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Design and Development of an IoT Based Smart Pesticide Spraying Robot

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Abstract: The experiment was conducted during the Rabi season of 2024–2025 at the Agronomy Main Research Farm, A.M. Reddy Memorial College, Narasaraopet, Palnadu District. A smart pesticide spraying robot was deployed to monitor and manage pest infestations across different crops, including tomato, brinjal, chilli, and cotton. The robot effectively identified pests such as aphids, whiteflies, and bollworms, adapting pesticide spraying quantities based on detection results. Observations indicated that pesticide application ranged from 150 mL to 250 mL, covering areas between 20 m² and 250 m², with corresponding battery usage and operational time. In cases of no pest detection, only monitoring activities were performed, demonstrating efficient energy and time management. Field results highlighted the robot's capability to optimize pesticide usage, reducing unnecessary spraying while maintaining pest control efficiency. The cost of the developed smart pesticide robot was ₹9,000, making it an affordable solution with minimal maintenance costs. This innovation presents a promising approach toward sustainable, automated pest management in agricultural practices.
Keywords: Smart pesticide robot, pest detection, automated spraying, energy efficiency, sustainable agriculture

I. INTRODUCTION

Agricultural productivity is critically dependent on effective pest management strategies. Conventional pesticide application methods often lead to excessive chemical usage, resulting in environmental hazards, economic losses, and potential harm to non-target organisms. To address these challenges, the integration of smart technologies in agriculture has gained significant attention. Automation and precision in pesticide application not only optimize chemical use but also contribute to sustainable farming practices.

In this context, a smart pesticide spraying robot was developed and deployed to monitor pest infestations and manage pesticide usage efficiently. The study was conducted during the Rabi season of 2024–2025 at the Agronomy Main Research Farm, A.M. Reddy Memorial College, Narasaraopet, Palnadu District. The experimental site, characterized by a moderate climate with temperatures ranging from 15°C to 45°C, provided a suitable environment for evaluating the performance of the smart pesticide robot across crops like tomato, brinjal, chilli, and cotton.

The robot was equipped with pest detection capabilities, enabling targeted pesticide application based on real-time field data. Performance parameters such as pesticide quantity, coverage area, battery usage, and operational time were recorded to assess efficiency. Additionally, a cost analysis was performed, revealing a total setup cost of ₹9,000 with minimal maintenance requirements. The implementation of such smart robotic systems offers a promising solution for achieving precise, eco-friendly, and cost-effective pest management in modern agriculture.

II. OBJECTIVES OF THE STUDY

1) To design & development IOT based smart pesticides robot.
2) To integrate sensors for real-time monitoring & precise pesticide application.
3) To minimized environmental impact.

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III. REVIEW OF LITERATURE

The advent of the Internet of Things (IoT) has significantly transformed the agricultural sector, offering new opportunities to enhance productivity, sustainability, and efficiency. In particular, IoT technologies have found critical applications in two key areas: precision pest management and smart irrigation.

Researchers have extensively explored how integrating IoT with autonomous robots, drones, and artificial intelligence (AI) can optimize pesticide spraying and water management practices, leading to more sustainable agricultural operations.

Several studies (Wang et al., 2021; Chakraborty et al., 2020; Zhang et al., 2020; Das et al., 2019) have highlighted the transformative role of IoT-powered autonomous pesticide spraying robots. By leveraging real-time environmental data, these systems can adapt spraying techniques to target pest-infested areas precisely, reducing chemical overuse and minimizing environmental impact. Moreover, the integration of AI with IoT, as discussed by Patel et al. (2020), further enhances the adaptability and efficiency of these robots, enabling continuous learning and optimization based on local farming conditions.

Similarly, IoT has been pivotal in advancing smart irrigation systems. Studies by Zhou et al. (2021), Tariq et al. (2019), and Gupta et al. (2018) demonstrate that IoT-enabled irrigation solutions, through real-time monitoring of soil moisture and weather conditions, can optimize water use, preventing both over-irrigation and water scarcity. These technologies ensure that crops receive the right amount of water at critical growth stages, thereby improving yields while conserving precious water resources.

The economic and environmental benefits of IoT-based agricultural automation are well documented. Research by Rani et al. (2020) and Shah et al. (2020) shows that IoT systems not only reduce operational costs by minimizing resource consumption but also promote eco-friendly farming practices by lowering the risks associated with pesticide overuse and chemical runoff. Furthermore, IoT-driven solutions address pressing challenges such as pesticide resistance (Nguyen et al., 2019) and the technical hurdles of deploying sustainable agricultural systems in rural areas (Kumar et al., 2019; Singh et al., 2018).

IV. MATERIALS AND METHODOLOGY

1) Water Tank

The IoT-based smart irrigation and pesticide-spraying robot features a 2-liter water tank, ensuring lightweight mobility for efficient crop management. IoT integration enables remote monitoring, optimizing resource use while promoting sustainable farming practices.

FIG1:WATER TANK

2) Wheels

The smart irrigation and pesticide-spraying robot uses four wheels with 40 mm inner and 35 mm outer diameters, ensuring smooth mobility. This design provides excellent stability for efficient operation across agricultural fields.

FIG 2: WHEELS

3) Chesis

The smart irrigation and pesticide-spraying robot features a durable 30 cm square cast-iron chassis, ensuring stability and structural integrity. Its compact design allows for efficient navigation between crop rows, enhancing precision in irrigation and spraying.

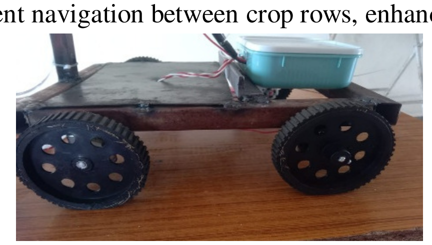

FIG 3: CHESIS

4) Nozzles

The robot is equipped with four durable black PVC nozzles that rotate 360 degrees, offering adaptable spray sizes from 0.5 mm to 5 mm for efficient irrigation and pesticide application. Their corrosion-resistant material and IoT integration ensure precise control, optimizing resource usage and enhancing crop care.

FIG 4: NOZZLES

5) 12v Rechargeable Battery

The 12V rechargeable battery provides stable power for efficient operation of the robot's motors, sensors, and modules, ensuring sustainability. Its compact design, high energy density, and rechargeable capability make it ideal for extended agricultural use, with options for solar or external charging.

FIG 5: 12V RECHARGEABLE

6) Arduino Uno

Arduino is an open-source platform that designs microcontroller boards and kits for building interactive digital and physical devices. It offers easy-to-use hardware and software tools, making it ideal for both beginners and professionals in creating projects like robots, thermostats, and motion detectors.

FIG 6: ARDUINO UNO

7) HC-05 Bluetooth Module

The HC-05 Bluetooth module enables wireless communication for IoT-based smart irrigation and pesticide-spraying robots, allowing remote operation and monitoring. With a range of up to 100 meters and low power consumption, it ensures efficient and flexible control in agricultural applications.

FIG 7: HC-05 BLUETOOTH MODULE

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8) L298N Motor Driver

The L298N motor driver controls the speed and direction of DC motors in IoT-based smart irrigation and pesticide-spraying robots. With dual H-Bridge capability, PWM support, and built-in protection features, it ensures reliable and efficient motor operation for agricultural automation.

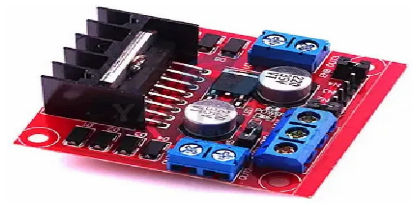

FIG 8: L298N MOTOR DRIVER

9) DC Motor

The DC motor powers the movement and spraying mechanisms of the smart irrigation and pesticide-spraying robot, enabling precise navigation across fields. Controlled by a microcontroller, it ensures smooth operation, enhancing efficiency and reducing the need for manual labor.

FIG 8: DC MOTOR

10) Relay

A relay in the smart irrigation and pesticide-spraying robot enables the microcontroller to control high-power devices like pumps and sprayers with low-power signals. It ensures safe, efficient operation, streamlining automation and enhancing farming productivity.

FIG 9: RELAY

11) Jumper Wires

Jumper wires are essential for connecting sensors, microcontrollers, and modules in a smart irrigation and pesticide-spraying robot. They ensure reliable signal transmission and simplify circuit assembly, supporting efficient and flexible robotic design.

FIG 10: JUMPER WIRES

V. METHODOLOGY

The development and testing of the IoT-based smart pesticide-spraying robot involved systematic planning and integration of multiple components to achieve efficient pest detection, precise pesticide application, and optimized resource utilization. The following steps outline the methodology adopted for the project:

1) *Robot Design and Fabrication:* The robot chassis was constructed using a 30 cm square cast-iron frame to ensure durability and stability. Four wheels with 40 mm inner and 35 mm outer diameters were mounted to provide smooth and stable movement across different agricultural terrains.
2) *Component Integration:* Key components such as the 2-liter water tank, four 360-degree rotatable PVC nozzles, a 12V rechargeable battery, and DC motors were integrated into the chassis. The nozzles were designed to adjust spray sizes between 0.5 mm and 5 mm, providing flexibility in pesticide application.
3) *Control System Development:* An Arduino Uno microcontroller was used to manage all robotic operations. The Arduino was programmed to control the motion, spraying actions, and sensor data acquisition. A L298N motor driver was employed to manage the speed and direction of the DC motors.
4) *Communication Setup:* Wireless communication was established using the HC-05 Bluetooth module, enabling remote control and monitoring of the robot through a smartphone or computer interface.
5) *Power Management:*
6) A 12V rechargeable battery supplied power to all robotic components. A relay module was used to safely control high-power devices like pumps and sprayers based on low-power microcontroller signals, ensuring efficient energy management.
7) *Sensor Connectivity and Wiring:* All electronic modules, sensors, and motors were interconnected using jumper wires for reliable signal transmission and power distribution. This setup ensured flexibility in prototyping and troubleshooting.
8) *Field Deployment and Testing:* The robot was deployed in the Agronomy Main Research Farm at A.M. Reddy Memorial College during the Rabi season of 2024–2025. It was tested across crops like tomato, brinjal, chilli, and cotton. Pest detection, pesticide usage, operational time, and battery consumption were systematically recorded.
9) *Performance Evaluation:* Observations were made regarding pesticide quantities (ranging from 150 mL to 250 mL), coverage areas (20 m² to 250 m²), and battery usage efficiency. In the absence of pest detection, the robot performed monitoring activities without pesticide application, demonstrating effective energy and time management.
10) *Cost Analysis:* The total development cost of the smart pesticide-spraying robot was calculated as ₹9,000, highlighting its affordability and minimal maintenance requirements, making it suitable for large-scale deployment in agriculture.

VI. RESULTS AND DISCUSSION

A. *Experimental Site*

The experiment was conducted at the Agronomy Main Research Farm of A.M. Reddy Memorial College, Narasaraopet, located in Palnadu district. The study was carried out during the rabi season of 2024–2025. The farm is positioned at 16° 10’ 25’’ N latitude and 79° 59’ 21’’ E longitude, at an altitude of 77 meters above sea level.

B. *Climate and Weather*

Narasaraopet experiences a moderate climate. The monsoon usually starts in the last week of December and lasts until April. Summer temperatures range from 27°C to 45°C, while winter temperatures range between 15°C and 22°C. During the experiment, weather conditions such as temperature, humidity, rainfall, and sunshine hours were recorded.

Table 1: Pesticide Detection Readings at College Farm

S.No	Date	Crop Type	Pest Detected	Pesticide Sprayed (mL)	Coverage Area (m²)	Battery Usage (%)	Time Taken (min)
1	15-01-25	Tomato	Aphids	150	20	15	12
2	25-01-25	Brinjal	No pest	0	25	10	10
3	13-02-25	Chilli	Whiteflies	200	30	20	15
4	17-02-25	Cotton	Bollworms	250	40	25	20

At the colege farm, the smart pesticide robot successfully detected pests such as aphids, whiteflies, and bollworms on different crops. Based on the type of pest found, it sprayed different amounts of pesticide, covering areas between 20 m² and 40 m².

When no pests were found (as in brinjal), no pesticide was sprayed, but the robot still monitored the crop. Battery usage and time taken were recorded, showing that the robot used energy efficiently depending on the work done

Table 2: Pesticide Detection Readings at Field

S.No	Date	Crop Type	Pest Detected	Pesticide Sprayed (mL)	Coverage Area (m²)	Battery Usage (%)	Time Taken (min)
1	28-01-25	Tomato	Aphids	150	150	25	30
2	07-02-25	Brinjal	No pest	0	20	10	20
3	14-02-25	Chilli	Whiteflies	200	250	35	25
4	17-02-25	Cotton	Bollworms	250	170	30	40

In the field experiments, the smart pesticide robot adjusted the amount of pesticide sprayed based on pest detection. When pests like whiteflies and bollworms were present, larger amounts of pesticide (200–250 mL) were used to cover bigger areas, up to 250 m². When no pests were found (in brinjal), only monitoring was carried out with low battery usage. Overall, battery consumption and time taken were higher when the area treated was larger and pest problems were more serious.

VII. DISCUSSION

The smart pesticide robot demonstrated its effectiveness in identifying pests and applying pesticides efficiently in both the college farm and open field conditions.

At the college farm, pests such as aphids, whiteflies, and bollworms were successfully detected. The robot sprayed pesticides only when necessary, conserving resources when no pests were found, such as in brinjal crops. The pesticide usage ranged between 150 mL to 250 mL, depending on the severity of the pest infestation. Battery usage and operation time were relatively low due to the smaller coverage areas (20–40 m²), showing that the robot worked efficiently on a controlled farm scale.

In the open field trials, the robot faced larger coverage areas (up to 250 m²) and still adapted effectively. When pests were detected, more pesticide was sprayed, and battery consumption was higher. For instance, in chilli and cotton crops, higher pesticide volumes (200–250 mL) were used to manage significant pest infestations. On the other hand, in crops where no pests were detected (like brinjal), pesticide spraying was avoided, saving chemicals and battery power.

Overall, the results show that:

1) The robot can accurately detect pest presence and adjust pesticide usage accordingly.
2) It saves pesticides by not spraying unnecessarily.
3) It optimizes battery usage based on the size of the treated area and pest intensity.
4) Time efficiency was maintained, with quicker operations in pest-free or low-infestation areas.

Thus, the smart pesticide robot proved to be a promising tool for precision agriculture, minimizing chemical use, saving energy, and reducing human labor.

VIII. CONCLUSION

The deployment of the IoT-based smart pesticide spraying robot in both controlled farm and field conditions demonstrated its significant potential to enhance agricultural efficiency and sustainability. By accurately detecting pests and adjusting pesticide application based on real-time data, the robot effectively minimized pesticide usage, thereby reducing environmental impact and conserving resources. The robot's ability to operate autonomously with optimized energy consumption, especially when no pests were detected, highlighted its efficiency in both time and power management. With its affordable setup cost and minimal maintenance requirements, this innovative solution offers a cost-effective alternative to traditional pesticide application methods.

Overall, the smart pesticide spraying robot proves to be a valuable tool in modern agriculture, enabling precision pest management, resource conservation, and eco-friendly farming practices. The system's successful performance during the rabi season of 2024-2025 further underscores its potential for widespread adoption in sustainable agricultural practices.

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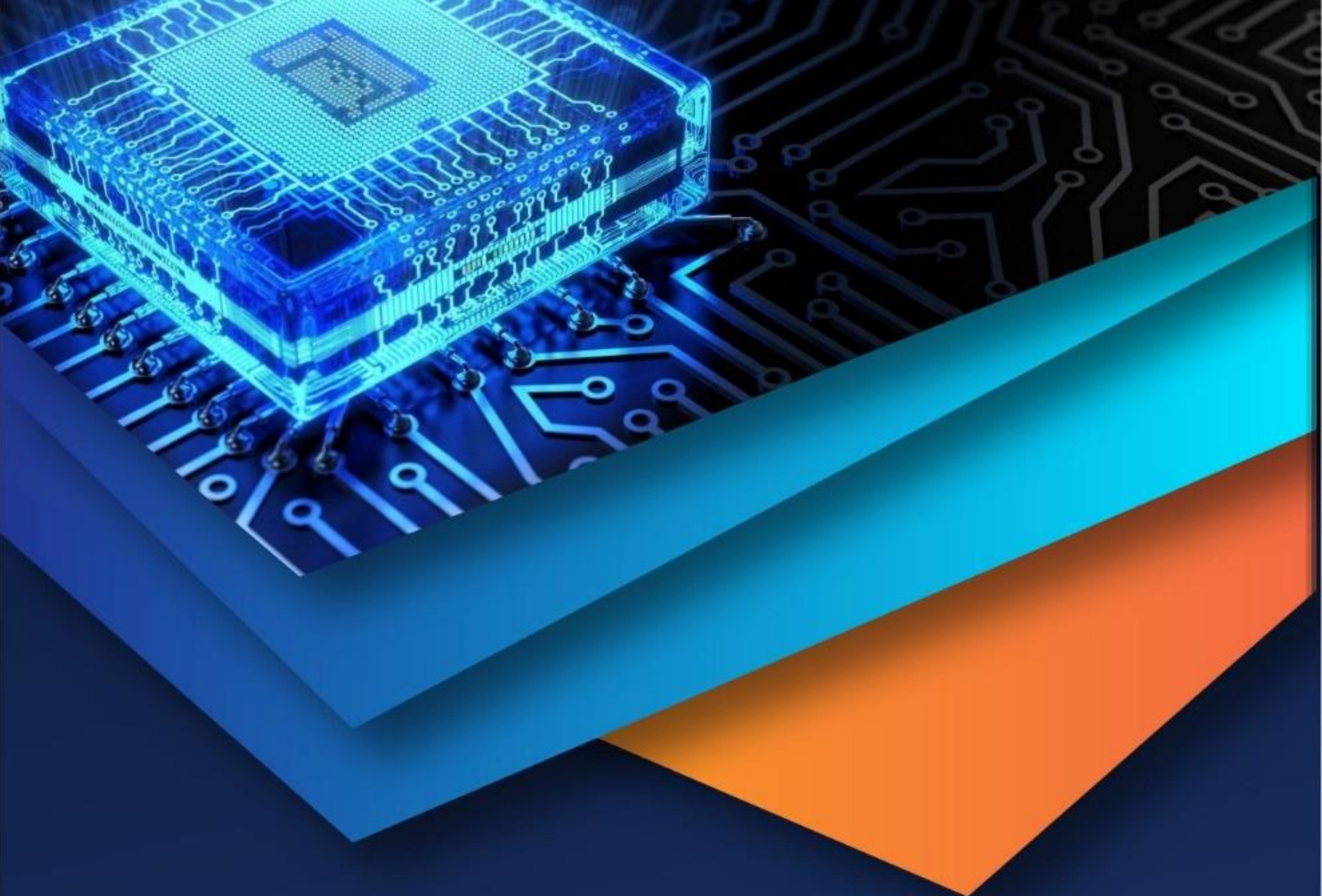

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