



Development of a Solar-Powered Remote-Controlled Seed Sprayer Machine

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ABSTRACT

This paper presents the design, construction and testing of a solar-powered remote-controlled seed sprayer aimed at enhancing small scale farming efficiency. The prototype integrates a 20 W mono-crystalline solar panel with a 3.7 V Li-ion battery pack and an ESP-32 microcontroller (with Wi-Fi) to enable off-grid operation and wireless control. A centrifugal disc mechanism coupled with a servo-controlled gate meters and flings lightweight seeds (e.g. pepper, spinach) uniformly onto the soil. Field trials on sandy, loamy, and clay soils showed high seed distribution uniformity ($\approx 85\text{--}90\%$ on loam). The ESP-32's Wi-Fi Access Point mode achieved rapid response ($\approx 50\text{ ms}$) and $>95\%$ command success at 10 m, and maintained $\sim 90\%$ reliability at 100 m. Under full sunlight, the 20 W panel supplied $\approx 12\text{ W}$ load power, sustaining $\approx 1.5\text{ h}$ operation with a 2200 mAh battery. By eliminating fossil fuels and enabling precise remote seeding, the system reduces labor and waste, offering a cost-effective tool for sustainable precision agriculture.

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INTRODUCTION

In many developing countries, farmers still rely on manual seed sowing and fuel-driven equipment, leading to inefficiency and high labor demand (Pal et al., 2021). Manual seeding is labor-intensive and often results in uneven coverage and seed wastage, hence, reducing yields and productivity (Ghaffar et al., 2020). Modern automated tools (drones, tractors) exist, but they are costly, complex, or grid/fuel-dependent and thus out of reach for many rural farmers. There is therefore an urgent need for an affordable and off-grid solutions. Renewable solar energy is abundant and eliminates fuel costs (Ahalya et al., 2017).

Likewise, wireless control over Wi-Fi can extend the operator's reach beyond short-range Bluetooth. For example, Abubakre et al. (2021) found Wi-Fi offers higher range and throughput than Bluetooth for field robots. In response to these challenges, this project designs

a solar-powered seed sprayer that is fully off-grid and wirelessly controlled via an ESP-32 microcontroller. The system harnesses solar power to charge a Li-ion battery, which drives the drive motors and seed dispenser. A centrifugal disc seeds by spinning seeds outward, while a servo-actuated gate meters the seed flow. By using an embedded web server on the ESP-32, a farmer can start, stop, and adjust the sprayer using a Smartphone over Wi-Fi. This approach aims to reduce manual effort, fuel dependency, and seed waste, in line with sustainable development goals. The remainder of this paper reviews relevant literature, details the methodology and design, presents performance results and conclusion.

LITERATURE REVIEW

This section provides a review of past work that are similar to this research. Shinde et al (2020) presents a solar-powered, wireless-

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controlled robot designed to automate seed sowing and fertilizer spraying, primarily for crops like wheat, jowar, and sunflower. Using an ATmega328P microcontroller, soil moisture sensors, ultrasonic sensors, a drill bit, DC motors, and a Wi-Fi module, the system checks soil suitability, digs to a fixed 5 cm depth, plants seeds uniformly, and sprays fertilizer as scheduled via an Android app. Powered by a 12V solar-charged battery, the robot reduces labor, time, and energy costs. It is limited by its dependence on sunlight but with the use of ESP-32 and buck converter makes our version of the project smarter, better connection in solving issues related to power instability, limited control range, and poor adaptability to variable conditions.

Muruganantham (2020) proposed on a battery powered automated seed sowing machine using readily available raw materials. The machine is built with a sealed lead-acid battery (12 V), a 12 V DC motor operating at 100 rpm, chain drives, various gears, and wheels mounted on a mild steel chassis. Seeds are stored in a seed storage tank and fed through a hopper made from mild CR sheet. The motor's rotation is transmitted via a chain-sprocket setup to drive a seed feeder that deposits seeds into a pipe, which is aligned with a furrow opener; a furrow closer then covers the sown seeds with soil. The project involved modeling the mechanical system, fabricating parts through machining, welding, and assembly, and testing the prototype. Results indicated that the machine dispenses seeds at a controlled rate and depth, achieves uniform seed spacing, and reduces the time and labor required compared to manual sowing methods, offering a practical solution for small-scale agricultural applications.

Basuki et al (2021) developed solar-powered pest spraying machine using a 10 Wp solar panel, lithium-ion batteries, a DC pump, and various nozzles. The system, built on a simple frame and tested with water, showed effective spraying under sunlight with good flow rates and energy efficiency. However, it lacked remote control, automation, and was limited to daylight use and flat terrain. My project improves on this by integrating Wi-Fi-based remote control via an Android app, motorized mobility, and a fan-based

seed dispensing system powered by solar-charged batteries making it more flexible, user-friendly, and suitable for real farm conditions.

Sharma & Yadav (2022) developed fully solar-powered seed sprayer machine that uses a centrifugal pump and blower to uniformly disperse seeds from a hopper onto ploughed land without manual effort. Key components include a 20 W solar panel, 12 V 8 Ah lead-acid battery, centrifugal pump (0.5–1 L/min at 1500 rpm), nozzle (2.9 L/min), and mechanical frame. The prototype delivered consistent seed coverage, recharging in about 4.2 hours under sunlight, and demonstrated a low-cost, sustainable solution for small-scale farmers. The limitations of this project is that it has limited control over seed dispersal, is unsuitable for long period planting since its performance depends heavily on adequate solar insolation but with the use of our project design we tend to solve it by swapping in an ESP-32, PVC chassis, a buck converter and rechargeable batteries which can overcome the seed-sprayer's key drawbacks.

Vajubhai (2023) proposed solar-powered seed sprayer machine using a solar panel for capturing sunlight, a battery bank for storing the generated energy, and a DC motor that drives the seed dispersal unit. The structure includes a seed hopper that accommodates various seed types and a mechanism for accurately spreading seeds over the prepared soil. The method involves converting solar energy into electrical energy that powers the motor and sprayer, which disperses seeds uniformly, as confirmed by both laboratory tests and field trials. The results show that the machine consistently dispenses seeds with uniform spacing on different terrains, thereby reducing manual labor in the seeding process.

Gangadhar et al (2024) built Solar powered remote controlled seed sowing machine with sprayer using key components such as a solar panel to harness renewable energy, a 12V battery with its associated charge controller, an Arduino Nano for system control, an L298N motor driver paired with a 60 RPM DC motor and servo motors for precise actuation, IR sensors for navigation, an HC-05 Bluetooth module for remote

communication, along with relays, wheels, and a sprayer assembly to facilitate simultaneous sowing and fertilization. The methodology integrated solar energy conversion and storage to power the automated system; the solar panel captured sunlight and charged the battery, which in turn supplied power to both the microcontroller and the driving mechanisms. Through remote commands received via Bluetooth, the Arduino controlled the motorized mechanisms to ensure that seeds were sown at the correct depth and spacing while an adjuster mechanically covered the seeds and activated the sprayer to apply water or fertilizer concurrently. The results demonstrated that the machine significantly reduced manual labor but lacks emphasizes that's needed for a cost effective solution like the ESP-32-based system approach with a longer control range in the current project.

Sasikala (2025) developed multipurpose farming machine powered by solar energy that performs several key agricultural tasks, such as soil cultivation, seed sowing, water or pesticide spraying, and even goods carrying. The machine uses a solar panel to collect sunlight, which is stored in two 12 V, 7.5 Ah batteries configured to deliver a 24 V output; this energy drives a permanent magnet DC motor through a gear system, which in turn powers the machine's movement and various attachments. The design

features a seed container equipped with a lever mechanism for controlled seed release, a tool system that converts a static blade into a rotary one for effective soil processing, and other straightforward mechanical components like a charging circuit and controller kit for adjusting the motor speed. The tests showed that the machine performs multiple farming operations with reduced manual labor and saves time compared to traditional methods but often face battery management challenges, particularly with non-standard configurations like the 16V battery in the current project.

MECHANICAL DESIGN

A CAD model of the frame was created as shown in Figure 3. The chassis uses PVC square tubing for ease of fabrication, providing a lightweight structure. The rear axle carries two DC gear motors driving rubber wheels, giving differential-drive mobility. A seed hopper (mounted above the disperser) feeds granules into a PVC pipe that directs seeds to the centrifugal fan. The servo motor gates the seed flow just before the fan. SolidWorks simulations allowed optimizing part placements and clearances. Technical drawings guided fabrication of the frame and mounting brackets.

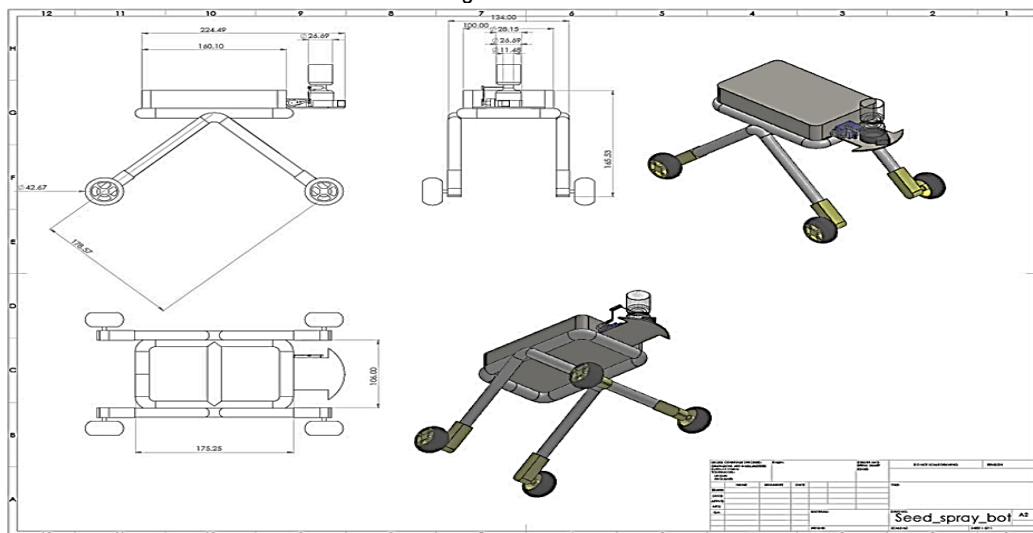


Figure 3: System CAD model

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ELECTRONIC DESIGN

The ESP-32 microcontroller is the control core. Its GPIO lines interface with the L298N dual H-bridge driver to power the two drive motors, and with a MOSFET to switch the blower fan. The servo motor is driven by a PWM signal from the ESP-32. The solar panel charges the 3S battery (3×3.7V cells) through the BMS and a solar

charge controller. The battery output is fed to an LM2596 buck converter to supply a stable 5 V rail for the ESP-32 and logic. The circuit design of the system is depicted in *Figure 1*. Breadboard prototyping and multimeter checks ensured correct wiring and logic-level interfacing before final assembly.

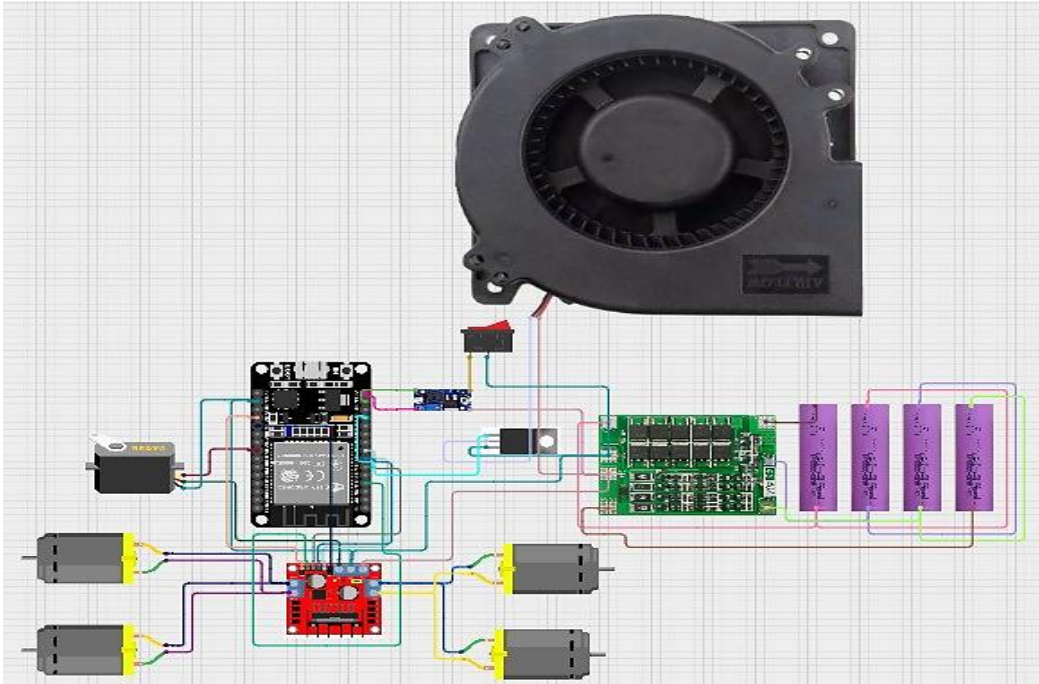


Figure1: System circuit design

FIRMWARE AND CONTROL INTERFACE

Firmware was written in Arduino C/C++ and uploaded to the ESP-32 via the Arduino IDE. It sets up a Wi-Fi AP (with a fixed IP) and hosts a simple web server. A lightweight dashboard allows the user to send commands: e.g., “forward”, “left”, “rotate fan on”, “servo open/close”. Interrupt routines ensure the seed metering servo pulses according to configured timings. Encoder feedback was not used in this prototype, but consistent speeds were achieved via careful selection of motor drivers. The web interface was tested on a Smartphone through the ESP-32’s AP (no external network needed). *Figure 2* shows the system web interface

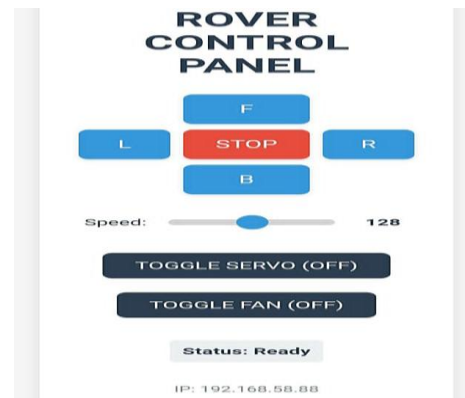


Figure 2: System web Interface

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Assembly and Calibration

The PVC chassis was cut and assembled, and all components were mounted (3D-printed and drilled brackets secured the electronics board and panels). Wiring was run along the frame and soldered on veroboard for reliability. The seed hopper and pipes were fitted,

and the fan was aligned with the outlet of the seed pipe. Once assembled, the mechanical system was balanced so the machine moved stably. The seed gate servo was calibrated to open just enough for flow without clogging; tests with dry pepper and spinach seeds ensured consistent dispensing.

Design Considerations

The Time required to charge the Battery

Battery Rating = 12Ah 12V

Solar Panel Maximum power = 50W

Solar Panel Voltage Rating = 12V

Current produced by the solar panel (I) = $\frac{\text{Maximum Power (P)}}{\text{Voltage rating (V)}} = \frac{50}{12} = 4.17\text{A}$

Theoretical charging time (T) = $\frac{\text{Rating of battery}}{\text{Total current consumed}} = \frac{12}{4.17} = 2.88\text{hrs}$

Backup Sprayer Time

Mini Gear Motor = 12V & 0.13A and Diaphragm Pump – 12V, 0.7A

Backup sprayer Time = $\frac{\text{Power stored in battery (w-hr)}}{\text{Power consumed (w)}}$

Backup sprayer time = $\frac{12 \times 12}{12 \times 0.13 + 12 \times 0.7} = \frac{144}{1.56 + 8.4} = \frac{144}{9.96} = 14.5\text{hrs}$

Power Conversion Efficiency of the Solar Panel

Solar power conversion efficiency can be calculated as follows.

Power Conversion efficiency (η) = $\frac{\text{output power}}{\text{input power}} = \frac{P_{\text{out}}}{P_{\text{in}}} \%$ P. C. E = $\frac{\text{Open circuit voltage} \times \text{Short circuit current}}{\text{incident solar radiation} \times \text{Area of the solar cell}} = \frac{12}{20} = 0.6 \text{ or } 60\%$

Application rate

The application rate of 1 L seed on a 25 m² land was calculated using:

Application rate (L/m²) = (Volume collected (L) × Time (min)) ÷ (Time (min) × Area of test plot (m²))

The time it took for the seed sprayer to empty a 1 L seed container during a controlled test over a 25m² plot: 1.27 minutes

A.R = (1 × 1.27) ÷ (1.27 × 25) = 1.27 ÷ 31.75 = 0.04 L/m²

Determination of Flow Rate

Flow rate (Q) = Volume of seed released (L) ÷ Time (min)

F.R = 1 ÷ 1.27 = 0.79 L/min

Power Efficiency

P.E (η) = (Power needed to drive sprayer ÷ Power from battery) × 100

The operating voltage of the sprayer system: 12V

The average current (power) consumed by the load (motors, blower, ESP-32): 0.7A.

The battery's total discharge capacity (i.e. the maximum current the 2200 mAh battery can provide per hour): 3A

P.E = (12 × 0.7) ÷ (12 × 3) × 100 = 8.4 ÷ 36 × 100 = 23.33%

RESULTS

Bench tests were conducted for the remote control (measuring command latency and success at various distances) and power tests

under different light levels. Field trials were then performed on sandy, loamy, and clay test plots. The seeds placement was measured by counting seeds in target grids. The results are presented in Table 1 and 2. Table 1 presents the relationship between solar panel output and battery discharge rate at varying sunlight intensity.

Table 1: Relationship between solar panel output and battery discharge rate at varying sunlight intensity.

Sunlight intensity (W/m ²)	Solar panel output (W)	Battery discharge rate (mAh/hr)
1000 (Peak)	12	1000
750 (Moderate)	9	1200
500 (Low)	6	1500

The Table 1 presents the system's ability to operate reliably in varying sunlight condition, critical for off-grid farming. At peak sunlight, the 12W output balances the 1000mh⁻¹ discharge rate, enabling sustained operation. In moderate and low sunlight, the output decreases to 9W and 6W, with higher discharge rates (1200 mh⁻¹ and 1500 mh⁻¹), indicating faster battery depletion. This data is significant as it confirms the machine's suitability for rural environments with inconsistent sunlight, supporting the objective of sustainable operation. Farmers can plan seeding tasks knowing the system sustains 1.5hour of operation on a full charge, extended by solar input during daylight.

These results demonstrate the system's ability to operate across a range of sunlight conditions, critical for rural Nigeria farms where grid electricity is often unavailable. The solar panel's contribution, even at low intensity, extend runtime beyond the battery's standalone capacity, supporting small scale seeding tasks. However, the high discharge rate in low sunlight limits extended operation, particularly during cloudy weather or early/late daylight hours, suggesting a need for a higher capacity battery or improved charge management.

Control Range Efficiency

Table 2 presents the performance of the control range efficiency. The tests were conducted using the ESP-32's Wi-Fi Access Point Mode, with commands sent via a smartphone web interface to control functions like motor movement and seed dispersal.

Table 2: The performance of the control range efficiency

Distance (m)	Response (ms)	Command (%)
10	50	98
50	80	95
100	120	90

The results show the robustness of the remote control system; a key feature for reducing manual labor. At 10m, the 50ms response time and 98% success rate indicate near instantaneous and reliable operation. At 50m, the 80ms response and 95% success maintain effective control. Even at 100m, the 120ms response and 90% success ensure functional remote operation. This long range capability allows farmers to reducing physical effort, directly supporting the project's goal of labor savings. The high success rate validates the ESP-32 Wi-Fi reliability for precision agriculture in large or uneven field.

CONCLUSION

The development of the solar-powered, remotely operated seed sprayer represents a significant advancement in sustainable agricultural practices. By harnessing renewable solar energy and integrating wireless Wi-Fi control via the ESP-32 microcontroller, the system offers an efficient, eco-friendly, and cost-effective solution for scale farmers. Its ability to uniformly disperse seeds across various soil types, coupled with reliable remote operation over considerable distances, demonstrates its potential to enhance planting efficiency and reduce manual labor. This innovative approach not only promotes precision and consistency in seed distribution but also contributes to the broader goal of sustainable and accessible farming technologies. Future enhancements could focus on increasing



operational duration, expanding control range, and incorporating additional functionalities to further meet the needs of diverse farming environments.

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