The Pharma Innovation Journal 2023; SP-12(12): 1689-1694

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(12): 1689-1694

www.thepharmajournal.com
Received: 19-10-2023
Accepted: 25-11-2023

MV Jalu
Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat, India

R Yadav
Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat, India

PS Ambaliya
Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat, India

DB Chavda
Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat, India

Corresponding Author:
MV Jalu
Department of Farm Machinery and Power Engineering, Collage of Agricultural Engineering and Technology, JAU, Junagadh, Gujarat, India

Evaluating the battery performance of solar powered remote-controlled boom sprayer

MV Jalu, R Yadav, PS Ambaliya and DB Chavda

Abstract
Among the various agricultural operations plant protection is an essential operation in the basic practices of crop production. The crop yield is generally reduced by 40% mainly due to attack of pest, diseases and weeds and farmers have adopted many chemical methods for controlling them. The conventional method of spraying (hand operated spraying) results in excessive application of chemicals ultimately leading to environmental pollution, high labour intensive, time consuming, less uniformity rendering to more operational cost and also continuous spraying operation leads to fatigue of the operator. Solar power is one of the important renewable energy sources. A large amount of solar radiation falls on the earth. In most part of our country very few days are without sunshine. India lies within the latitude of 8º N to 37º N with annual average intensity of solar radiation of 1361 W/m^2. The time required for charging of battery was found to be 8 hours to achieve full voltage of 27.8 V. Solar powered remote-controlled sprayer worked continuously for 5 hours and 30 minutes (9:30 a.m. to 1:15 p.m.) without interruption due to availability of power from solar panel.

Keywords: Solar powered, automation, crop protection, agricultural sprayer, cost economics

Introduction

Agriculture sector holds significant importance in the Indian economy, accounting for approximately 20.19% of the national Gross Domestic Product. Farm mechanization is an important component for the economic and social development of any country. The concept of farm mechanization involves the integration of machines on agricultural land to accomplish various farm operations, resulting in increased agricultural production that is quicker, easier and more efficient (Pal *et al.*, 2016) [9]. The use of mechanization is critical to modern agriculture as it increases productivity and enables the judicious use of other inputs such as seeds, fertilizers, chemicals, pesticides and natural resources like water and soil nutrients, while reducing the cost of cultivation and human drudgery. Furthermore, it improves the safety and comfort of agricultural workers, enhances the quality and value of farm produce and enables farmers to plant second and subsequent crops, making Indian agriculture more attractive and profitable. It also helps the Indian farming to become commercial instead of subsistence. Therefore, it can be argued that farm mechanization is a crucial component of agricultural development that offers significant benefits to farmers and the economy as a whole.

Now-a-days, the concept and technology employing non-conventional energy has become very popular for all the developing activities as today's world faces a huge "energy crisis" problem. To meet the future "energy demands", the use of non-conventional energy sources as an alternate source is inescapable. Renewable energy has been an important part of India's energy planning process. To ensure energy security and to reduce the dependency on oil import, India started to develop and deploy alternative fuels such as hydrogen, bio-fuels and synthetic fuels. The technology that opted by India are bio, wind, hydro, solar, geothermal and tidal energy technologies (Osmani, 2014) [8].

Today the environmental impact of agricultural production is very much in focus and the demands to the industry is increasing. In the present scenario most of the countries do not have sufficient skilled man power in agricultural sector and that affects the growth of developing countries. Therefore, farmers have to use upgraded technology for cultivation operation (digging, seed sowing, fertilizing, spraying etc.). So, it's a time to automate the sector to overcome this problem. In India there are 70% people dependent on agriculture. Since we have lack of man power in our country, it is very difficult to do spraying operation on time; automation saves a lot of manual work and speed up the cultivation activity.

The energy required for this robotic machine is less as compared with other machines like tractors or any agriculture instrument, also this energy is generated from the solar energy which is found abundantly in nature. Pollution is also a big problem which is eliminated by using solar plate (Shantanu and Shubham, 2019) [11].

Review of Literature

Solar Energy Status in India

Sharma *et al*. (2012) [12] studied solar energy in India: strategies, policies, perspectives and future potential. The average intensity of solar radiation received on India is 200 MW/km^2 with 250–300 sunny days in a year. Solar energy intensity varies geographically with Western Rajasthan receiving the highest annual radiation energy and the north-eastern regions receiving the least. India has a good level of solar radiation, receiving the solar energy equivalent of more than 5000 trillion kWh/year. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m^2, with the hours of sunshine ranging from 2300 to 3200 per year. The annual global radiation varies from 1600 to 2200 kWh/m^2, which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6000 million GWh of energy per year. It can be observed that although the highest annual global radiation is received in Rajasthan, Northern Gujarat and parts of Ladakh region, the parts of Andhra Pradesh, Maharashtra, and Madhya Pradesh also receive fairly large amount of radiation as compared to many parts of the world especially Japan, Europe and the US where development and deployment of solar technologies is maximum.

Pathak and Muller (2016) [10] studied on Gujarat state: pioneering and scaling up solar energy in India. Located in western India, Gujarat is one of India’s most industrialized states. With a share of 7.5%, the state is the fourth largest contributor to national GDP. It has a population of around 60 million and is among India’s most prosperous states with a per capita GDP higher than the national average. Since the 1960s, the state has witnessed rapid industrial growth and has established leadership in several industrial sectors. Gujarat also has abundant solar resource potential, receiving 5.5–6 kW/m^2 per day with over 300 days of sunshine.

Suman and Ahamad (2018) [14]state that in India, there is a huge gap between the energy generation and energy consumption. India has a great potential for solar power and it is estimated so many times of the energy requirement which is about 5000 trillion kWh per year. The solar radiation incident over India is equal to 4–8 kWh/m^2 per day with an annual radiation ranging from 1200–2300 kWh/m^2. It has an average of 250–300 clear sunny days and 2300–3200 hours of sunshine per year. India's electricity needs can be met on a total land area of 3000 km^2 which is equal to 0.1% of total land in the country.

Development and Evalution of Different Sprayers

Dobariya and Vaja (2016) [4] investigated the performance of a battery-operated knapsack sprayer. They stated that knapsack sprayer was mostly used due to its light in weight, durable, strong, corrosion resistance, and comparatively low initial cost over larger power spray units. But still, the knapsack sprayer was lacking its best performance due to certain constructional and mechanical drawbacks. The battery-operated knapsack sprayer is widely affected by several parameters such as wind velocity, type of nozzle, and discharge.

Swami *et al.* (2016) [15] designed and developed a solar PV sprayer. The proposed solar PV sprayer had two modes of operation, direct and indirect. The sprayer was operated in two modes, stored electric energy in a battery and electricity generated by 100 W polycrystalline PV modules mounted on the sprayer. A 60 W DC motor pump was employed in all modes to create the requisite operating pressure for spraying the liquid pesticide formulations. The brass nozzle can be used for spraying, which required working pressure of 1.5-2 kg/cm^2 to provide a 900 cm^3/min discharge. The sprayer 50-lit liquid tank was used for continuous operation with two nozzles for two hours.

Ahalya *et al.* (2017) [1] designed and fabricated solar powered semi-automatic pesticide sprayer. A solar powered semi-automatic pesticide sprayer model consisted of a solar panel, a battery, two DC motors, pump, container, microcontroller and ZigBee device which was operated by a wireless remote (range of 30 to 50 meters) which run on power source as a DC battery (12 V, 9.5 2 Ah). The capacity of the container in the sprayer was designed with 4 litres capacity for an uninterrupted operation of 10 minutes with the discharge rate of 0.556 lpm. The vehicle was powered using an on board solar powered battery which run down the running cost.

Kim *et al.* (2017) [7] studied on analysis of spray characteristics of tractor-mounted boom sprayer for precise spraying. The performance test was conducted to investigate the spray characteristics of the nozzles on a commercial boom sprayer. In their experiment the flow rate and spray width of a single nozzle were measured at three levels of spray pressure of 0.5, 0.7, and 1.0 MPa at a spray height of 15, 30 and 45 cm respectively. They observed that the spray width tended to increase as the spray height and spray pressure increased. The effective spray width for a single nozzle was the largest at a spray pressure of 1.0 MPa and spray height of 45 cm which resulted in a coverage of 84 cm of width. The effective spray width for the entire boom sprayer was also the largest at the spray pressure of 1.0 MPa and spray height of 45 cm with a magnitude of 424.5 cm.

Sinha *et al.* (2019) [13] developed of multipurpose battery-operated wheel sprayer. Knapsack sprayer developing adequate pressure was laborious, time consuming and it increased the drudgery of the farmers. In order to overcome these difficulties a battery-operated sprayer had been proposed based on the general principle of spraying. This system was operated by direct current of battery. So, we used pressure pump whose flow liquid capacity was 7.5 lit/min at pressure 8 bar. The developed multipurpose battery-operated wheel sprayer comprised of 12 V and 12 Ah rechargeable battery; 12 V, 5 A pressure pump, charging unit and control switch.

Basavaraj *et al.* (2020) [3] designed a solar-operated sprayer that sprays using solar energy as a source of power. It was made up of a 20 W solar panel, a 12 V DC battery that was charged by solar energy collected by the solar panel, a DC motor, a pump, and an 18 lit pesticide tank. The theoretical field capacity, effective field capacity, and field efficiency of the developed sprayer were assessed at 0.6 ha/h, 0.5 ha/h, and 83.33%, respectively. The maximum discharge was 2.1 lit/min, while the minimum was 1.02 lit/min. The sprayer weighed 15 kg. The battery was also used for other applications.

Karale *et al.* (2020) [6] formulated design considerations in battery electric vehicle. To reduce the dependency on the fossil fuels, a low-cost battery electric vehicle (BEV) power requirement was estimated. The estimated mass of the BEV including the sprayer attachment was 375.22 kg for which theoretical torque requirement calculated as 67.53 Nm. The selected motor of 1 kW 48 V with 3000 rpm was found capable to propel the vehicle for spraying of crops with 25:1 gear ratio which produced 90.24 Nm torques. The maximum speed of the vehicle was calculated as 8.29 km/h during the transportation while spraying operations it was calculated as 3.5 km/h.

Ambaliya *et al*. (2022) [2] developed mini tractor operated sprayer cum weeder and evaluate its performance. A developed sprayer cum weeder was developed in the department of Farm Machinery and Power Engineering at Collage of Agricultural Engineering and Technology, Junagadh Agriculture University, Junagadh. The developed system was tested at 3 different forward speeds (1.5, 2.0 and 2.5 km/h) to evaluate performance. The maximum weeding efficiency (88.94%), field efficiency (86.27%), spray application rate (395.35 l/ha), lowest fuel consumption (1.15 l/h) and minimum plant damage (3.00%) were found at forward speed of 1.5 km/h. Operational cost of the developed machine was determined as ` 244.73 /h and ` 584.90 /ha.

Jalu *et al*. (2023) [5] studied that, in modern agriculture, the use of sprayers has become indispensable for crop protection and management. The effectiveness and efficiency of sprayers are essential to achieving optimal yields. There are various types of sprayers available, such as boom sprayers, air blast sprayers, and electrostatic sprayers, each with its own advantages and limitations. Factors that influence their performance include nozzle design, spray quality, and application rate. Moreover, here we discuss recent developments in sprayer technology and their potential impact on the future of agriculture. This review aims to assist farmers, researchers, and agricultural practitioners in selecting the most appropriate sprayer for their specific needs and applications. It also provides insight into the current state and future prospects of sprayer technology, with the goal of promoting sustainable and efficient agricultural practices.

Materials and Methods

Location of experiment: Battery performance of the developed sprayer was tested at the laboratory of Testing Centre of Farm Machinery under the college of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during the year 2022-2023. Junagadh (21.5° N latitude and 70.5° E longitude, 60 m above mean sea level) is located in the foothills of Mount Girnar in the South Saurashtra Agro Climatic Zone of Gujarat. The climate of Junagadh is semi-arid subtropical, with dry hot summers and cool winters. Average annual rainfall is 860 mm and over 75% of this received through the southwest monsoon during July to September.

Developed solar powered remote controlled sprayer: The developed solar powered remote-controlled sprayer consisted of front and rear frame, power transmission system (*i.e.*, pneumatic wheel, chain sprocket, DC motor), spraying unit (*i.e.*, liquid spray tank, hose pipe, pressure gauge, spray pump with motor, valve, nozzle, T-joint, boom), battery, transmitter and receiver, circuit box, solar panel, solar charge controller and steering unit. The developed sprayer was propelled by an electric motor that was powered by a rechargeable battery rather than an engine. A battery that is continuously charged by a solar photovoltaic panel via a solar charge controller. The overall dimensions of the developed sprayer are 2450×1750×1900 mm and having a weight of 261 kg.

Solar Photovoltaic Panel: A polycrystalline solar panel with a wattage of 330 was chosen and installed on the top of the sprayer. The features of the selected solar panel are listed in Table 1 and the solar panel is shown in Fig. 1.

Fig 1: Solar photovoltaic panel

Table 1: Specifications of solar photovoltaic panel

Sr. No.	Specifications	Value
1.	Model	GOLDI072F330PY24
2.	Type	Polycrystalline
3.	Rated maximum power (P_{max})	330 W
4.	Rated operating voltage (V_{max})	37.40 V
5.	Rated operating current (I_{max})	8.83 A
6.	Open circuit voltage (V_{oc})	46.20 V
7.	Short circuit current (I_{sc})	9.19 A
8.	Maximum system voltage	1500 V
9.	Panel dimensions (L×W×T)	1985 mm × 1000 mm × 35 mm
10.	Panel weight	22 kg

Solar Charge Controller: Solar charge controllers are vital components within solar power systems, serving a critical role in overseeing the battery charging process. The primary function of a solar charge controller is to regulate and control the current flow from the solar panels to the batteries, ensuring efficient and safe charging. The solar charge controller details can be found in Table 2, while it can be seen in Fig. 2.

Fig 2: Solar charge controllers

Table 2: Specifications of solar charge controllers

Sr. No.	Particulars	Specifications
1.	Manufacturer	Generic
2.	Type	Three-stage PWM regulation charging
3.	Model No.	AS-SCC-A-30
4.	Current	30 A
5.	Voltage	12/24 V
6.	Dimensions (L×W×H)	138 mm × 79 mm × 38 mm
7.	Weight	160 g

Battery: Lead-acid batteries were chosen for their effectiveness in supplying the power requirements of the DC motor and other electronics systems in solar powered remote-controlled sprayer. The sprayer system was powered by four batteries of 12 V arranged in a series-parallel format, with two batteries connected in series to form a single unit and then the two series-connected units joined in parallel. The battery specifications are listed in Table 3, while Fig. 3 depicts the battery.

Fig 3: Battery

Table 3: Specifications of battery

Sr. No.	Particulars	Specifications
1.	Model No	12V26AHSMF
2.	Battery Model	12 V, 26 Ah
3.	Capacity	26 Ah
4.	Number Of Cells	6

Battery Performance of developed sprayer

Battery discharge testing of the sprayer: The battery discharging characteristics of a solar powered remote-controlled sprayer were studied to determine the duration of the discharge and the level of the voltage drop. After the solar panel was unplugged from the solar charge controller, the battery was fully discharged by operating the sprayer. The battery voltage was measured at an interval of 15 minutes. The voltage reduction was noted till the full discharge of battery.

Testing of battery charging by solar panel: The solar powered remote-controlled sprayer's battery charging characteristics were examined in order to determine the charging time and battery voltage rise or increase. For battery charging, the solar panel was connected with the solar charge controller and the sprayer fully exposed in sunlight. The solar intensity and battery voltage were measured at an interval of 30 minutes. The battery was charged till it reached up to 27.8 V and the observed values were reported.

Battery charge and discharge testing of sprayer: The sprayer's operating time was determined by analysing the battery charging and discharging characteristics. A solar panel that was fully exposed to the sunlight was used to charge the battery while it was simultaneously used for operating the sprayer. The solar intensity and battery voltage were measured at an interval of 30 minutes. The sprayer was operated till the motor stopped working up to 22.6 V and the observed values were reported.

Results and Discussion

Battery discharge testing of the sprayer: The variation of battery voltage with time and corresponding discharge of the sprayer is shown in Fig. 4. It was observed that the charged battery (27.7 V) of solar powered remote-controlled sprayer and the battery voltage reduces gradually up to 22.9 V. The average operating time of sprayer was found to be 3 hours and 45 minutes. It was attributed for the fact that the use of only battery as a power source reduced the efficiency of overall system due to gradual reduction in operating voltage.

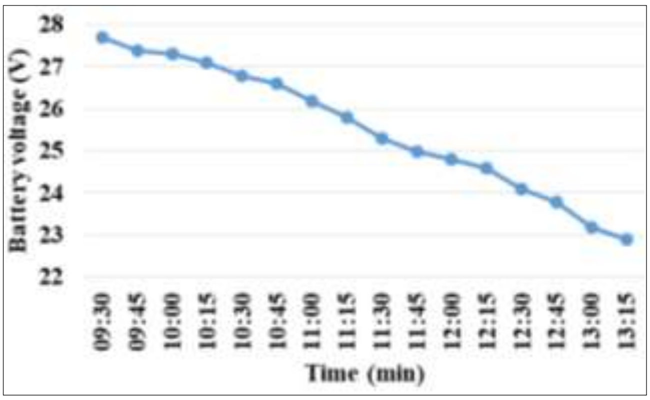

Fig 4: Battery discharging characteristics of sprayer

Testing of Battery Charging by Solar Panel: The solar panel was fully exposed to sunlight for battery charging. The solar intensity and battery voltage were measured. The variation of battery voltage corresponding to solar intensity with time is shown in Fig. 5. It was found that the time required for charging of battery starting from 8:30 A.M. (22.7 V) was found to be 8 hours to achieve full voltage of 27.8 V. The solar intensity ranged from 250 to 850 W/m^2 during the test. It was revealed that without solar panel, sprayer was operated only for 3 hours and 45 minutes, which indicates that there is a need of solar panel for a prolonged spraying operation.

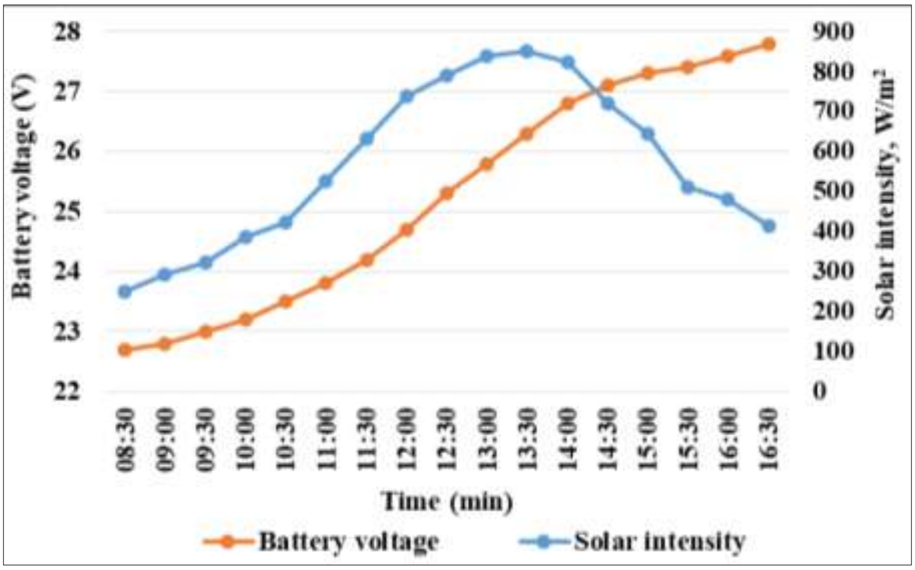

Fig 5: Battery charging characteristics of the sprayer

Battery Charge and Discharge Testing of Sprayer: The variation of battery voltage with solar intensity is shown in Fig. 6. The battery voltage varied from 27.5 to 22.6 V during operating period. It was revealed that solar powered remote-controlled sprayer operated continuously for 3 hours 45 min only without solar panel and with solar panel it was operated for 5 hours and 30 min continuously.

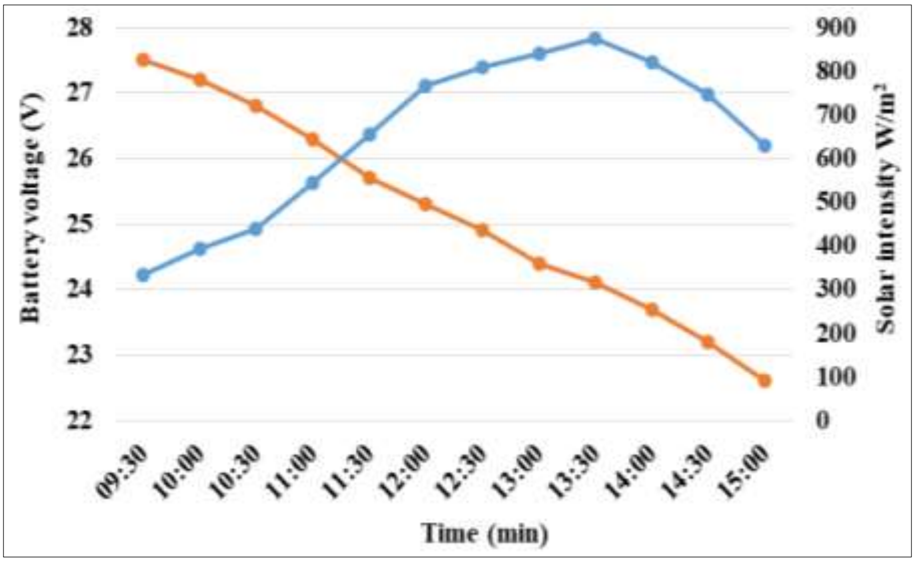

Fig 6: Battery charging – discharging of sprayer

Conclusion

The average operating time for spraying operation of developed solar powered remote-controlled sprayer was found to be 3 hours and 45 minutes. It was found that the time required for charging of battery starting from 8:30 a.m. (22.7 V) was found to be 8 hours to achieve full voltage of 27.8 V. The solar intensity ranged from 250 to 850 W/m^2 during the test. It was observed that, the solar powered remote-controlled sprayer worked continuously for 5 hours and 30 minutes (9:30 a.m. to 1:15 p.m.) without interruption due to availability of power from solar panel.

References

1. Ahalya M, Muktha A, Veena M, Vidyashree G, Rehna VJ. Solar powered semi-automatic pesticide sprayer for use in vineyards. Int J Electron Commun Eng. 2017;4(4):54-57.
2. Ambaliya PS, Tiwari VK, Jalu MV. Development and performance evaluation of mini tractor-operated sprayer cum weeder. Int J Agric Innov Res. 2022;11(1):2319-1473.
3. Basavaraj PR, Ajaykumar K, Swathi M. Development and evaluation of solar-operated sprayer. Indian J Ecol.

2020;47(11):245-248.
4. Dobariya UD, Vaja KG. Performance of battery-operated knapsack sprayer. An Int e-Journal. 2016;5(2):146-157.
5. Jalu MV, Yadav R, Ambaliya PS. A comprehensive review of various types of sprayers used in modern agriculture. Pharma Innovation. 2023;12(4):143-149.
6. Karale DS, Thakre SH, Khambalkar VP, Deshmukh MM, Walke RD. Design considerations in battery electric vehicle. Int J Eng Creat Sci. 2020;3(6):2581-6667.
7. Kim KD, Lee HS, Hwang SJ, Lee YJ, Nam JS, Shin BS, *et al*. Analysis of spray characteristics of tractor-mounted boom sprayer for precise spraying. J Biosyst Eng. 2017;42(4):258-264.
8. Osmani AR. Conventional energy to renewable energy. North-Eastern Hill Univ J. 2014;12:41-60.
9. Pal R, Ram K, Mishra R, Bhatia S, Singh AB. Study of tillage and performance evaluation of zero seed drill. Int J Eng Sci Res Technol. 2016;5(11):491-499.
10. Pathak M, Muller SA. Gujarat state: Pioneering and scaling up solar energy in India. Low Emission Development Strategies Global Partnership; c2016.
11. Shantanu SC, Shubham SC. Design and fabrication of multipurpose solar-operated seed sowing machine. Int Res J Eng Technol. 2019;6(5):55-57.
12. Sharma NK, Tiwari PK, Sood YR. Solar energy in India: Strategies, policies, perspectives and future potential. Renew Sustain Energy Rev. 2012;16:933-941.
13. Sinha Y, Chauhan J, Tandan J, Patel K, Kaushik SP. Development of multipurpose battery-operated wheel sprayer. Int J Curr Microbiol Appl Sci. 2019;8(11):1766-1772.
14. Suman SK, Ahamed J. Solar energy potential and future energy of India: an overview. Int J Eng Sci Comput. 2018;8(5):17575-17579.
15. Swami V, Chauhan DK, Santra P, Kothari K. Design and development of solar PV based power sprayer for agricultural use. Ann Arid Zone. 2016;55(1-2):51-57.