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Battery Powered Agricultural Sprayers: A Review

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Review Article

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ABSTRACT

Agricultural technology is undergoing rapid change, with continuous improvements in farm machinery, buildings, and production facilities. The quest for cheaper and enhanced energy sources is essential for the efficient and seamless operation of these facilities. Day to day depleting reserves of fossil fuels has motivated researchers to work on alternate source of energy. A battery has been proved a good alternative to fossil fuels for the operation of moving objects. A battery-powered agricultural sprayer, driven by a DC pump running on electricity stored in a battery, offers numerous advantages. Their operation is more cost-effective due to lower maintenance costs and has a lesser environmental impact compared to pumps powered by internal combustion engines (ICE). Additionally, they produce less vibration than petrol sprayers. With such sprayers, farmers can conduct spraying operations themselves, thus enhancing efficiency without needing additional labor.

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Several researchers carried out work on battery powered sprayers, in the different locations of the world. Different types of sprayers have been modified and successfully and efficiently operated on electricity generated in batteries. The review cover both solar power charged batteries and domestic electricity charged batteries. Research findings also indicated the reduction in drudgery of human labours involved in the spraying operation. These sprayers are an excellent means to cover large areas quickly and effortlessly. In summary, this innovative solution addresses the challenges of manual labor while promoting efficient, precise and sustainable agricultural practices.

Keywords: Battery sprayers; farm machinery; pump running; pesticides duster; manual pumping; spray application.

1. INTRODUCTION

In agriculture, spraying is a crucial task performed by farmers to safeguard cultivated crops from insects, pests, fungi and diseases. This necessitates the application of various insecticides, pesticides, fungicides and nutrients. Hand-operated knapsack sprayers are widely used in India, demanding operators to continuously pump the heavy knapsack for liquid discharge. This repetitive action often leads to fatigue and strain on the operator's back, shoulders and hand muscles. Fuel-operated power sprayers, while effective, come with drawbacks such as high operational costs due to fuel consumption and emission of polluting gases, contributing to environmental concerns. To address these challenges, the battery-operated sprayer emerges as a groundbreaking innovation in precision spraying technology. These sprayers offer consistent pressure for uniform liquid coverage, catering to diverse needs in gardening, agriculture, pest control and sanitation. Their versatility, eco-friendly design, reduced noise levels and enhanced safety position them as the preferred choice for professionals and homeowners seeking efficient and reliable spraying solutions.

2. BATTERY POWERED SPRAYERS

Jivrag et al*.* [1] developed a solar-operated multi-granulated pesticides duster. This creation accomplished by the utilization of a solar panel, an impeller-type centrifugal blower, gear reduction mechanism, dispensers, DC motors, and batteries. Additionally, the duster was equipped to operate on electric power, a useful feature for situations lacking sunlight. The primary function of this device was to evenly distribute solid granulated (powder) pesticides. The operator could regulate the pace and discharge of various insecticides through push buttons and toggle switches. Technical parameters of the device were devised and evaluated to achieve objectives like weight reduction and the ability to empty the feeder unit dispenser within a three-hour timeframe. The duster, characterized as portable and cost-effective, proved to be a valuable asset for small-scale agriculture, nurseries, horticulture, and community farming endeavors.

Varikuti et al*.* [2] designed a multiple power-supplied fertilizer sprayer. The proposed system underwent testing using both AC and solar charging methods. The study's results revealed that the calculated analytical and practical times required to fully charge a 12V, 7Ah battery were 16.67 hours and 17.2 hours, respectively. Once fully charged, this battery could spray 580 liters of fertilizer, providing coverage for approximately 2 to 2.5 ha of land. Although the proposed system incurs a slightly higher initial cost compared to a conventional sprayer, its ongoing operational expenses are significantly lower. This system can be utilized for the application of fertilizers, insecticides, fungicides, and paint using the established methodology.

Ritiesh et al*.* [3] developed and fabricated a solar-powered agricultural pesticide sprayer, which was subjected to field testing following established protocols. The solar-powered spray pump system functioned effectively for 6 hours, with the battery still indicating a charge of 12.74V, indicating that it hadn't been fully discharged. The sprayer exhibited a fluid discharge rate of 327 ml/min. The device took approximately 3 hours to cover an acre of land. The system's weight was 8 kg, and when filled with fluid, the maximum weight reached 23 kg. The sprayer successfully produced fine droplets of atomized particles.

Yadav et al*.* [4] investigated a solar-powered sprayer designed for agricultural applications. Their study revealed that it took 14.45 hours to fully charge a 12V, 12Ah battery. A fully charged battery could then spray 580 liters of fertilizer, effectively covering approximately 5-6 acres of land.

Shailesh et al*.* [5] designed and developed a multipurpose pesticide spraying machine. The employed solar panel had a capacity that generated 17V and 0.58A. The flow rate achieved with this machine was 2.5 times greater compared to a manually operated sprayer. Furthermore, the spraying area covered per hour was 2.6 times higher than that of a manually operated sprayer and 1.5 times greater than a backpack sprayer.

Anisa and Geeta [6] designed and assessed a solar-powered pesticide sprayer. The solar panel generated 17 V and 1A during daylight hours, from 9.30 AM to 4.30 PM. Additionally, a 12V, 8Ah battery could be fully charged in 7 hours with a simultaneous charging rate of 1.3A. The sprayer's module was capable of continuous spraying for 7 to 8 hours. The total cost of the model was Rs. 7000.

Bharatbhai [7] designed an automatic agricultural pesticide spraying vehicle with specific features. A 6-meter long boom was constructed using 20 mm square and 2 mm thick hollow pipes. The power source was a 6.5 HP self-propelled toolbar (measuring 1570 L × 600 W × 1290 H in mm), coupled with an HTP pump (ASPEE HTP pump) of 3.5 hp, operating at 900-950 rpm. The pump had a discharge rate of 24 l/m and a maximum pressure of 800 PSI. Hollow cone spray nozzles were used with a discharge of 0.9 l/m and a cone angle of 40°. The tank capacity was 250 liters. During field testing, the prototype of the self-propelled boom sprayer was evaluated in cotton and chilli crops for parameters such as actual field capacity, theoretical field capacity, fuel consumption, etc. The self-propelled sprayer was tested at an average speed of 3.27 km/h in cotton crops and 3.12 km/h in chilli crops. The average actual field capacity of the self-propelled boom sprayer was found to be 1.28 ha/h in cotton crops and 1.69 ha/h in chilli crops. The average field efficiency of the self-propelled boom sprayer was 62.74% in cotton crops and 81.02% in chilli crops.

Aravinda et al*.* [8] designed a solar-powered high clearance sprayer that was drawn by bullocks and subsequently tested on a farm. The system employed two 250 W capacity Solar PV panels to power a DC motor combined with a pump. The selection of the 1500 rpm DC motor was based on the available voltage output from the solar PV panels. The solar module produced and delivered 20.88 Ah of current and required 9.6 hours for a complete charge. Releasing 100 Ah from the battery necessitated 2.6 hours. Prior to complete battery discharge from a fully charged state, approximately 888.46 liters of fertilizer was dispensed. In the field, the developed sprayer exhibited a field capacity of 0.945 ha/h for cotton crops and 1.012 ha/h for red gram crops. The average operating speed was determined to be 2.7 km/h for cotton crops and 3.0 km/h for red gram crops. The spraying activity draft was recorded as 802.65 N for cotton crops and 804.38 N for red gram crops.

Singh et al*.* [9] developed a solar powered knapsack sprayer. This device has been developed to alleviate the constant energy application required for throttle regulation in conventional knapsack sprayers. Laboratory and field tests were conducted to assess the flow rate, application rate of the sprayer, and the charging time of the battery utilized in this developed sprayer. The time needed to fully charge a 12 V, 8 Ah battery capacity was determined to be 9.6 hours analytically and 11.2 hours practically. Results indicated a flow rate ranging from 2 to 3 L/min using various nozzles, with an application rate of 850 l/ha to 1280 l/ha. The sprayer demonstrated its capacity to cover 850 l/ha to 1280 l/ha in 7.15 hours at a walking speed of 0.70 m/s. Additionally, the 10W solar panel generates 0.833 Amp. The overall design of the developed solar-operated knapsack sprayer places the weight of both the panel and the sprayer on the operator's shoulders, yet it ultimately ensures effortless operation.

Murthy et al*.* [10] developed a solar pesticide sprayer. The operation of solar-powered pumps is more economical primarily due to lower operation and maintenance costs and has a smaller environmental footprint compared to pumps powered by internal combustion engines. Solar pumps are particularly useful in areas where grid electricity is unavailable and alternative sources, such as wind, cannot provide sufficient energy. The cost of solar panels typically constitutes the majority, up to 80%, of the system's overall cost. The size of the PV system depends directly on the pump's size, the required water volume (m^3/d) and the available solar irradiance. Solar sprayers offer numerous advantages. Apart from reducing spraying costs, they also save on fuel or petrol expenses. Additionally, there are savings on transportation costs associated with purchasing petrol.

Maintenance for solar sprayers is simple, and they produce less vibration compared to petrol sprayers. Farmers can carry out spraying operations themselves without needing additional labor, thereby increasing spraying efficiency.

Chandrashekar et al. [11] evaluated the performance of solar operated push type sprayer. The push-type solar-operated sprayer comprises a 20W PV module and two diaphragm-type pumps, each with a capacity of 0.03hp. The system underwent performance testing to assess nozzle discharge variation concerning different operating pressures and heights. Under normal climatic conditions, the sprayer exhibited higher discharge rates between 12 noon and 1 pm due to increased solar intensity, measured at 991 and 980 W/m^2, respectively. Solar intensity dropped to a minimum of 580 W/m^2 by 5 pm in the evening. The panel generated a current of 1.25 A, requiring 4.31 hours to discharge the 7.2 Ah battery fully. A fully charged battery covers an area of 1.9 hectares. The calculated actual and theoretical field capacities for a field bean crop, with forward speeds of 0.528m/s and 0.583m/s, were 0.29 ha/h and 0.32 ha/h, respectively. Consequently, the overall field efficiency of the push-type solar sprayer is 90.62%. The operational cost of the solar-operated push-type low clearance sprayer was determined to be 38.5 Rs./h. The total cost for one unit of the push-type solar sprayer is approximately Rs. 12,685.

Gururaj et al. [12] developed and evaluated performance of cycle mounted battery operated boom sprayer. The cycle-mounted battery-operated boom sprayer technology is highly suitable as an alternative energy device for power sprayers. These energy sources are clean, risk-free, and pose no harm to humans or the environment. The developed sprayer was tested for chilly crops, with a crop spacing of 0.60×0.45 m (row × plant) and observed crop height ranging from 0.55 to 0.84 m, with an average value of 0.69 m. The nozzle discharge rate was measured at 51.1 liters per hour, with a spray coverage width of 2.91 m and an operational speed of 2.52 km/h. Comparatively, the initial investment and operational costs of the cycle-mounted battery-operated boom sprayer were lower than those of existing power sprayers in the market. Uniform spray distribution was observed throughout the field, and the sprayer performed satisfactorily under field conditions. It can also be used for vegetables, row crops, and orchard crops to apply chemicals, bio-pesticides, or herbicides. The developed sprayer reduces labor drudgery, time and is very much suitable for marginal and small farmers. This sprayer is user and eco-friendly. The area coverage of the developed boom sprayer was 0.61 ha/h, with a field efficiency of 83.56%. The production cost of the boom sprayer was Rs. 5,650.0 and the operational cost was 92.0 Rs./hr.

Bankar and Dable [13] developed a battery-operated agricultural sprayer that includes a 20 W solar panel, a 12 V DC pump with a discharge rate of 2.89 L/min, a 12 V 8 Amp lead-acid battery, a 20-liter pesticide tank, and spray nozzles, among other components. It is powered by solar energy, with the solar panel absorbing solar energy first, which is then converted into electrical energy by the photovoltaic cell. This electricity charges the battery, which subsequently powers the DC motor. The DC motor operates the DC pump, drawing liquid from the intake of the liquid tank. The liquid is then sprayed from the DC motor outlet through a nozzle attached to the spray pipe. The developed solar-powered sprayer, with a 14 L capacity, features an efficient system to prevent deep discharging and overcharging of the battery, performing efficiently at 2.8 kg/cm^2 (40 psi) operating pressure for pesticide application. The spray spectrum was found to be uniform with the selected nozzle and operating pressure, enhancing the quality of spray and ultimately improving chemical efficacy and pest control efficiency. The battery can be fully charged in three hours, enabling the sprayer to operate for six hours. Additionally, the mean heart rate and BPDS were lowest for the solar sprayer, covering an area more than twice as large (3000 m^2) compared to manual and air-assisted sprayers, indicating lower physiological demand and discomfort on body parts.

Mohite et al. [14] developed a solar-powered pesticide sprayer to reduce the labor-intensive tasks associated with manual pesticide spraying in agriculture. The system involves the creation of a remotely controlled, semi-automated vehicle powered by solar energy. This vehicle is specifically designed to apply pesticides and insecticides directly onto individual lesions with high precision, thereby minimizing chemical waste and ensuring efficient application. Its sustainable solar-powered design, coupled with a 12 V 7 Ah battery, renders it cost-effective and environmentally friendly. The vehicle's operations are managed by an Arduino Uno and controlled remotely. Movement is facilitated by a 12 V DC gear motor, which is driven by the IBT_2 motor driver. In essence, this innovative solution addresses the challenges of manual labor while promoting efficient, precise and sustainable agricultural practices. The prototype offers substantial area coverage at low costs, eliminating the need for harmful chemicals and reducing farm labor. It can also be remotely monitored, making it suitable for small and medium-sized farmers. Moreover, it has the potential to be scaled up for applications such as fertilizers, pesticides, fungicides, and lawn watering, thereby contributing to the advancement of Indian farming practices. The project's integration of pesticide spraying not only reduces farmers' workload and health risks but also involves the construction of robust vehicles capable of traversing uneven terrain and carrying necessary equipment.

Karale et al. [15] designed and developed a battery-electric vehicle sprayer to reduce dependency on fossil fuels, featuring a low-cost battery-electric vehicle with a boom sprayer attachment. The developed system ensures high uniformity of spray distribution along with swath coverage and offers easy adjustment of the boom height over the target crop. The battery-electric vehicle (BEV) sprayer underwent testing in both laboratory and experimental field settings to optimize operating parameters for green gram crops. It was determined that a 1 kW, 48 V BLDC electric motor was capable of propelling the vehicle. Various forward speeds (2.0, 2.5, and 3.0 km/h) and nozzle configurations (operating pressures of 2.5, 3.0, and 3.5 kg/cm^2, with orifice diameters of 0.6 mm, 0.8 mm, and 1.0 mm) were studied in the experimental field. Field tests conducted using these optimized parameters revealed that the effective field capacity of the sprayer was 1.09 ha/h, with a field efficiency of 79.81 percent.

Mishra et al., [16] developed a battery-operated walk-behind type sprayer aimed at reducing discomfort and the time required for spraying. This type of sprayer is economical, more efficient, and sprays at a faster rate. It proves helpful for small-scale farmers and unskilled laborers who can operate it without difficulties. The operating hours of the pump using 8 Amp or 12 Ah batteries were expected to be 2-3 hours or 5-6 hours, respectively. The total annual cost of the battery-operated walk-behind type sprayer was Rs 19,165.80. The break-even point (BEP) calculated on an area basis for the battery-operated walk-behind type sprayer was 171 hectares. On a yearly basis, the break-even point (BEP) for the battery-operated walk-behind type sprayer was 2.21 years.

Sinha et al. [17] developed a battery-operated sprayer based on general spraying principles. This system operates using direct current from a battery, utilizing a pressure pump with a liquid flow capacity of 7.5 LPM at a pressure of 120 PSI (8 bar). The developed multipurpose battery-operated wheel sprayer includes a 12V, 12AH rechargeable battery, a 12V, 5AH pressure pump, a charging unit, and a control switch.

El-Sayed et al. [18] conducted a study on a knapsack sprayer powered by a DC motor via a 12 V lead acid battery charged by a solar panel (photovoltaic) oriented towards sunlight. The main components of the system include photovoltaic (PV) or solar cells, a charger controller, a rechargeable battery, a DC motor with speed control using a dimmer, and a pump connected to a 20-liter capacity tank for suction and pressurization of the liquid to the sprayer boom via a flexible hose. The complete recharge time for the battery was determined to be 330 minutes (5.5 hours). Depending on the motor speed, battery discharge time ranged from 4 to 9 hours, with the motor drawing 0.85 to 1.85 Amps at 2000 to 3400 rpm. This discharge time, at different speeds, is sufficient to cover an area of 3 to 6.82 fed/day (assuming a day's work is 6 hours) with an application rate of 67 to 104.7 liters per fed. Spray intensity notably increased with nozzle discharge. Maximum spray deposition was observed at the center of the spray, with droplet deposition decreasing as the spray width increased. This technology is highly suitable for energy-efficient agricultural machinery for powering sprayers, and its principles can be applied to various types of agricultural sprayers.

Chavan et al. [19] developed a solar-powered agricultural pesticide sprayer. The prototype was designed considering parameters such as desired spraying efficiency, low weight, affordability, user-friendliness, extended operating time and rapid area coverage. The sprayer consists of a 16-liter PVC tank, a 20 W solar panel, a 12V-5A charge controller, a 12V-9Ah lead-acid battery, a 12V-2.2A brushless DC motor, a diaphragm pump with 3 lit/min discharge rate, an 11 mm diameter, 2-meter length hose pipe and a potentiometer. For testing, it was exposed to sunlight from 10 am to 1 pm to completely charge the battery from 10.55 V to 13.56 V. The battery continuously drew current through the charge controller from the solar panel to meet the motor's demand for operating the pump. The solar-powered spray pump system functioned for 6 hours and the battery indicated a charge of 12.74 V, indicating it had not been fully discharged. The fluid discharge rate of the system was 327 ml/min. It takes 3 hours for the system to cover 1 acre of land. The weight of the system is 8 kg, and the maximum weight of the system, considering fluid is 23 kg. The system produced fine droplets of atomized particles, reducing user fatigue and improving the quality of pesticide spraying.

3. ADVANTAGES OF BATTERY OPERATED SPRAYER

Battery-operated sprayers offer several advantages:

1. **Cost Efficiency:** They reduce operational costs by eliminating the need for fuel or petrol, thus providing long-term savings for farmers.
2. **Environmental Friendliness:** Battery-powered sprayers have a lower environmental impact compared to traditional petrol-powered sprayers, as they produce fewer emissions and pollutants.
3. **Less Maintenance:** These sprayers typically have simpler maintenance requirements compared to petrol-powered counterparts, reducing downtime and repair costs.
4. **Reduced Vibration:** Battery-operated sprayers generally produce less vibration during operation, resulting in a smoother spraying process and potentially reducing operator fatigue.
5. **Ease of Use:** They are often easier to use and operate, requiring less physical effort from the operator. This can increase efficiency and productivity, especially for longer spraying tasks.
6. **Versatility:** Battery-powered sprayers can be used in various settings and environments, including indoor applications where emissions from petrol-powered equipment may pose health or safety concerns.
7. **Independence:** With battery-operated sprayers, farmers can conduct spraying operations independently, without the need for additional labor, thus increasing operational flexibility and efficiency.
8. **Quiet Operation:** They tend to operate more quietly compared to petrol-powered sprayers, which can be advantageous in noise-sensitive areas or during early morning or late-night operations.

4. LIMITATIONS OF BATTERY OPERATED SPRAYER

While battery-operated sprayers offer numerous advantages, they also have some limitations:

1. **Limited Battery Life:** The runtime of battery-operated sprayers is limited by the capacity of the battery. Depending on the size of the battery and the intensity of use, operators may need to recharge or replace batteries frequently, leading to downtime during recharging.
2. **Charging Time:** Recharging batteries can take several hours, which can disrupt workflow and may not be feasible for continuous or time-sensitive spraying operations.
3. **Initial Cost:** Battery-operated sprayers typically have a higher upfront cost compared to traditional petrol-powered sprayers. While they may offer long-term savings in operating costs, the initial investment can be a barrier for some farmers.
4. **Limited Power:** Battery-powered sprayers may have lower power output compared to petrol-powered counterparts, which could affect their performance, particularly when spraying thick or viscous liquids or covering large areas.
5. **Maintenance of Batteries:** While battery-powered sprayers generally have simpler maintenance requirements compared to petrol-powered ones, proper care and maintenance of batteries are essential to ensure optimal performance and longevity. This includes periodic inspection, cleaning and replacement of batteries when necessary.
6. **Environmental Impact of Battery Production:** The production and disposal of batteries can have environmental consequences, including resource extraction, energy consumption, and waste disposal. While battery technology continues to improve, addressing these

environmental concerns remains a challenge.

5. CONCLUSION

Battery-powered sprayers are well-suited for small and medium-sized farmers and they can be scaled up for use with fertilizers, pesticides, and fungicides. These sprayers also provide greater flexibility and mobility since they are not reliant on a tractor or other vehicle for power. Battery-operated sprayers offer several advantages over traditional sprayers. Firstly, they provide greater mobility and convenience since they don't require a constant power source or manual pumping. This allows users to cover larger areas with less effort and time. Additionally, battery-operated sprayers are often more environmentally friendly and cost-effective in the long run, as they eliminate the need for fuel or electricity, and can be recharged for multiple uses. Moreover, they typically offer more precise control over spray application, resulting in reduced waste and more efficient use of resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jivrag A, Vinayak C, Aditya B. Solar operated multiple granulated pesticide duster. Pro. Wor. Cong. Engg. 2011;3(2): 88-92.
2. Varikuti VR, Mathapati S, Amarapur B. Multiple power supplied fertilizer sprayer. International Journal of Science and Research Publications. 2013;3(8):1-5.
3. Ritiesh C, Amir H, Sanika M, Swapnil N, Deepak D. Design and construction of solar powered agricultural pesticide sprayer. International Journal of I. and Applied Computer Science. 2015;4(4):145-150.
4. Yadav SP, Pooja MK, Anushree V, Bhujade. Solar powered sprayer for agricultural use. Int. J. Res. Sci. Engg. 2015;1(3):182-186.
5. Shailesh M, Shubham K, Pratik K, Roadney J, Nishat I, Rupesh DK. Design and development of multipurpose pesticides spraying machine. International Journal of Advance Engineering. Glob. Tech. 2016;4(3):1945-1944.
6. Anisa and Geeta. Convert the fuel operating system as free energy operating system for agriculture implementation. International Journal of Agricultural Engineering. 2017;10(1):124-129.
7. Bharatbhai JD. Automatic agriculture pesticide spraying vehicle. International Journal of Engineering Development and Research. 2017;5(4):1585-1590.
8. Aravinda YK, Veerangouda M, Prakash KV, Anantachar M, Nadagouda S. Development and field evaluation of bullock drawn solar powered high clearance sprayer. International Journal of Chemical Studies. 2019;7(6):2102-2105.
9. Singh K, Padhee D, Parma AK, Sinha BL. Development of a solar powered knapsack sprayer. Journal of Pharmacognosy and Phytochemistry. 2018;7(1):1269-1272.
10. Murthy K, Kanwar R, Yadav I, Das V. Solar pesticide sprayer. International Journal of Latest Engineering Research and Applications. 2017;2(5):82-89.
11. Chandrashekar Neeraja J, Raghavendra V. Performance evaluation of solar operated push type sprayer. International Journal of Current Microbiology and Applied Sciences. 2018;7(12):1448-456.
12. Gururaj TR, Mallesh KU, Basavaraj, Chaitanya. Development and performance evaluation of cycle mounted battery operated boom sprayer. International Journal of Agriculture Sciences, 2020; 12(24):10503-10505.
13. Bankar V, Dable NA. Design and analysis of modified agricultural sprayer machine. International Journal for Research in Applied Science & Engineering Technology. 2022;10(8):222-230.
14. Mohite N, Mahadik S, Jadhav H, Mhamunkar S, Asokan S. International Journal of Creative Research Thoughts. 2024;12(3):964-969.
15. Karale DS, Shinde A, Awate NP, Thakare SH. Design, development and testing of battery electric vehicle sprayer. International Conference on Advances in Mechanical Engineering-2022, IOP Conf. Series: Materials Science and Engineering. 2022;1259(2022):012021 IOP Publishing. DOI:10.1088/1757-899X/1259/1/012021.
16. Mishra PK, Kumar M, Shivam Singh VK, Singh DK, Singh RJ, Kumar A, Gupta A. Development of battery operated walk behind type sprayer. The Pharma Innovation Journal. 2023;12(9);67-73.

17. Sinha Y, Jay Chauhan J, Tandan J, Patel K, Kaushik SP. Development of multipurpose battery operated wheel sprayer. International Journal of Current Microbiology and Applied Sciences. 2019; 8(11):1766-1772.
18. El-Sayed AH, Kabany AF, Elhelew W. A study on pesticide sprayer powered by solar energy appropriate for small farms. Arab Universities Journal of Agricultural Sciences. 2021;29(2):505-17.
19. Chavan R, Hussain A, Mahadeokar S, Nichat S, Devasagayam D. Design and construction of solar powered agricultural pesticide sprayer. International Journal of Innovations & Advancement in Computer Science. 2015; 4(4):145-150.

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