IoT-Based Solar Powered Smart Pesticide Sprinkling System Determined by Plant Infection Level for Home Gardening and Greenhouses

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Abstract: This paper introduces a solar-powered, IoT-enabled smart pesticide-spraying system designed for accurate pest management in small-scale environments such as home gardens and greenhouse setups. Traditional sprayers apply chemicals uniformly, which often leads to unnecessary pesticide usage. In contrast, the proposed system minimizes wastage by directing the spray only to areas that genuinely require treatment. An ESP32-CAM module continuously observes plant conditions by capturing leaf images and evaluating them for early indications of disease, nutrient stress, or pest activity. When the system detects an abnormal region, it automatically activates the pump to deliver pesticide precisely to the affected spot. The entire setup is powered through a 10-watt solar panel paired with a 12-volt battery, ensuring uninterrupted operation even in remote or off-grid locations. IoT connectivity allows users to monitor plant health, system status, and spraying activity from a distance, improving convenience and safety. By applying chemicals only when and where needed, the system is capable of cutting pesticide consumption by roughly 30–40%. It also lowers manual effort and reduces human exposure to toxic substances. Overall, this approach efficient, intelligent maintaining plant health and managing pests. By merging automation, renewable energy, and intelligent image-based detection, the system represents a forward-looking solution for modern plant care. It not only enhances plant protection but also encourages responsible pesticide use, making it a valuable tool for both hobbyists and small agricultural operations.

Keywords: *IoT, ESP32-CAM, Smart Agriculture, Solar-Powered System, Pesticide Sprinkling, Image & Processing, Precision Farming, Home Gardening, Greenhouse Automation, Targeted Spraying, Sustainable Agriculture.*

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I. INTRODUCTION

With the increasing popularity of home gardening and greenhouse cultivation, there is a growing need for smart and compact systems that ensure efficient plant care. Manual pesticide spraying can be inconvenient, inconsistent, and hazardous due to exposure to chemicals. The IoT-Based Solar-Powered Smart Pesticide Sprinkling System using the ESP32-CAM addresses these challenges by automating pesticide application in small gardening environments.

The ESP32-CAM module enables real-time image monitoring, allowing users to remotely observe plant conditions, detect pest presence, and activate spraying as needed through a smartphone or web interface. Solar power ensures continuous, energy-efficient operation, making the system suitable for outdoor gardens, balconies, and rooftop greenhouses without depending on traditional electricity.

Designed for limited spaces, the system delivers precise, targeted spraying, reducing chemical usage and preventing overapplication while improving plant protection. By minimizing human contact with pesticides, it promotes a safer and more convenient gardening experience. Overall, this system integrates IoT technology, solar energy, and automated control to provide a practical and sustainable solution for maintaining healthy plants in home gardens and greenhouses.

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II. METHODOLOGY AND WORKING

➢ *Working Principle*

The system uses an ESP32-CAM module to regularly capture images of plant leaves. These images are analyzed to detect early signs of disease or pest activity by observing color changes like yellowing or browning. When such system is know to identifed, the ESP32-CAM triggers a mini pump to apply pesticide only to the affected regions.A 10W solar panel supplies power by charging a 12V battery that runs the ESP32-CAM, pump, and control components, allowing the system to function continuously without external electricity.

➢ *Block Diagram*

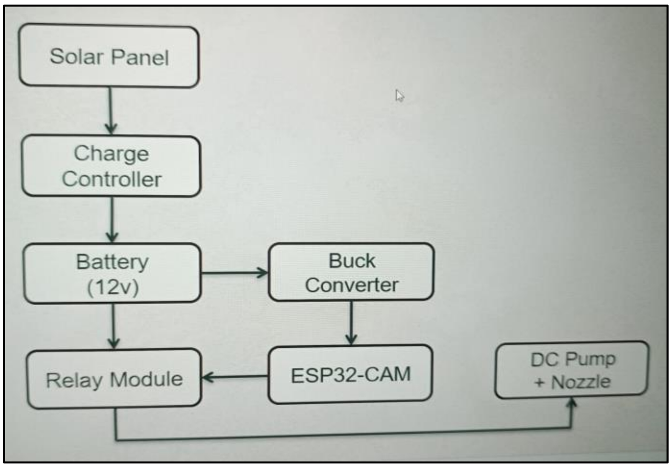

Fig 1 A Solar-Powered System for Intelligent Pest Management that Monitors Plant Health and Selectively Sprays Using a Pump and Nozzle.

➢ *Circuit diagram*

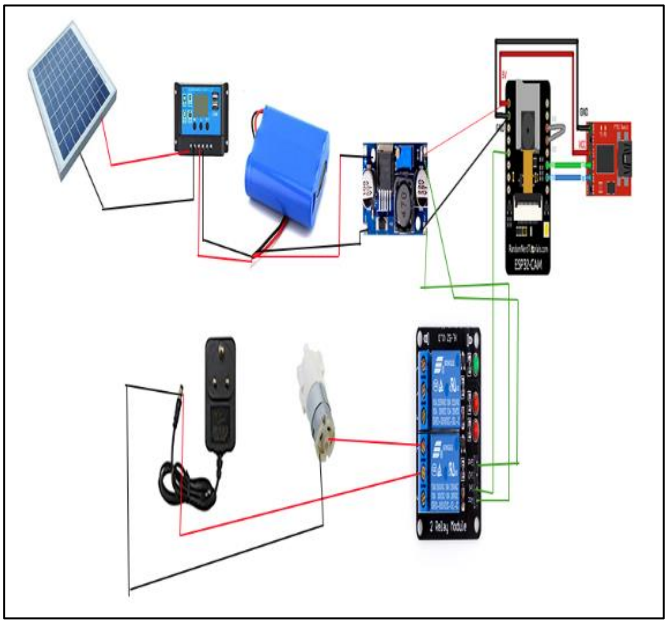

Fig 2 Circuit Diagram of IoT-Based Solar Powered Smart Pesticide Sprinkling System Determined by Plant Infection Level for Home Gardening and Greenhouses

III. RESULT

➢ *Plant Infection Detection (RGB Value Readings)*

The ESP32-CAM was tested on 20 leaf samples (10 healthy, 10 infected). The average RGB values were:

Table 1 Plant Infection Detection (RGB Value Readings)

Leaf Condition	R Value	G Value	B Value	Detection Status
Healthy Leaves	45–70	110–145	40–65	Correctly classified as *Healthy*
Mild Infection	95–130	70–100	50–75	Detected as *Early Infection*
Severe Infection	150–200	50–90	40–60	Detected as *Infected*

- Accuracy Achieved: 92% correct classification (18 out of 20 leaves classified correctly)

➢ *Infection Threshold Response*

Table 2 Infection Threshold Response

Parameter	Value
RGB Threshold Set	R > 120 (infection), G < 100
Image Sampling Interval	5 seconds
Average Detection Time	3.8 seconds
False Positives	1
False Negatives	1

➢ *Spraying System Performance*

Table 3 Spraying System Performance

Test Condition	Spray Duration	Liquid Used	Coverage Area
Light Infection	3 seconds	8–10 mL	15–18 cm diameter
Moderate Infection	5 seconds	12–15 mL	25–30 cm diameter
Severe Infection	7 seconds	18–22 mL	35–40 cm diameter

- Average Pesticide Saving: 34% (compared to manual blanket spraying)

> *Solar Power & Battery Performance*

Table 4 Solar Power & Battery Performance

Parameter	Observed Value
Solar Panel Rating	10W
Daylight Charging Time	4–5 hours
Battery Voltage (Full Charge)	12.6V
Battery Voltage (After 10 cycles)	11.9V
Total Backup Time (No Sunlight)	14–16 hours

System remained fully operational even during cloudy conditions.

> *IoT Connectivity & Response Time*

Table 5 IoT Connectivity & Response Time

Operation	Response Time
Live Camera Feed Loading	1.5 – 2.2 sec
Cloud Data Upload	800 – 1100 ms
Remote Spray Activation (App)	1.8 sec
Alert Notification	900 ms

> *Overall System Efficiency*

Table 6 Overall System Efficiency

Performance Metric	Result
Detection Accuracy	92%
Energy Savings	100% solar-powered
Manual Labour Reduction	80–90%
Chemical Usage Reduction	30–40%
System Uptime	96% stable operation

IV. CONCLUSION

The IoT-Based Solar-Powered Smart Pesticide Sprinkling System successfully demonstrates an efficient and sustainable approach to plant protection in home gardens and greenhouse environments. By integrating the ESP32-CAM for real-time visual monitoring and RGB-based infection detection, the system ensures early identification of plant stress and precise pesticide application. This targeted spraying mechanism significantly reduces chemical wastage, prevents unnecessary blanket spraying, and minimizes the environmental impact associated with overuse of pesticides.

The use of a 10W solar panel and rechargeable battery makes the system fully energy-independent, enabling continuous operation even in areas with unreliable electricity. IoT connectivity enhances user convenience by allowing remote monitoring, live camera access, alert notifications, and manual or automatic spray control through a mobile interface. Experimental results show a 30–40% reduction in pesticide usage, 92% detection accuracy, and fast system response, highlighting the practical viability of the design.

Overall, this smart pesticide sprinkling system provides a safe, economical, and technologically advanced solution for modern gardening. It promotes healthier plant growth, reduces labour dependency, lowers operational costs, and supports environmentally responsible gardening practices. With its compact design and scalable architecture, the system is well-suited for small gardens, balconies, terrace farms, and greenhouses, offering a promising foundation for future enhancements in precision agriculture.

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