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AUTONOMOUS ELECTROSTATIC SPRAYER

Specially Designed for Horticulture

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Abstract: This paper presents the design and development of a mobile electrostatic pesticide sprayer for horticultural applications. The system uses an electrostatic charging mechanism to electrically charge pesticide droplets, enabling better adhesion to plant surfaces and improved spraying efficiency. An Arduino UNO and Arduino Nano are used to control the spraying mechanism and system operation. The developed prototype sprays pesticide over the upper portion of plant leaves while reducing chemical wastage and human exposure. The proposed system demonstrates a simple and cost-effective approach for improving pesticide application in small and medium-scale agricultural fields.

***Index Terms* -** Electrostatic Spraying, Precision Agriculture, Pesticide Application, Agricultural Robotics, Arduino-Based Automation, Smart Farming

I. INTRODUCTION

Agriculture plays a vital role in meeting the growing global demand for food production. One of the major challenges faced by farmers is the efficient application of pesticides for crop protection. Conventional pesticide spraying methods often result in uneven distribution, excessive chemical usage, and increased exposure of farmers to harmful chemicals. These limitations not only reduce spraying efficiency but also contribute to environmental pollution and increased operational costs.

Electrostatic spraying technology has emerged as an effective solution to improve pesticide deposition and reduce chemical wastage. In this method, pesticide droplets are electrically charged before being released from the spray nozzle. The charged droplets are attracted toward plant surfaces, allowing better adhesion and more uniform coverage compared to conventional spraying methods. This technique also helps droplets reach difficult areas of plants, improving the overall effectiveness of pesticide application.

Automation in agriculture has also gained significant attention in recent years due to the increasing need for efficiency and labor reduction. The integration of robotic platforms with smart spraying systems enables controlled and targeted pesticide application while minimizing human intervention. Such systems can improve spraying accuracy, reduce pesticide consumption, and enhance safety for farmers.

This paper presents the design and development of a mobile electrostatic pesticide sprayer for horticultural applications. The proposed system uses Arduino UNO and Arduino Nano microcontrollers to control the spraying mechanism and system operation. The electrostatic charging unit improves droplet adhesion to plant surfaces while the mobile platform enables efficient spraying across crop rows.

The developed system aims to provide a simple, cost-effective, and practical solution for improving pesticide spraying efficiency in small and medium-scale agricultural environments.

II. LITERATURE REVIEW

In recent years, significant research has been conducted to improve pesticide spraying efficiency in agricultural applications. Conventional spraying techniques often suffer from problems such as chemical drift, uneven coverage, and excessive pesticide consumption. These limitations have encouraged researchers to explore advanced spraying technologies that improve deposition efficiency and reduce environmental impact.

Electrostatic spraying technology has gained attention as an effective method for improving pesticide application. In this technique, liquid droplets are electrically charged before being sprayed onto plant surfaces. The electrostatic charge causes the droplets to be attracted to plant leaves, allowing better coverage and improved adhesion. Several studies have reported that electrostatic spraying can significantly reduce pesticide loss and increase spraying efficiency compared to conventional spraying methods.

Automation and robotics have also been increasingly adopted in modern agriculture to enhance productivity and reduce labor dependency. Mobile robotic platforms integrated with spraying mechanisms allow controlled and targeted pesticide application in crop fields. These automated systems help improve operational efficiency, reduce human exposure to chemicals, and support precision agriculture practices.

Based on these advancements, the development of a mobile electrostatic pesticide sprayer using embedded control systems can provide an effective and economical solution for agricultural spraying applications.

III. METHODOLOGY

The proposed system is a mobile electrostatic pesticide spraying platform designed to improve pesticide application efficiency in horticultural environments. The system integrates a robotic vehicle, electrostatic spraying mechanism, plant detection system, and a dual-microcontroller control architecture.

The mobile platform consists of a four-wheel drive chassis powered by DC motors and lithium battery packs. The platform carries the pesticide tank, pump, electrostatic charging unit, and control electronics. The robotic vehicle enables movement along crop rows for targeted pesticide application.

The electrostatic spraying mechanism is designed to charge pesticide droplets before they are discharged through the spray nozzle. A high voltage generator is used to produce an electrostatic field inside the PVC tank. As the pesticide solution flows through the system and reaches the nozzle, the droplets become electrically charged. These charged droplets are attracted to plant surfaces, improving droplet adhesion and reducing spray drift.

Plant detection is achieved using a LiDAR sensor mounted on the robotic platform. The LiDAR sensor continuously scans the environment and detects the presence of plants in front of the vehicle. The sensor data is processed by the Arduino UNO which acts as the master controller of the system.

The control system consists of two microcontrollers: Arduino UNO and Arduino Nano. The Arduino UNO functions as the main controller responsible for LiDAR data processing, navigation control, and system coordination. The Arduino Nano acts as a slave controller responsible for controlling the pesticide pump and spraying mechanism based on commands received from the master controller.

The integration of electrostatic spraying, robotic mobility, and plant detection allows efficient and targeted pesticide application while minimizing chemical wastage and environmental impact.

PROCEDURE

1. The pesticide solution is filled into the PVC tank mounted on the mobile robotic platform.
2. The lithium battery packs supply power to the entire system including the Arduino controllers, motor driver, LiDAR sensor, pump, and electrostatic generator.
3. The electrostatic high voltage generator is activated to create an electric field used for charging pesticide droplets.
4. The Arduino UNO initializes the system and controls the movement of the robotic platform through the motor driver and DC motors.
5. The LiDAR sensor continuously scans the surrounding area to detect plants in the path of the robot.
6. The Arduino UNO processes the LiDAR data to determine the presence of plants.
7. When a plant is detected, the Arduino UNO sends a control signal to the Arduino Nano.
8. The Arduino Nano activates the pesticide pump through a relay module.
9. The pump transfers pesticide from the tank to the spray nozzle.
10. As the pesticide passes through the electrostatic charging region, the droplets become electrically charged.
11. The charged droplets are sprayed onto the plant leaves where electrostatic attraction improves droplet adhesion.
12. The spraying process continues as the robot moves along the crop row and stops automatically when no plants are detected.

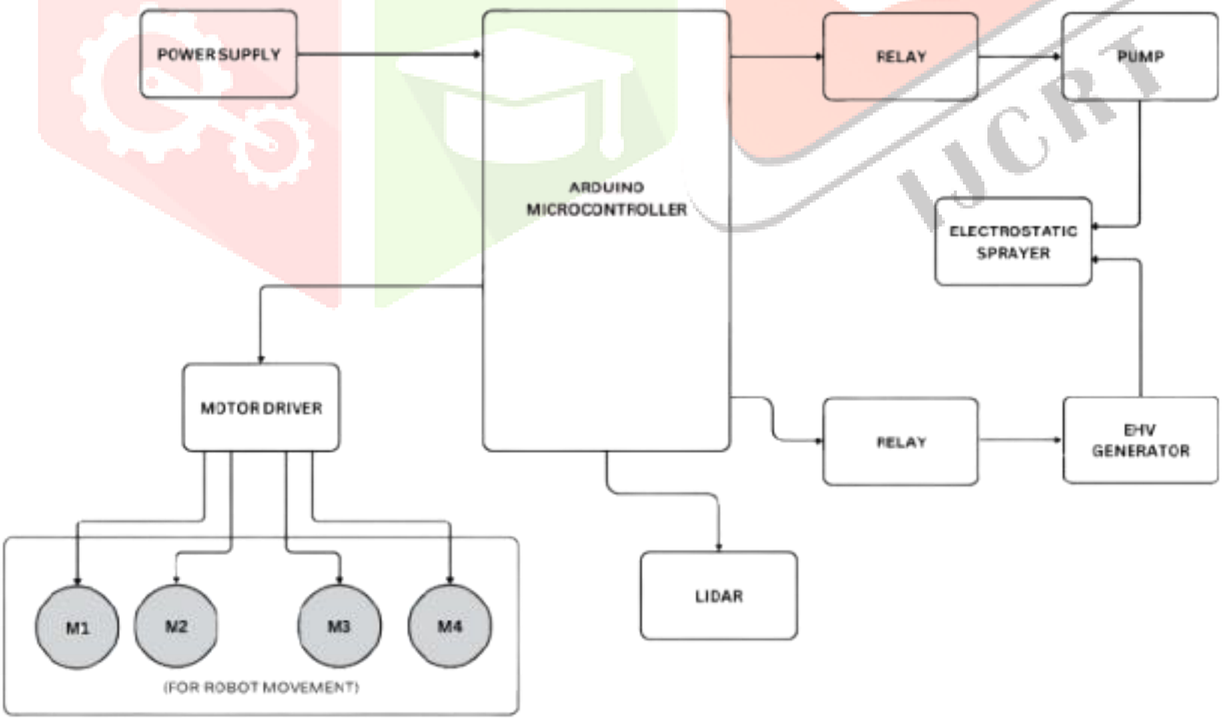

fig.1 block diagram

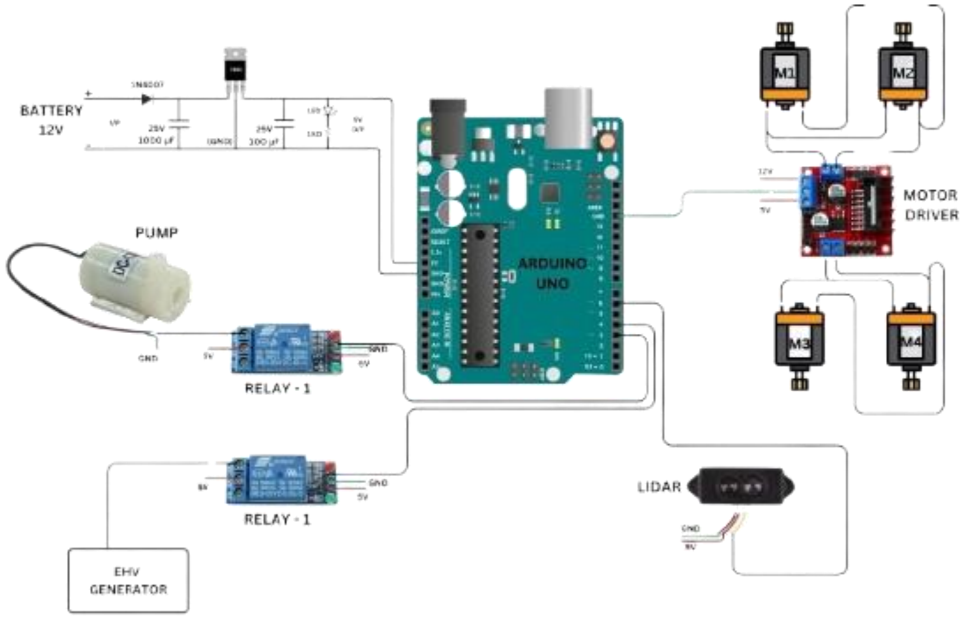

fig.2 circuit diagram

IV. RESULTS

The developed prototype of the autonomous electrostatic pesticide sprayer was tested to evaluate its functionality and spraying performance. The robotic platform was able to move along the test path using four DC motors controlled through the motor driver module. The Arduino UNO successfully processed LiDAR sensor data and detected the presence of plants in front of the system.

When a plant was detected by the LiDAR sensor, the Arduino UNO transmitted a control signal to activate the spraying mechanism. The Arduino Nano controlled the relay module to switch the pump and electrostatic generator. The pump delivered pesticide from the PVC tank to the spray nozzle while the electrostatic generator produced an electric field to charge the pesticide droplets.

During testing, the electrostatic spraying mechanism improved droplet adhesion on plant surfaces, particularly on the upper portions of the leaves. The charged droplets demonstrated better attachment compared to conventional spraying methods. The robotic platform was able to perform continuous movement and spraying operations without interruption.

The integration of plant detection and automated spraying allowed the system to spray pesticide only when plants were detected, reducing unnecessary chemical usage. The prototype demonstrated stable system operation and effective coordination between the sensing, control, and spraying subsystems

Parameter	Conventional Spraying	Electrostatic spraying
Droplet charge	Neutral droplets	Electrically charged droplets
Adhesion on leaf surface	40–55 %	70–85 %
Coverage of upper leaf surface	Moderate	High
Coverage of hidden leaf areas	Low	Improved due to electrostatic attraction
Pesticide utilization efficiency	45–60 %	75–90 %
Chemical wastage	High	Reduced

comparison of pesticide adhesion between conventional and electrostatic spraying

fig.3 prototype of the autonomous electrostatic pesticide sprayer

V. DISCUSSIONS

The experimental results demonstrate that the proposed electrostatic pesticide spraying system can improve spraying efficiency compared to conventional pesticide spraying techniques. The integration of electrostatic charging allowed the pesticide droplets to acquire an electrical charge before being sprayed onto plant surfaces. As a result, the droplets exhibited better adhesion to plant leaves, particularly on the upper leaf surfaces, which improved pesticide coverage and reduced spray drift.

The use of LiDAR-based plant detection enabled the system to activate spraying only when plants were detected in the robot's path. This selective spraying mechanism reduced unnecessary pesticide usage and improved overall spraying efficiency. The coordination between the Arduino UNO and Arduino Nano microcontrollers ensured reliable control of the sensing, actuation, and spraying subsystems.

The robotic platform also contributed to improved operational efficiency by enabling the sprayer to move along crop rows while maintaining continuous spraying operation. The four-wheel drive system provided stable mobility during testing and allowed uniform pesticide distribution across the test area.

Compared to conventional spraying systems, the proposed electrostatic sprayer demonstrated improved pesticide utilization and reduced chemical wastage. The results obtained from the prototype indicate that integrating electrostatic spraying with automated plant detection can significantly enhance pesticide application efficiency in agricultural environments.

Although the system performed effectively during testing, certain limitations remain. The current prototype primarily sprays the upper portions of plant leaves, and further improvements may be required to achieve better coverage of the underside of leaves. Future work may include optimization of nozzle orientation, improved droplet atomization, and enhanced sensing capabilities to further improve spraying performance.

VI. CONCLUSION

This paper presented the design and development of an autonomous electrostatic pesticide spraying system for horticultural applications. The proposed system integrates a mobile robotic platform, electrostatic spraying mechanism, LiDAR-based plant detection, and Arduino-based control architecture. The electrostatic charging mechanism improved pesticide droplet adhesion on plant surfaces, which enhanced spraying efficiency and reduced chemical wastage.

The LiDAR sensor enabled the system to detect plants and activate spraying only when necessary, thereby minimizing unnecessary pesticide usage. The dual-controller architecture using Arduino UNO and Arduino Nano ensured reliable coordination between the sensing, control, and spraying subsystems.

Experimental results demonstrated that the developed prototype can effectively perform automated pesticide spraying with improved droplet deposition compared to conventional spraying techniques. The proposed system provides a cost-effective and practical solution for improving pesticide application efficiency in agricultural environments.

Future work may focus on improving spraying coverage for the underside of leaves, optimizing nozzle orientation, and integrating advanced navigation systems for enhanced autonomous field operation.

VII. REFERENCES

1. Cost-Effective Targeting vs. High-Overhead AI

- The Paper: Koc, D. G. (2025). AI-Powered Autonomous Spraying Robot for Precision Orchard Applications.
- Their Limitation: This paper relies on complex, computationally heavy Artificial Intelligence and vision systems to detect plants and control the nozzles. This requires expensive microprocessors, high power consumption, and is difficult for everyday farmers to repair.

2. Autonomous Agility vs. Heavy Machinery and Soil Compaction

- The Paper: Salcedo, R., et al. (2023). Evaluation of an Electrostatic Spray Charge System Implemented in Three Conventional Orchard Sprayers...
- Their Limitation: This study proves electrostatic spraying works, but they retrofitted massive, heavy, tractor-pulled conventional sprayers. These heavy machines cause severe soil compaction, require fossil fuels, and cannot navigate tight greenhouse or crop rows

3. Integrated Action vs. Navigation-Only Focus

- The Papers: Jiang, A., & Ahamed, T. (2023). Navigation of an Autonomous Spraying Robot... Using LiDAR...
- Jiang, S., et al. (2024). Navigation System for Orchard Spraying Robot Based on 3D LiDAR SLAM...
- Their Limitation: Both of these highly technical papers focus almost entirely on using LiDAR for complex navigation and mapping (SLAM) so the robot doesn't crash. They treat the actual spraying mechanism as an afterthought.

4. Superior Adhesion vs. Standard Automated Wasting

- The Paper: Jat, D., et al. (2023). Development of an Automated Mobile Robotic Sprayer to Prevent Workers' Exposure...
- Their Limitation: While this paper successfully builds a microcontroller-driven robotic sprayer to keep humans safe from chemicals, it relies on standard hydraulic pressure to push the liquid out of the tank. This still results in chemical runoff, wind drift, and poor coverage on the underside of leaves.