continuously for 8 hours (9.00 A.M. to 4.00 P.M.) without interruption due to availability of power from solar panel. The battery voltage varied from 12 volt to 11 volt during the operating period on a clear sunny day.
3. The cost of solar photovoltaic weeder is Rs.10,600 /-

It may be concluded that the solar operated weeder can be used for weeding in rural areas.

5. Acknowledgement

The author acknowledges the financial support from College of Agricultural Engineering, Madakasira, Acharya N.G. Ranga Agricultural University.

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