Journal of AgriSearch, 12 (4) : 237-244
An Open Access International Peer Reviewed Quaterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v12i04.15262

Design, Implementation, and Performance Assessment of an Ultrasonic-Guided Bluetooth-Controlled Spraying Rover for Vegetable Crop Rows

Ankit Kumar*[1], Sravan Kumar Jogunuri[2] and D K Vyas[3]

ABSTRACT

Precision agriculture is an emerging and transformative approach that utilises advanced technological tools to enhance crop management and increase overall agricultural productivity. This paper presents the conceptualisation, development, and practical execution of an automated spraying rover system designed to support precision spraying applications in vegetable farms. The system comprises a mobile rover equipped with ultrasonic sensing, a fluid spraying mechanism, and a wireless control interface, which can be operated using an Android smartphone via Bluetooth connectivity. The system design framework outlines both the hardware assembly and software structure, including the mechanical design of the rover, sensor integration, wireless communication protocols, control algorithms, and real-time farm-level deployment strategies. The rover design prioritises lightweight construction, directional mobility, and smooth navigation, ensuring efficient movement between crop rows under field conditions. Bluetooth communication enables seamless bidirectional interaction between the Android controller and the onboard microcontroller, allowing for the transmission of movement and spraying commands with minimal human intervention. Bluetooth is utilised as the primary communication channel due to its ease of use, low cost, and reliability for outdoor signal transfer. Field implementation of the automated spraying rover validates its feasibility for optimising spraying processes in real agricultural landscapes. The rover's ability to move accurately via Bluetooth commands while delivering controlled spray discharge demonstrates its potential to modernise and improve conventional spraying practices. This work contributes to the advancement of precision agriculture by demonstrating the practical use of rover-based spraying automation combined with a simple and accessible mobile control interface. The automated spraying system establishes a new pathway for improved spraying efficiency, reduced operational time, resource optimisation, and enhanced utilisation of farm inputs, supporting safer and more sustainable agricultural spraying solutions.

Keywords: Precision agriculture, Automated spraying system, Bluetooth control, Ultrasonic sensor

ARTICLE INFO

Received on	:	27/10/2025
Accepted on	:	04/12/2025
Published online	:	18/12/2025

INTRODUCTION

Automation of irrigation techniques is necessary to address the prevailing issues in agriculture, including labour constraints, water scarcity, and the need to optimise resource efficiency. Due to human error, traditional irrigation techniques frequently include inefficiencies that result in water waste and unequal distribution across fields. Automation offers a solution by enhancing the accuracy and control of irrigation systems, thereby improving their efficiency. With the ability to adjust instantly to shifting climatic conditions, automated irrigation systems maximise water efficiency by providing crops with the exact quantity of water they require at the precise moment. Automated spraying systems minimise environmental effects and chemical consumption by accurately targeting areas that require treatment. With the use of these technologies, pest and weed management can be more effectively achieved by scheduling spraying dates and times that take into account crop development phases and weather conditions. Additionally, automation lessens the need for physical labour, which relieves farmers of some of their workload and lessens the effects of a labour shortage. Farmers can make data-driven decisions that lead to increased crop yields, resource conservation, and sustainable agricultural practices by utilising technologies such as sensor systems (Kumar et al., 2024).

Naik et al. (2016) proposed robot design for seeding operations utilises input switches for crop selection and IR sensors to monitor seed tank conditions and detect field conditions. Mechanical parts controlled by DC motors execute the seeding process. The system follows a predetermined pattern for seeding rows, detected by IR sensors. Mechanical parts, driven by DC motors, perform the seeding process, ensuring precision and efficiency. Terra et al. (2020) proposed a modular automation solution for individual spray nozzle control, in the context of precision agriculture with the site-

[1]B.Tech Agricultural Engineering, Dept. of Renewable Energy Engi., College of Agri. Engi. and Tech., Anand Agricultural University, Godhra, India
[2]Assistant Professor, Dept. of Renewable Energy Engi., College of Agri. Engi. and Tech., Anand Agricultural University, Godhra, India
[3]Associate Professor & Head, Dept. of Renewable Energy Engi., College of Agri. Engi. and Tech., Anand Agricultural University, Godhra, India
*Corresponding Author E-mail: Ankituday123@gmail.com

specific application (SSA). The solution can be easily adapted with minimal intervention for use with tractor-mounted boom sprayers, which are widely used in family farming worldwide. Mashori et al. (2023) proposed a prototype having a navigation system as well as a spraying mechanism. Studies indicate that workers may save time and money by utilising robots to replace traditional pesticide sprayers, reducing the number of humans needed, and optimizing pesticide usage on the chilli farm. Murugan et al. (2020) proposed a bluetooth-based pesticide spraying robot for spraying pesticides using a servo motor for broader angle coverage. The robot reduces labour costs for farmers, leading to increased profits.

Based on the reviewed literature, there is a clear need for the development and field-level evaluation of advanced agricultural spraying robots. The present model has been designed by referencing the systems proposed by Mashori et al. (2023) and Murugan et al. (2020), while incorporating several enhancements to improve operational efficiency, spraying performance, and field adaptability.

First, the prototype has been upgraded by increasing both the pump capacity and the tank size, which enables a higher spraying output compared to earlier models. The communication system has also been improved by integrating enhanced Bluetooth technology, achieving a maximum range of 80–100 meters with a reliable operational range of 60–70 meters. Murugan et al. (2020) recommended free-flow spraying equipment, however, has its limitations in providing controlled and uniform spraying, prompting the adoption of a fixed spraying nozzle in the present design. This modification ensures better precision and improved spraying efficiency.

Additionally, several new performance parameters have been incorporated into the evaluation framework, including turning radius, operational range, sprayer throw radius, and pump performance under both high and low input conditions. The output characteristics of the ultrasonic sensor have also been evaluated to validate the reliability of obstacle detection.

Mashori et al. (2023) implemented remote control through Blynk IoT using Wi-Fi technology for chilli fields. In contrast, a Bluetooth-based control system is adopted for a broader range of vegetable crops. This design choice enables improved reliability in open-field conditions, facilitating the evaluation of rover speed, range, and consistency during field operations. These refinements address the gap in field-level performance assessment identified in previous research.

Furthermore, comprehensive reviews by Nasir et al. (2023) and Bargoti and Underwood (2016) highlighted the effectiveness of robotic fleets, computer vision, and autonomous navigation in achieving environmentally safe and precise pesticide application. Bargoti and Underwood (2016) emphasise challenges in perception and path planning, laying foundational insights for improving robotic accuracy in complex agricultural environments.

Collectively, existing research demonstrates that automated agricultural robots equipped with robust sensing, adaptive control systems, and wireless communication technologies can substantially enhance spray uniformity, reduce chemical usage, and overcome labour shortages. In alignment with these findings, the present study introduces an improved automated spraying rover optimised for vegetable crops, featuring enhanced pump and tank capacities, refined wireless control, and a comprehensive field-level performance evaluation under realistic farm conditions.

MATERIALS AND METHODS

The automated spraying rover is based on a sensing system that incorporates ultrasonic sensing technology for plant detection, with a rover control system utilising Bluetooth technology to communicate with Android phones via any generic Bluetooth application. The Rover has dimensions of 50 cm in length, 30 cm in width, and 20 cm in height. An acrylic sheet has been used to prepare the chassis.

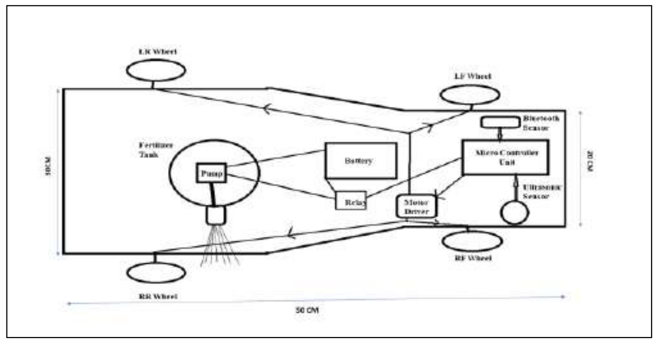

Fig. 1: Conceptual block diagram of automated spaying rover

Realisation of the block diagram, as shown in Fig. 1, leads to the fragmentation of the rover into three-unit operations. These operations are illustrated in Fig. 2.

- Power Supply Unit
- Control unit
- Application unit

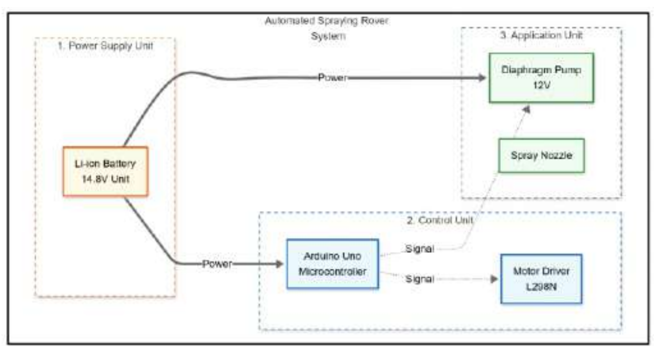

Fig. 2: Different units of automated spraying rover

Power Supply

For powering this prototype, we have used two types of batteries.

a. Lithium-ion battery unit

A lithium-ion battery unit powers the rover. This unit consists of four batteries, each with a voltage of 3.7 V and a capacity of 2600 mAh, totalling 10400 mAh for the entire unit. This battery supplies power to the Rover and pumping unit of this system.

b. Zinc Chloride Battery

A 9V 6F22 non-rechargeable battery is used for powering the Micro Controller.

Control Unit

This unit consists of an automated spraying Rover tracking system. For sensing, controlling and transmitting the system, several components are used.

These components are listed-

a. Ultrasonic Sensor

In this system, an HC-SRO4 ultrasonic sensor is used, which is equipped with two transducers. One acts as a transmitter, transforming the electrical signal into ultrasonic sound pulses at 40 kHz, and the other acts as a receiver, detecting the transmitted pulses. These pulses are used to measure the distance between the sensor and the plant. It operates at a voltage of 5V and a current of 15mA across a range of 2 cm to 1200 cm. This sensor uses the Echo effect to measure distance.

b. Microcontroller

An Atmel Mega328p-based Arduino Uno is used in this work. It contains 14 pins, 6 of which can be utilised for PWM and 6 for analogue inputs. It interacts by utilising UART, I2C, and SPI protocols. It features a clock speed of 16 MHz, 2 KB SRAM, 32 KB FLASH, and 1 KB EEPROM. It has a working voltage range of 7V to 20V. It is a dependable MCU that is commonly utilised in prototypes as well as academic applications. For programming the MCU, we utilised the Arduino IDE software.

c. Bluetooth sensor

The HC-05 sensor is used for this work, which employs a master-slave configuration. It is used for communication with the MCU with the help of Bluetooth technology

d. Relay

For the Safe operation of the pump, a relay module having a rated voltage of 5V is used.

e. Motor Driver

The L298N Motor driver is used to control the direction of the rover.

This system encompasses all the controls and movement for the rover, including an Android app, a Bluetooth sensor, a Micro Controller Unit, a Motor Driver, Motors, and wheels. In this system, an Android app establishes communication with the rover via the Bluetooth HC-05 sensor, facilitating the exchange of commands and data. Here, the Android app communicates with the rover using the Bluetooth sensor HC05. These signals are transmitted to the microprocessor. This motor driver acts as the intermediary between the microprocessor and the physical motors, translating the digital commands into precise motor movements. By adjusting the voltage and direction of the motors, the L298N motor driver ensures that the rover responds accurately to the commands issued by the user.

Algorithm for the rover tracking system

Algorithm for the rover motion (Forward/ backward, right/left turn) control logic is shown in table 1.

Table 1: Rover motion control logic truth table

Motion Command	Microcontroller Output (Logic State)				Action Mechanism
	Left Pin 1	Left Pin 2	Right Pin 1	Right Pin 2	
Forward	HIGH (1)	LOW (0)	HIGH (1)	LOW (0)	Both motors rotate clockwise
Backward	LOW (0)	HIGH (1)	LOW (0)	HIGH (1)	Both motors rotate counterclockwise
Left Turn	LOW (0)	HIGH (1)	HIGH (1)	LOW (0)	Left reverse, Right forward (Zero Radius)
Right Turn	HIGH (1)	LOW (0)	LOW (0)	HIGH (1)	Left forward, Right reverse (Zero Radius)
Stop	LOW (0)	LOW (0)	LOW (0)	LOW (0)	No power to the motors

Application

This system encompasses all the instruments used in the rover's spraying mechanisms. This system includes an ultrasonic sensor, Arduino, pump and nozzle. In this system, an ultrasonic sensor serves as the primary sensory organ, emitting an ultrasonic pulse of 40 kHz directed towards the surrounding plants. Upon striking a surface, the pulse is reflected to the sensor. Upon reception of these echoes, the sensor computes the distance of the reflecting object, generating an output signal that correlates with this distance. When the plant is detected within this range by the ultrasonic sensor, it transmits signals to the Arduino, which determines whether the plant is within 30 cm or beyond. When the plant distance is less than 30 cm, the plant transmits a signal to the pump to start spraying. This pump has a rating of 12 V and a capacity of 240 litres per hour. This pump is connected to a nozzle for spraying, which sprays fertilisers to plants.

Algorithm for Spraying Mechanism

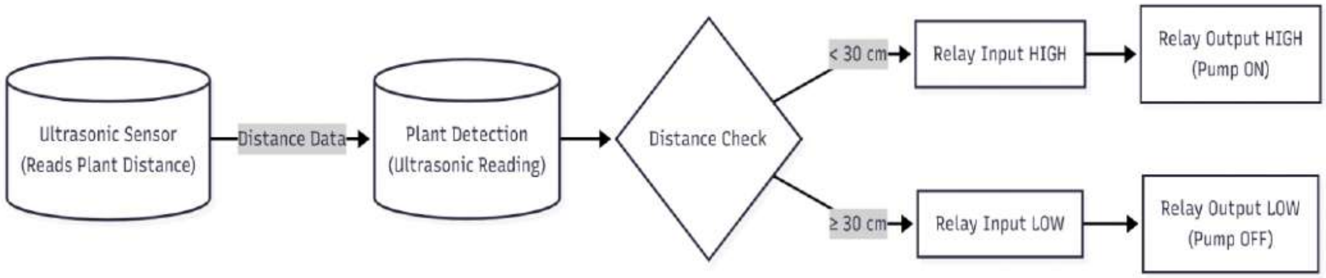

Fig. 3: Algorithm for spraying system

This System consists of all the spraying mechanisms used as shown in fig. 3. All the equipment used for the spraying mechanism and technical specification (table 2) is listed below.

a. **Pump**
   In this system, a self-priming diaphragm pump is used to pump the liquids in the prototype. It has a rated voltage of 12V (DC), a load current of 0.3A, and a flow rate of 240 litres per hour.
b. **Motor with wheels**
   For the movement of the rover, four geared motors with a 12V rating and a 120 RPM speed, each having a 10 cm wheel diameter, are used.
c. **Nozzle**
   For spraying purposes, a cone nozzle is used in the Spraying Rover.
d. **Fertiliser Tank**
   For the fertiliser tank, a 1.5-litre capacity tank is used.

Table 2: Complete technical specifications of automated spraying rover

Component	Specification	Performance
Rover Dimensions	50×30×20 cm	-
Battery (Li-ion)	14.8V, 10400mAh	4-5 hours of operation
Motors	12V DC, 120 RPM	Torque: High
Pump	12V, 0.3A	240 L/hr flow rate
Ultrasonic Sensor	HC-SR04, 5V	Range: 2-1200 cm
Bluetooth	HC-05	Range: 60-70m operational
Controller	Arduino Uno (ATmega328P)	16 MHz clock

Hardware Interfacing and Circuitry

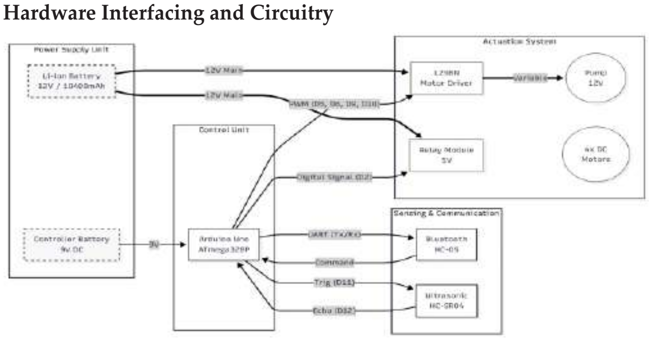

Fig. 4: Circuit diagram of system

The physical system integration of the Automated Spraying Rover is governed by the Arduino Uno microcontroller, which operates as the primary embedded control unit responsible for real-time sensor data acquisition and bidirectional motor actuation. All peripheral subsystems, including the L298N motor driver, HC-SR04 ultrasonic ranging sensor, HC-05 Bluetooth communication module, and the pump switching relay, are electrically interfaced with the microcontroller. The corresponding pin-level configurations are documented in Fig. 4 and systematically summarised in Table 3.

A dual-domain power architecture is implemented to decouple high-current electromechanical loads from low-power logic circuits, thereby improving electrical stability and mitigating noise interference. Propulsion motors and the 12V spraying pump draw power from a 12V Li-ion battery pack through the L298N driver and a 5V relay switching circuit, respectively. In parallel, the Arduino Uno and sensitive signal-processing modules (HC-05 and HC-SR04) are supplied by a regulated 5V rail derived from the onboard voltage regulation stage. All power subsystems maintain a unified common ground reference (GND) to ensure signal coherence, suppress ground-loop anomalies, and preserve data integrity across mixed-voltage interfaces.

The communication subsystem utilises the HC-05 module in hardware serial mode (UART via TX/RX) to receive ASCII-formatted command frames from a custom Android HMI (Human–Machine Interface) application. The L298N driver utilises digital control lines D6–D9 to execute differential motion vectors based on closed-loop directional logic, as previously modelled in Figure 3. The ultrasonic sensing unit operates using D11 (Trigger) and D12 (Echo) for time-of-flight-based distance estimation, enabling reactive obstacle detection under natural rover navigation constraints. Furthermore, pump excitation is mediated through a digital trigger signal on pin D2, which drives the relay interface to achieve galvanically-isolated high-voltage switching for the 12V pump circuit, ensuring safe and controlled fluid actuation.

Table 3: PinMap of System

Component	Component Pin	Arduino/Power Connection	Function
L298N Driver	ENA / ENB	Pin 5 / Pin 10	Speed Control (PWM)
	IN1 / IN2	Pin 6 / Pin 7	Left Motor Direction
	IN3 / IN4	Pin 8 / Pin 9	Right Motor Direction
	12V Input	Battery (+)	Main Motor Power
	GND	Battery (-) & Arduino GND	Common Ground
HC-SR04	Trig	Pin 11	Trigger Pulse (Output)
	Echo	Pin 12	Receive Echo (Input)
	VCC / GND	Arduino 5V / GND	Sensor Power
HC-05 (Bluetooth)	TX	Arduino RX (Pin 0)	Data Receive
	RX	Arduino TX (Pin 1)	Data Transmit
	VCC / GND	Arduino 5V / GND	Module Power
Relay Module	Signal (IN)	Pin 2	Trigger Pump Spray
	VCC / GND	Arduino 5V / GND	Relay Coil Power
Pump	Positive Wire	Relay (NO) Terminal	Switched Power
	Negative Wire	Battery (-)	Ground Return

RESULTS AND DISCUSSION

Field Trial Setup

Field experiments were conducted at the research farm of CAET, Anand Agricultural University, on vegetable crops (tomato and brinjal) over 10 days. The field area was 2500 m², divided into test plots of 250 m² each for systematic evaluation of rover performance under varying conditions. The developed prototype, as shown in Fig. 5, underwent several field experiments to assess its performance.

Fig. 5: Prototype of the developed rover

Movement Control

The rover accurately executed commands for forward, left, and correct movements as instructed by the user through the Android mobile application. During the experiment, turning radii were found to differ between the no-load and full-load conditions of 1.5 litre capacity fertilizer tanks. During the full-load condition, the turning radius is measured to be 35 cm, while during the no-load condition; it is measured to be 31 cm. No load speed and full load speed are found to be in the range of 5-8 km/hr and 3-4 km/hr, respectively.

Reliability

The HC-05 Bluetooth module facilitates wireless communication between the Android application and the rover, operating on the 2.4 GHz ISM band with Bluetooth version 2.0 + EDR (Enhanced Data Rate). The module supports data transmission rates of up to 1 Mbps, with a theoretical maximum range of 100 meters. However, the practical operational range in agricultural field conditions is typically 60-70 m. The decrease in detection accuracy beyond 30 cm is consistent with findings by (Dvorak et al., 2016), who noted that ultrasonic sensors often struggle with soft, irregular surfaces, such as plant foliage, due to signal absorption and scattering. However, for short-range obstacle avoidance in vegetable rows, the sensor demonstrated sufficient reliability.

Bluetooth Reliability Considerations

The HC-05 module demonstrates robust performance in outdoor agricultural environments through several key features. The Bluetooth protocol utilises adaptive frequency hopping spread spectrum (FHSS) technology, which dynamically switches between 79 distinct frequency channels to prevent interference from other wireless devices operating in the 2.4 GHz band. This technique enables the system to identify congested or noisy channels and automatically select more reliable communication paths, thereby significantly reducing packet loss and ensuring consistent transmission of control signals.

Field testing revealed that the module maintains reliable connectivity with a typical sensitivity of -80 dBm and can operate effectively even with partial obstructions, such as crop canopies. The small, fast data packets used by Bluetooth technology (typically half the size of competing protocols) reduce collision probability and enable more efficient spectrum utilisation. During operational trials, the rover maintained stable communication with response times averaging 195-245 milliseconds across varying field conditions, including the presence of electromagnetic interference from irrigation systems and power lines.

However, certain limitations were observed. Signal strength degradation occurred at distances exceeding 70 m in open fields, while metallic structures or dense vegetation reduced the effective range by 15-20%. The observed reduction in

Bluetooth range within the crop canopy can be attributed to the high water content of vegetable foliage, which causes significant attenuation of 2.4 GHz radio signals. This phenomenon aligns with foundational findings by Thelen et al. (2005), who quantified signal loss in wireless sensor networks deployed in dense crop fields due to vegetation moisture. To mitigate these challenges, the system incorporates automatic reconnection protocols and local failsafe mechanisms that halt rover operation if communication is interrupted for more than 3 seconds, ensuring safe operation.

Detection Performance Evolution

Multiple field trials were conducted to assess system reliability and the learning curve. The detection accuracy improved from 78% in initial trials to 94% by the tenth trial, while response time decreased from 245ms to 192ms, indicating system optimisation and operator familiarity (Fig. 6).

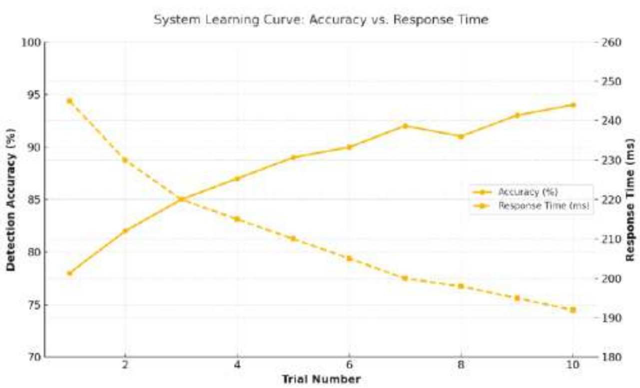

Fig. 6: Detection performance over trials

Autonomous Spraying

The rover autonomously navigates its environment while continuously monitoring for obstacles or target areas using the ultrasonic sensor. Upon detection of plants under 30 cm, the auto-spraying system activates, effectively applying the required fertilizers. The spread distance is approximately 50 cm.

Optimal Spray Distance Analysis

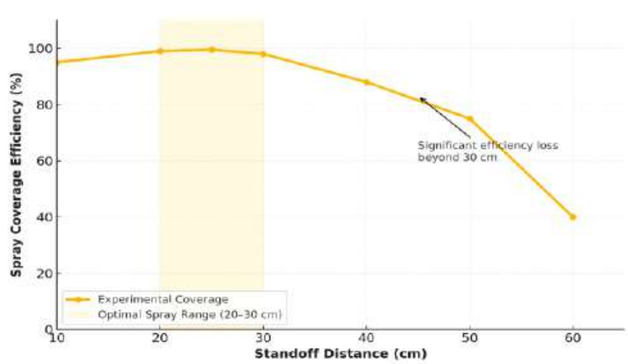

Fig. 7: Optimum spray distance

Spray coverage quality analysis revealed optimal performance at a distance of 20-30 cm from the target plants, achieving 98-100% coverage. Beyond 30 cm, coverage quality degraded progressively, reaching only 40% at 60 cm distance (Fig. 7).

Signal Acquisition and Instrumentation

To validate the electronic control logic, the detection of signals generated at the pump input was performed using a Tektronix TBS1102B-EDU digital oscilloscope. This analysis provided a visual representation of the control waveforms, enabling the determination of the specific digital HIGH or LOW states of the input supplied to the pump relay (Fig. 8). These oscilloscope readings confirmed the correlation between the ultrasonic sensor's obstacle detection and the subsequent triggering of the spray mechanism

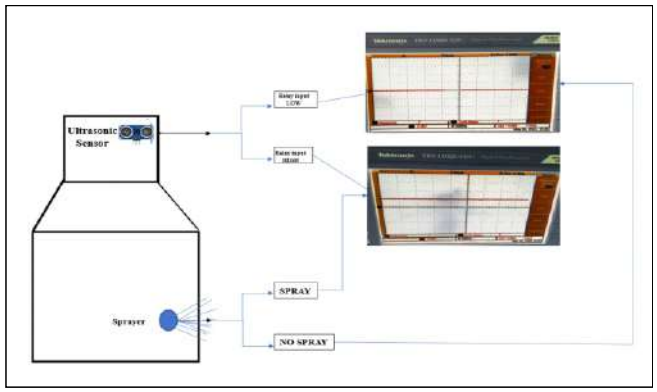

Fig. 8: Signals generated by pump input against plant detection

Precision and Efficiency

The automated spraying rover was evaluated against conventional manual methods to assess its application precision and operational efficiency. Precision metrics included spray uniformity, targeting accuracy, and pesticide waste reduction, while efficiency was measured by coverage rate, labour input, and chemical consumption. Field trials demonstrated that the rover achieved significantly better spray uniformity than manual knapsack spraying. This improvement is attributed to the rover's fixed nozzle height and consistent travel speed, which minimised application errors. Furthermore, the system's ability to maintain an optimal spray distance of 20–30 cm resulted in higher coverage quality and more reliable pest control (Fig. 9). Operational efficiency also saw a marked improvement. The integration of automated motion control and sensor-based navigation allowed the rover to cover larger areas per hour with minimal human supervision. This navigation precision reduced overlaps and missed patches, resulting in decreased pesticide usage and operating time. These findings align with recent studies, such as Gaadhe et al. (2024), which report that automated systems can reduce chemical wastage by 30–50%. Overall, the developed system proves that low-cost robots can enhance both precision and resource efficiency in sustainable agriculture.

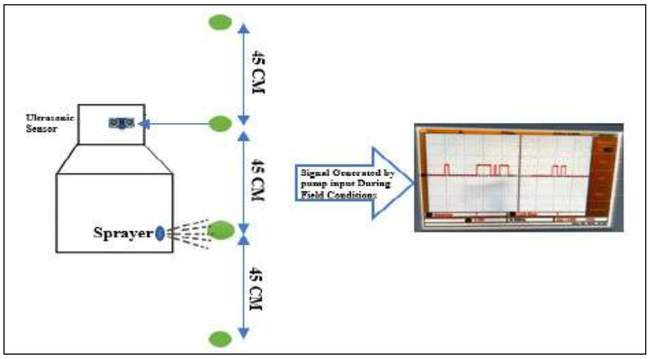

Fig. 9: Signal captured triggering pump in actual field condition

Economic Viability Studies

Table 4: Economic viability of study

Cost Component	Amount (Rs.)	Notes
Hardware (Motors, Sensors)	3,500	-
Controller & Electronics	2,800	Arduino, Bluetooth
Pump & Nozzle System	2,200	Self-priming diaphragm
Battery Unit	3,000	Li-ion 10400mAh
Chassis & Mechanical	1,500	Acrylic sheet
Total Initial Cost	13,000	One-time investment
Annual Maintenance	1,500	Consumables, repairs
Operating Cost per hour	25	Electricity, depreciation

The economic feasibility of the prototype was evaluated through a preliminary component cost analysis, establishing a total fabrication cost of ₹13,000 and a projected operational expenditure of ₹25 per hour. Based on experimental trials yielding a coverage rate of 2500 m^2/hour, the prototype demonstrates the potential to generate labour savings of ₹800 per hectare, suggesting a theoretical payback period within a single growing season for landholdings exceeding 0.5 hectares (Table 4). These projections align with broader economic models by Farmonaut (2025), which indicate that autonomous robotic solutions are critical for mitigating labour shortages and could reduce associated costs by up to 20%. Furthermore, the prototype's remote-controlled architecture addresses significant safety concerns; consistent with Nuyttens et al. (2023), the design removes the operator from the immediate application zone, theoretically reducing exposure to hazardous agrochemicals by over 90%.

CONCLUSION

This work successfully developed and field-validated a low-cost automated spraying rover for precision input delivery in vegetable crops. The mobility system realised using an acrylic-chassis rover and differential drive logic via the L298N motor driver, ensured smooth inter-row navigation with minimal load-induced turning variations (31-35 cm). Ultrasonic sensing through the HC-SR04 module enabled reliable short-range plant/obstacle detection, autonomously triggering the 12V diaphragm pump via a 5V relay when targets fell within a 30 cm range. Wireless control, based on the HC-05 Bluetooth module, maintained stable command execution up to 60-70 m outdoors with low latency, resisting moderate attenuation from the crop canopy. The fixed-cone nozzle sprayer produced uniform spray deposition and the highest coverage (98–100%) at the optimal 20-30 cm spray zone, significantly reducing overspray, drift, and inconsistencies associated with manual spraying. The system achieved a growth in detection accuracy from 78% to 94% over trials, with optimisation of response time (245 ms to 192 ms). Economic analysis demonstrated the viability of small farms, with an initial cost of ₹13,000 and an operating cost of ₹25/hr, delivering meaningful labour savings and reducing operator agrochemical exposure by more than 90%. The prototype confirms that accessible microcontroller-driven mobile sprayers can enhance spray uniformity, reduces input wastage, improve field safety, and offer a scalable pathway toward sustainable precision spraying for small farm holder agricultural systems.

FUTURE SCOPE

The prototype can be enhanced by adding edge-AI vision using boards like the NVIDIA Jetson Nano for crop and disease-aware spraying, moving beyond distance-based actuation. Navigation reliability can be improved through the use of 360° scanning sensors, such as the RPLIDAR A1, and IMU-assisted row-tracking, which helps handle dense foliage. Range scalability can be increased using LoRa telemetry hardware (e.g., RYLR896) for over 500 m of command/control in mid-scale farms. Traction and load handling can be enhanced with high-torque drive options, such as brushless DC motors, and optimised wheel profiles. Energy upgrades with solar-assisted charging and larger, modular tanks can support over 1 ha/hr coverage and seasonal field evaluations of additional vegetable varieties, enabling intelligent, long-range, and robust precision spraying.

ACKNOWLEDGEMENTS

We extend our heartfelt gratitude to Anand Agricultural University for their support in providing all necessary facilities to conduct this study.

REFERENCES

Bargoti S and Underwood J. 2016. Deep fruit detection in orchards. *arXiv preprint arXiv:1610.03677*.

Dvorak J S, Stone M L and Self K P. 2016. Object detection for agricultural and construction environments using an ultrasonic sensor. *Journal of Agricultural Safety and Health* **22**(2):107–19.

Farmonaut. 2025. Autonomous robots in agriculture: 7 economic impacts. Precision Farming Reports.

Gaadhe S K, Chavda D B, Mehta T D, Chavda S K, Gojiya K M and Bandhiya R D. 2024. A comparative study of drone spraying and conventional spraying for precision agriculture. *Plant Archives* **25**(Special Issue):771–8.

Kumar D, Choudhary V, Kumar N, Jyoti B, Mandal S, Jeet P, Sundaram P K and Singh A K. 2024. Robots for harvesting of horticultural crop: A review. *Journal of AgriSearch* **11**(3): 152-164.

Mashori S, Azmi M A A, Sahari N, Jalaludin N A, Yi S S, Norjali R and Yusof M H M. 2023. Development of a Pesticide Sprayer Robot Prototype for Chilli Farm Agricultural Applications. *International Journal of Integrated Engineering* **15**(3):217–26.

Murugan K, Shankar B J, Sumanth A, Sudharshan C V and Reddy G V. 2020. Intelligent automated pesticide spraying bot. *Proceedings of the 3rd International Conference on Intelligent Sustainable Systems (ICISS 2020)*:864–8.

Naik N, Shete V and Danve S. 2016. Precision agriculture robot for seeding function. *International Conference on Inventive Computation Technologies (ICICT)*:1–3.

Nasir F E, Tufail M, Haris M, Iqbal J, Khan S and Khan M T. 2023. Precision agricultural robotic sprayer with real-time tobacco recognition and spraying system based on deep learning. *PLoS ONE* **18**(3): e0283801.

Nuyttens D, De Schampheleire M and Steurbaut W. 2023. Operator exposure to pesticides: Manual spraying safety vs. remote systems. *Annals of Agricultural and Environmental Medicine* **30**(1):12–8.

Terra F P, da Rosa G R A, Prado J J P and Drews-Jr P L J. 2020. A low-cost prototype to automate agricultural sprayers. *IFAC-PapersOnLine* **53**(2):15835–40.

Thelen J, Goense D and Langendoen K. 2005. Radio wave propagation in potato fields. *Proceedings of the First Workshop on Wireless Network Measurements (WiNMee 2005)*.

Citation:

Kumar A, Jogunuri S and Vyas D K. 2025. Design, implementation, and performance assessment of an ultrasonic-guided bluetooth-controlled spraying rover for vegetable crop rows Journal of AgriSearch 12(4): 237-244