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Solar Powered Sprayer- A review

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Abstract— Solar powered sprayer hold promise toward the agriculture's unmechanized and drudging tasks of manually or small engine operated sprayer. The solar-powered sprayers also save crop cultivation cost and reduce environmental pollution. This review describes the current status of the solar-powered sprayer, flow chart and circuit diagram required for the successful development of the sprayer. The capacity of solar panel varied from 10 W to 60 W. A very good relation was found between the size and weight of the solar panel with the power rating of the solar panel. The capacity of the spray tank was varied between 12 L to 16 L. However, there was no relation found between the capacity of the spray tank and power rating of the solar panel. The weights of the panel were varied from 2 kg to 6 kg. The power rating of the solar panel increases its weight raises but the time for charging the battery decreases if the solar panel is operating at its maximum rating. The relation between power rating of solar panel and charging time of battery was established and presented graphically. A few complete solar powered sprayers have demonstrated the potential of the technology in the field. Additional research and development is needed to fully realize this potential.

Index Terms— solar panel, charging battery, flow chart of sprayer, circuit diagram, spray and ergonomics.

1 INTRODUCTION

IN agriculture sector there is a lot of field work, such as weeding, reaping, sowing etc. Apart from these operations, spraying is also an important operation to be performed by the farmer to protect the cultivated crops from insects, pests, funguses and diseases for which various insecticides, pesticides, fungicides and nutrients are sprayed on crops for protection [1]. Most of the developing countries of the world use hand operated compression type (fig.1) or lever operated sprayer (fig. 2) or a small engine operated sprayers (fig.3) to apply pesticides in their field. The operation of compression type, lever operted knapsack and engine operted spryers are shown in fig. 4 and 5 respectively.

A hand operated sprayer is a continuous type of sprayer with a fairly constant discharge rate. A person maintains pressure in the tank by pumping air with a lever with one hand and directs the spray lance with the other hand. The recommended lever strokes per minute are 20-30 and 10-25 by FAO [5] and [6] and RNAM [7] respectively. Maintaining a constant pressure is very difficult with a manual knapsack sprayer and causes user fatigue due to maintain a constant pressure and excessive heavy bulky construction [8],[9],[10],[11] and [12]. The maximum discomfort in the body parts experienced in the lever-operated knapsack sprayer were in the left clavicle region, followed by lower back, neck, left thigh and right clavicle [13], [14] and [15]. In addition, the lever operation induces greater variation in spray pressure results inconsistency of application which adversely affects pest control [16], [17], [18] and [19].

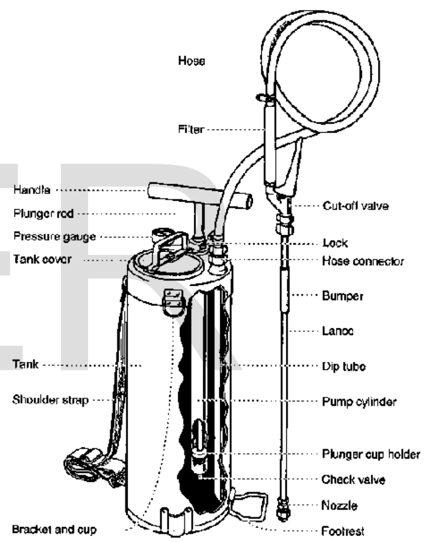

Fig.1. Manually operated compression sprayer [2]

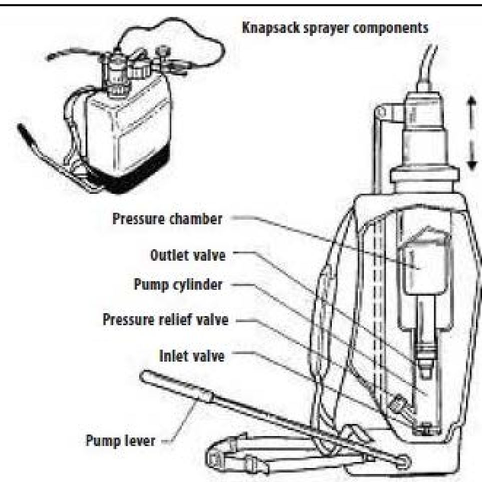

Fig.2. Components of lever operated knapsack sprayer. [4]

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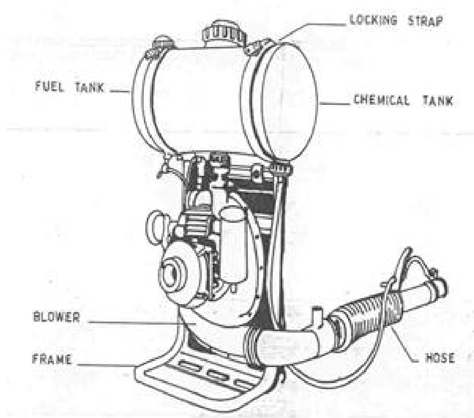

Fig.3. Engine operated sprayer [3]

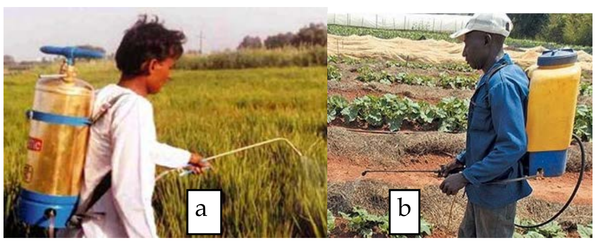

Fig.4. Farmers are operating; (a) a compression sprayer [3], (b) a lever operated knapsack sprayer [4]

Fig.5. Farmer is using a small engine operated sprayer [4]

Engine operated sprayers are harmful because of vibrations transmission to human body parts results in early fatigue and reduced work output of the workers [20]. The vibration levels transmitted to specific body parts of the operator besides causing discomfort could be a source of long-term health hazards [21]. The heart rate of the operator is also increased with the vibration to the human body in power knapsacks sprayer operation [22]. The engine operated sprayer is working on petrol. The use of conventional energy i.e. petrol produces pollutants which are harmful to the environment [11]. On the other hand, the world faces a huge “energy crisis” problem [8] and [23] due to decreasing the supply of petroleum, gas, and coal. To meet the future “energy demands”, the use of non-conventional energy, solar energy, as an alternate solution is inescapable. Solar radiation is collected by solar panels and then converted it into electrical energy by photovoltaic conversion process [24]. Therefore, many researchers are planning to conduct research to design and development a solar power sprayer. This paper will help to new researchers to work on the solar-powered sprayer.

2. METHODOLOGY

Different books, journals, research papers, websites were searched to get the information on solar power sprayers. Those were studied thoroughly and collected information to write the paper. The flow charts and circuit diagrams of various developed solar-powered sprayers are presented in the paper. The selection of the solar panel was done by considering the weight criteria as well as its ability to charge the battery. The current produced by the solar panel was calculated by knowing the maximum rating power of the solar panel and the voltage rating of the battery. Charging time was computed by the ratio of battery rating to the total current produced by the solar panel [26]. The technical specifications of different components used for developing the solar-powered sprayer by the researchers were summaries in a table to get the information at a glance. Relations were investigated between the size and weight of the solar panel with the power rating of the solar panel. The relation between power rating of solar panel and charging time of battery was also investigated. Those relations were presented graphically to get quick information.

3. RESULTS & DISCUSSIONS

The main functional parts of the developed solar-powered sprayers of different researchers were; solar panel, DC motor, battery, micro control sensor, emergency LED, spray nozzle, pesticide tank, etc. The solar radiation is collected by solar panels and then converted it into electrical energy by photovoltaic conversion process [24]. The battery uses electricity to charge itself. The electricity which is stored is used to run the motor and other portable devices [12]. When the switch is turned ON the electricity is provided to suck pesticide from the tank and deliver it through the motor. But the ON and OFF state of the motor is controlled by spray gun trigger. When the trigger is pulled, the motor is made ON and pressure is maintained by micro control sensor. The motor is made OFF as trigger is released. Block diagram of solar operated sprayer and the circuit diagram are shown in fig. 6 and 7 respectively [11] and [12]. They provided 2 adopters with the rechargeable battery for plug-in and out connection for emergency LED and DC mobile charger.

Singh et al. used two ways in energy conversion; Alternating Current (A.C) and a solar panel to charge a deep cycle lead-acid battery. A.C supply converted into Direct Current (D.C) supply with the help of full wave bridge rectifier which consist a step-down and diodes in star connection. In case of solar energy mode, solar energy converted into electrical energy using solar panel by photovoltaic effect and stored in the battery. The output of battery was connected to a DC pump to suck the spraying liquid from the sprayer tank and spray it through nozzle. Figure 8 shows the block diagram of the developed solar sprayer by Singh et al.

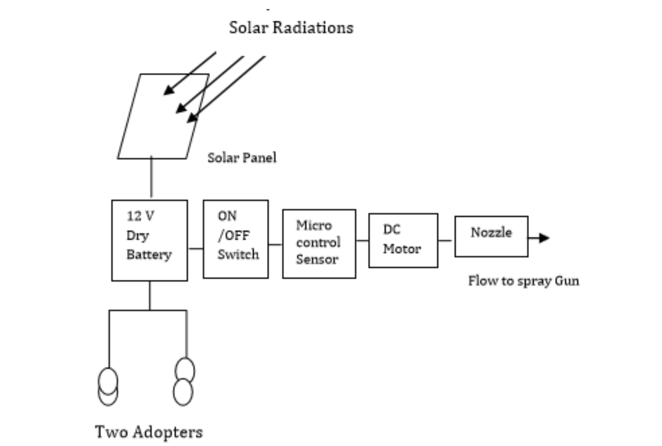

Fig.6. Block diagram of solar powered sprayer [11] and [12].

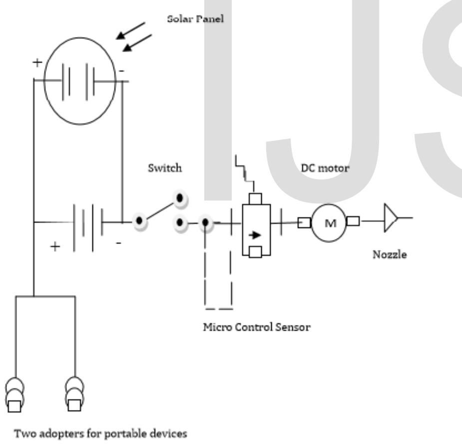

Fig.7. Circuit Diagram of the sprayer [11] and [12].

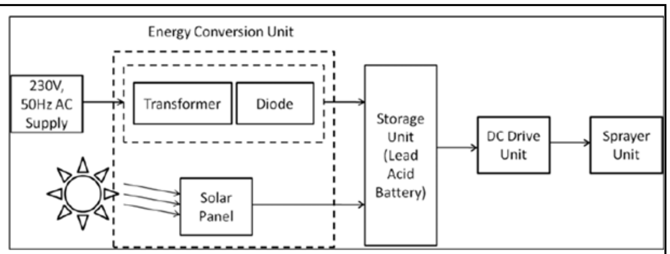

Fig.8. Block diagram of the sprayer [1]

Sinha et al. used solar photovoltaic (SPV) panel of 60 W for charging the power pack of the sprayer system. They reported that deep discharge of battery was a common problem encountered by farmers in the commercially available battery. In order to overcome this problem, an electronic module was designed to cut off the power supply to the motor whenever the battery voltage reduced to 10 V with the help of voltage comparator circuit and magnetic relay. The voltage-current comparator circuit with magnetic relay was designed for cut off from charging source to the battery as and when the current drops below 70 mA [25]. The module was also embedded overcharging cutoff feature to protect the battery from the detrimental effect on service life due to overcharging. Sinha et al. also reported that the maximum performance of SPV found when the irradiation falls perpendicular to the panel surface so an adjustable frame was designed to alter the angle of SPV as per latitude of the site. Figure 9 shows the block diagram of the developed solar powered sprayer by Sinha et al.

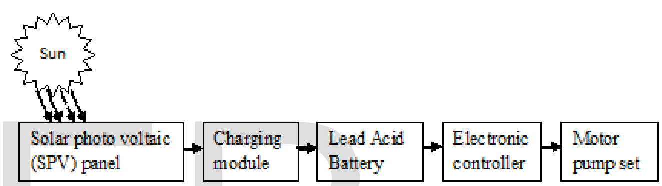

Fig.9. Block diagram of solar powered sprayer [9]

Chavan et al. used a charge controller between a solar panel and a lead-acid battery for limiting the rate of electric current is added to the battery. The output from the charge controller was given to the battery by a 3 pin socket through an electrical network. This circuit was designed to control the revolution of the motor by controlling the amount of resistance between the motor and the battery while simultaneously providing a charging supply for the battery. The circuit had 3 states. O state; the switch was off in this state. The circuit was in the dead state but the battery would be charged through the plug. II state; the 2nd part of the circuit is switched on. When VA=VB, there was no current flowing through the connecting wire AB by which the motor loop was isolated from the battery. Even there the plug charged the battery but the motor did not run. I state; the switch was turned to I. Thus, the entire circuit was switched on. The motor operates while there was simultaneous charging of the battery through the plug. The motor's revolution was controlled by the value of the variable resistance as shown in fig. 10. Figure 11 shows the block diagram of spraying system.

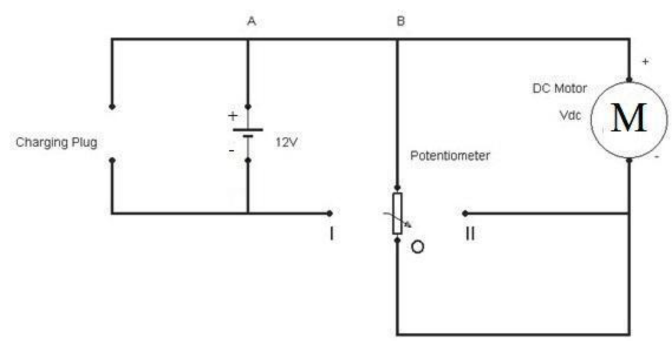

Fig.10. Electric circuit for speed control of motor [26]

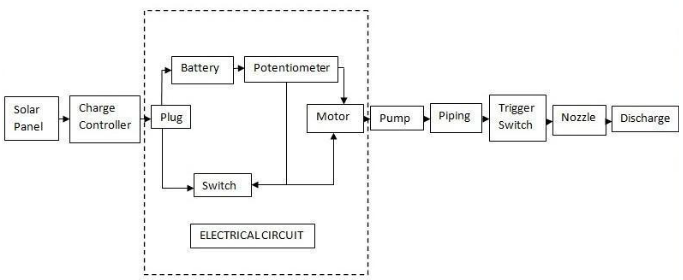

Fig.11. Block diagram of spraying system [26]

Tukaram et al. used infrared (IR) green sensor to detect the green leaves. When green leaves were detected by the sensor, it started to pump the pesticides otherwise not. Thus, the machine eliminates the wastage of chemical due to continuous spraying and reduces environmental pollution [27].

Singh et al. reported that their sprayer was capable of spraying 850 l/ha to 1280 l/ha in 7.15 hrs at a walking speed of 0.70 m/s. The fully charged battery could be used to spray 850 L to 1285 L of pesticides or fungicides, which approximately spray 2.5 to 3 acres of land. They concluded that the developed system would enhance the working capacity of the farmer by reducing time and fatigue from continuous hand spraying [1].

Details ergonomics studies; heart rate along with postural parameter of Overall Discomfort (ODS) and Body Part Discomfort Score (BDPS) were done by Sinha et al. They found that the mean heart rate (light work category) and BPDS was lowest for solar sprayer compared to manual and air-assisted sprayer indicating lower physiological demand and discomfort to the body parts. The spray spectrum was also found uniform with the selected nozzle and operating pressure. It would be considerably enhancing the quality of spray and ultimately chemical efficacy as well as efficient pest control [9]. The weight of the system was 8 kg and a maximum weight of the system by considering fluid was 23 kg for developing the solar-powered sprayer by Chavan et al. The spray discharge was 327 ml/min and covered 1 acre in 3 hrs. They reported that their sprayer reduced user fatigue and improved the quality of spraying pesticides. In addition, the cost was low and easy to move in the field [26].

Kothari et al. reported that their solar operated sprayer was eco-friendly and lower cost, and thus would prove to be more efficient when compared to petrol based pesticide sprayer. The proposed sprayer is most suitable for small and medium scale farmers and remote areas like the field, forest where fuel is not available easily. The portable devices, the adaptors are fixed on the body of the tank and this adaptor provide plug-in and out connection for emergency LED and mobile charger [11].

The capacity of solar panel varied from 10 W to 60 W. A very good relation was found among volume and weight of the solar panel with the power rating of the solar panel. Relation among volume and weight of the solar panel with the power rating of the solar panel are presented in Fig.12 and 13 respectively.

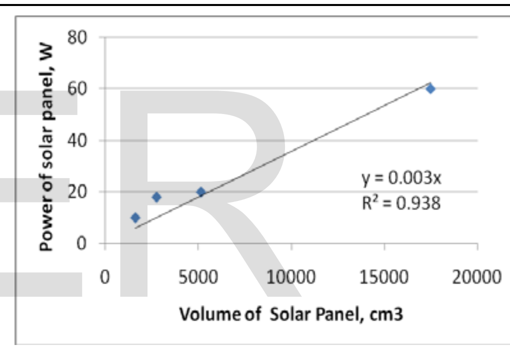

Fig.12. The relation between power rating and volume (size) of the solar panel

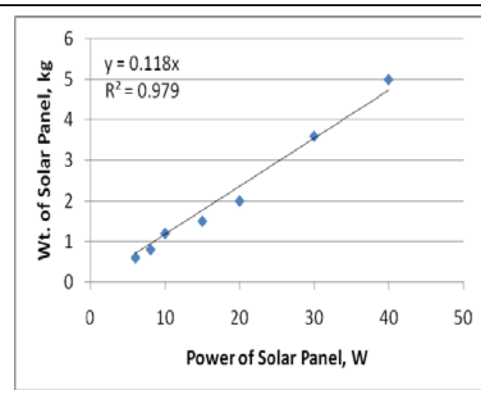

Fig.13. The relation between power rating and weight of the solar panel

The technical specifications of different components used for developing the solar sprayer by some researchers are presented in table 1.

TABLE 1
TECHNICAL SPECIFICATIONS OF DIFFERENT COMPONENTS USED FOR DEVELOPING THE SOLAR SPRAYER BY SOME RESEARCHERS

Parts	Specifications of solar powered sprayers developed by different researchers			
	Chavan et al.	**Kothari et al.**	**Singh et al.**	**Sinha et al.**
Tank	PVC, 16 L, wt =1 kg	12 L, DIM = 59 x 42 x 18.5 cm, wt = 4.4 kg		14 L
Solar panel	P_m = 20 W, wt = 2 kg, DIM = 49×35×3 cm, V_{mp} = 17 V, I_{mp} = 1.18 A, V_{oc} = 21 V, I_{sc} = 1.2 A, Tolerance: ± 5%	P_m = 18 W, DIM = 397×278×25 mm, wt = 1.6 kg, I_{mp} = 0.66A, V_{oc} = 12V, I_{sc} = 0.65 A, I_{op} = 12 A	P_m =10 W, V_{mp} = 16.8V, I_{mp} = 0.66A, V_{oc} = 15V, I_{sc} = 0.33A Tolerance : ±5% DIM = 180×360×25 mm	V_{oc} =21.57 V, I_{sc} = 3.71 A, V_{mp} = 17.26 V, I_{mp} = 3.48 A, DIM = 740 × 675 × 35 mm, wt = 6kg
Charge controller	Capacity: 12V, 5A, Pulse Width Modulation (PWM) technique			
Battery	Sealed Lead Acid battery, 12 V, 9 Ah, DIM = 15×9×6 cm, wt = 2.5 kg, Constant voltage charge with regulation, Standby use : 13.5 V-13.8 V, Cycle use: 14.5 V – 14. 9 V, I_{mi} = 2.4 A	P_o = 144 W, V_{op} = 12V, I_{op} = 9A, wt = 2 kg, Rs.1200-1500, V_{oc} = 12 V, I_{sc} = 0.65A	Model No. : SPG12032W, Capacity= 12V, 8Ah, P_o = 96 W, I_{mi} = 1.4 A, Standby use : 13.6V -13.8V Cycle use: 14.1V-14.4V. Battery Charging time 11.2 hr, Discharge time = 2.66 hr, Facility to charge by 220V.	Fully charged by solar energy within 2 hours and can be operated continuously for 6 hours.
Motor	Brushless DC motor, 12 V, 2.2 A, RPM :0-6000	84 W, 12V, 3A, 1,600 rpm, 1kg, 1 L/min, 1.6 kgf/cm², Rs.1500-2000	Model no. : LF1524210 V_{Op} = 12V, I_{Op} = 3A Wt = 800g	P_m = 20 W, Motor efficiency = 0.80
Pump	Diaphragm, DIM = 17×6×6 cm, wt = 550 gm, Q_{max} = 3 l/min at 80 psi. In built operating pressure switch to cut off the pump from the motor when the pressure exceeds the max value.		Model No. : LF1524210 Q_{max} = 2.5 to 4.5 L/min at 40 psi or 2.81 kg/cm²	Q = 1.83 L/min at 3 kg/cm², pump efficiency: 0.70, 25% safety factor

V_{oc} = Open circuit voltage, I_{sc} = Short circuit current, V_{mp} = Voltage at maximum power, I_{mp} = Current at maximum power, Weight = wt, P_m = Maximum power, DIM = Dimension, P_o = Power output, I_{mi} = Max initial current, V_{op} = Operating voltage, I_{op} = Operating current

The capacity of the spray tank was varied between 12 L to 16 L. However, there was no relation between the capacity of the spray tank and power rating of the solar panel. The weight of the panel varied from 2 to 6 kg. The power rating of the solar panel increases its weight raises but the time for charging the battery decreases if the solar panel is operating at its maximum rating [26]. The relation between power rating of solar panel and charging time of the battery is shown in Fig. 14.

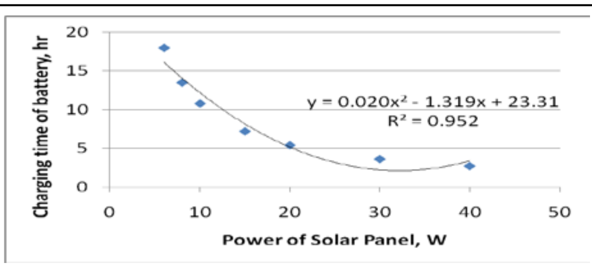

Fig.14. The relation between power rating of the solar panel and charging time of the battery

4. SUMMARY & CONCLUSION

Agriculture operation consists of many tedious processes and practices, one of which is the application of pesticides in the fields to control the pests. In the developing countries, farmer carries a sprayer and manually develops pressure and pump the pesticide through a tube. This operation makes the operator maximum discomfort in lower back, neck, left thigh and right clavicle of the body. Some farmers of the developing country carry engine operated sprayer to spray pesticides. The vibration of the engine transmits to human body parts results in early fatigue and creates long-term health hazards. In addition, the use of conventional energy i.e. petrol produces pollutants which are harmful to the environment. However, the solar energy which is available from the sun at free of cost might be used to operate the spray pump to reduces labor, vibrations, noise, and cost. This paper investigates available solar power sprayers and present design, flow chart of fabrication, and circuit design of different sprayers. Some solar operated sprayers have achieved a high level of development and some commercial success to spray pesticides in the field, of agricultural applications. However additional research is needed to develop improve version of solar operated sprayer to use widely in developing countries.

REFERENCES

[1] K. Singh, D. Padhee, A.K. Parmar and B.L. Sinha, " Development of a Solar Powered Knapsack Sprayer," Journal of Pharmacognosy and Phytochemistry, vol.7, No.1, pp. 1269-1272, 2018

[2] WHO, Vector Control - Methods for Use by Individuals and Communities, pp.425, 1997. http://www.nzdl.org/gsdlmod

[3] http://eagri.org/eagri50/FMP211/lec12.html, Lecture Note.

[4] https://www.africanfarming.com/mechanisation-effectively-use-knapsack-sprayers/

[5] FAO, Pesticide application equipment use in agriculture. *Manually Carried Equipment*, Vol 1. Food and Agriculture Organization, Rome. 1994.

[6] FAO, Agriculture pesticides sprayers. *FAO Technical Standards: Sprayer Specifications and Test Procedures*, pp 7-8, 1998

[7] RNAM, Regional network for agricultural machinery. *RNAM Test Codes and Procedures for Farm Machinery, pp* 171, 1995.

[8] G.A. Matthews, "Pesticide Application Methods, "Longman, New York, 1st ed. pp. 110, 1979

[9] J.P. Sinha, J.K. Singh, A. Kumar and K.N. Agarwal, "Development of Solar Powered Knapsack Sprayer", *Indian Journal of Agricultural Sciences, vol.* 88, No.4, pp. 590–595, April 2018

[10] R. Chavan, A. Hussain, S. Mahadeokar, S. Nichat, D. Devasagayam, "Design and Construction of Solar Powered Agricultural Pesticide Sprayer", International Journal of Innovations & Advancement in Computer Science IJIACS ISSN 2347 – 8616 Vol. 4, No.4, April 2015

[11] P.H. Kothari, H. M. Age, J.A. Kathuria, A.A. Bagul, R.D. Hucche, " Design and Fabrication of Solar Operated Agro Sprayer," *International* Journal of Innovative and Emerging Research in Engineering Vol. 4, No. 3, pp.223-226, 2017

[12] P.J. Mali, Y.G. Ahir, A.S. Bijagare, R.S. khadayate, "Solar Operated Spray Pump", International Research Journal of Engineering and Technology (IRJET), Vol.3, No.22 , Feb-2016

[13] S.H. Ghugare, L.P. Adhaoo, A.C. Gite, S.L. Pandya, and Pate. "Ergonomics evaluation of a lever-operated knapsack sprayer Applied Ergonomics", Vol. 22, Issue 4, pp. 241-250, August 1991

[14] B. Riley, L.Newman, "Health Hazards Posed to Pesticide Applicators", Northwest Coalition for Alternatives to Pesticides, pp.17-24, 2003.

[15] B. Ghugare, S.H. Adhaoo, L.P. Gite, A.C. Pandya and S.I. Patel, "Ergonomics Evaluation of A Lever-Operated Knapsack Sprayer", *Applied Ergonomics*, 22(4): 241–50.

[16] J.O. Awulu and P.Y. Sohotshan, "Evaluation of A Developed Electrically Operated Knapsack Sprayer", *International Journal of Science and Technology* 2(11): 769–72. 2012.

[17] P.K. Nag and A.Nag, "Drudgery, accidents and injuries in Indian agriculture", *Industrial Health* 42: 149–62. 2004.

[18] M. Alam, M.A. Bell, A.M. Mortimer and M.D. Hussain, "Pesticides application techniques of rice farmers in Philippines and option to improve application and protect the environment", The XIV Memorial CIGR World Congress Japan.pp.29-36, 2000

[19] M. Alam and M.D. Hussain, "Variability of the performance of Lever Operated Knapsack Sprayer", Agricultural Mechanization in Asia, Africa, and Latin America Japan, 41(3), pp.64-69, 2010.

[20] V. K. Mittal, B. S. Bhatia and S. S. Ahuja, " A Study of the Magnitude, Causes and Profile of Victims of Accidents with Selected Farm Machinery in Punjab", *Final Report of ICAR Adhoc Research Project*, Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana. 1996.

[21] H.S. Bawa and R.N. Kaul, "Some studies on vibration of a Knapsack power sprayer effecting operator comfort", *Journal of Agricultural Engineering* 11(1): 34–7. 1974

[22] P.K. Gupta, "Human body response to vibrations induced by an experimental power knapsack equipment", M. Tech. thesis, Punjab Agricultural University, Ludhiana, 1979.

[23] Chavan & Ritesh, "Design and Construction of Solar Powered Agricultural Pesticide Sprayer", International Journal of Innovations & Advancement in Computer Science, Vol. 4. No.4, pp. 145-150, 2015

[24] D.K. Baetens, M.D. Schampheleire and B. Sonck," Effects of Nozzle Type, Size and Pressure on Spray Droplet Characteristic" Biosystems Engineering, vol.97, pp 333-345, 2007.

[25] S.J. Hou, Onishi, S. Y. Minami, H. Ikeda, M. Sugawara, and A.Kozawa, "Charging and discharging method of lead acid batteries based on internal voltage control", *Journal of Asian Vehicles* 3(1): 733–737, 2005.

[26] R. Chavan, A. Hussain, S. Mahadeokar, S. Nicha, D. Devasagayam, " Design and Construction of Solar Powered Agricultural Pesticide Sprayer," International Journal of Innovations & Advancement in Computer Science (IJIACS) ISSN 2347 – 8616, Vol. 4, No.4, pp. 145-150, April 2015

[27] K. Tukaram, C. Mahesh, K. Ganesh, P. Rahul, G. Jay, "Solar Powered Pesticide Agriculture Sprayer," International Journal and Magazine of Engineering, Technology, Management and Research, Vol. 4, No. 5, pp.96-100, May 2017.