International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Development of an Agricultural Spraying Robot (AgroMax) for Efficient Farming Operations

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A B S T R A C T :

Agricultural practices heavily rely on pesticide and herbicide application to protect crops from pests and diseases. However, manual spraying methods are labor-intensive, time-consuming, and often result in uneven pesticide distribution, excessive chemical use, and health risks for farmers. Additionally, insects residing under crop leaves pose significant challenges for traditional spraying techniques, leading to inefficient pest management. To address these issues, this project focuses on developing an autonomous agricultural spraying robot to enhance efficiency, precision, and sustainability in farming operations. Equipped with sensors, cameras, and automated spraying nozzles, the robot ensures targeted spraying, significantly reducing pesticide wastage and minimizing environmental impact. Furthermore, automation reduces farmers' exposure to harmful chemicals, promoting a safer working environment. By automating pesticide application, the proposed agricultural spraying robot offers a sustainable alternative to traditional methods. It contributes to improved pest management, increased crop productivity, and environmentally friendly farming practices. This research aims to develop a cost-effective, scalable solution adaptable to different crop types and farm layouts.

Keywords: Agricultural Robot, Crops, Microcontroller, ESP32, Arduino, Pesticide Sprayer.

1. Introduction:

In India, farming is done in traditional ways besides that there has been a larger development of the industry and service sector as compared to that of the agriculture sector. To mechanize agriculture in India, some equipment has been developed. Agriculture is one of the oldest activities practiced by man. Due to its importance in our daily life and reliance on it, many technologists try to update new developments based on agricultural robots that perform well in a strict, efficient, and timely manner due to the tremendous development in the field of robotics, the solution to the main problems faced by the agricultural field those problems such as random sowing which cost more seeds that is costly, consumption more water and quantity of fertilization. The manual spraying of pesticides and herbicides on crops is quite laborious work. The manual trimming of unwanted plants or harvested crops from the field is also difficult. Traditional spraying methods can lead to uneven coverage and excessive chemical use, causing environmental harm and health risks. The management of pest insects is a critical component of agricultural production, especially in the fertigation-based farm. Since most of the insects and pests live under the crop's leaves, it is difficult labor work to spray under the leaves of the crop. Almost all agricultural plants are damaged, weakened, or killed by insect pests especially. These result in reduced yields lowered quality, and damaged plants or plant products that cannot be sold. Even after harvest, insects continue their damage in stored or processed products. The existing manual agricultural pesticide spraying systems have limitations in terms of spraying accuracy, pesticide usage reduction, health safety, etc. Thus, there is a need to design and develop an automated agricultural pesticide spraying robot that can navigate autonomously, detect crops accurately, and reduce pesticide usage efficiently.

1.1 Purpose (Need) of the Project:

The manual spraying of pesticides and herbicides, as well as the manual removal of unwanted plants, is a labor-intensive and inefficient process in agriculture. Traditional spraying methods often result in uneven coverage, excessive chemical use, and increased environmental and health risks. Additionally, pest management remains a significant challenge, especially in fertigation-based farms, where insects often reside under the leaves of crops, making manual spraying difficult. These inefficiencies contribute to lower yields, reduced product quality, and economic losses for farmers. Furthermore, insect damage continues post-harvest, affecting stored or processed agricultural products. There is a critical need for an efficient, automated solution to optimize pesticide application and improve agricultural productivity. To address these challenges, this project aims to develop an automated pesticide-spraying robot that ensures, efficient and uniform pesticide application to minimize excessive chemical usage, targeted spraying under crop leaves to enhance pest control effectiveness, reduction of manual labor associated with pesticide application and weed removal, minimized environmental and health risks due to controlled pesticide usage.

This project focuses on the development of an Agriculture robot (AgroMax) that can perform two essential tasks in modern farming: liquid fertilizer/pesticide spraying and grass cutting. The robot is operated using an Android application that provides ease of use and control. It is designed with a 4-wheel-drive system for mobility and a T-shaped pipe arrangement at the front for mounting the spray nozzles and servo motors. A grass-cutting system is installed at the rear, powered by a 12V DC motor with a metal cutter blade. A 2-liter water tank feeds water to the spray nozzles via two submersible 12V pumps. The nozzles are controlled by MG995 servo motors to periodically rotate and spray the liquid. The ESP32 microcontroller acts as the central processing unit, integrating all components like the motor control via an L298 motor driver, and relays for controlling pumps and the grass cutter. Additionally, the ESP32's built-in camera module enables live video streaming, providing real-time monitoring of the field. The entire system is powered by a 12V lithium-ion battery pack. This robot aims to automate essential agricultural tasks and increase farming efficiency.

1.2 Objectives of the Project:

[1] To develop an automated pesticide spraying system with precision targeting to reduce chemical wastage and can perform both liquid spraying and grass-cutting operations.
[2] To integrate sensor-based technology to detect pest presence and optimize pesticide application.
[3] To integrate the robot with an Android app for easy and efficient operation.
[4] To enable the robot to stream live video via the ESP32 camera module for real-time monitoring.

2. Literature Survey:

The Development of an Agricultural Spraying Robot aims to enhance precision farming by automating pesticide application, reducing labor dependency, and optimizing resource utilization. A detailed literature review highlights the benefits of robotic spraying, including improved efficiency, uniform application, and reduced environmental impact. Existing studies emphasize advancements in GPS and AI-based navigation, yet challenges remain in adapting to unstructured field conditions, optimizing energy consumption, and reducing costs for small-scale farmers. Current robotic sprayers often lack real-time adaptability, comprehensive field testing, and integration with IoT for remote monitoring. Additionally, most designs focus solely on spraying rather than multi-functionality, limiting their overall value in farm automation.

- ***Ghafar, Afif & Hajjaj, Sami et al,*** developed a low-cost agricultural robot for spraying fertilizers and pesticides in agriculture fields and general crop monitoring. The prototype system is a two-wheeled robot that consists of a mobile base, a spraying mechanism, a wireless controller for controlling the robot's movement, and a camera for crop health and growth monitoring and detecting the presence of pests in the agriculture field. Tests conducted on the prototype system showed that while the productivity of the robot in terms of crop coverage is slightly lower than a human worker, the labor cost savings afforded by the agricultural robot prototype are much greater as it functions completely in an autonomous mode and only requires the operator to control the robot when placing it at the start of the crop path. [1]
- ***V. A. Aher, Nibe Nikita, et al***, developed a piece of equipment that utilizes a renewable energy source (Solar energy), which is eco-friendly. The solar panel gives out an electric supply to the system, and the radio-controlled transmitter and receiver minimize the drudgery of the farmer. Also, it minimizes the wastage of pesticides and time. This mechanism offered eco-friendly, reliably available solar energy as a main source, making this multifunctional sprayer device advance the spraying methods, which make it friendly to use and operate and can be used in different spraying stages of farming as per process requirements. [2]
- ***Vaishali Raut, Hitesh Patil, et al***
, presented the design, development, and evaluation of a multipurpose agriculture robot aimed at revolutionizing farming practices. The robot is equipped with advanced sensing, actuation, and control capabilities to perform various tasks, including crop monitoring, precision spraying, harvesting, weeding, and soil analysis. By automating and assisting in these crucial agricultural operations, the multipurpose robot aims to increase efficiency, reduce labor requirements, minimize environmental impact, and optimize crop productivity. [3]
- **Abhishek More, Nikhil Kemble, et al**, proposed a multipurpose, solar, semiautomatic, remote-controlled vehicle with a three-way adjustable chassis (i.e., the height, length, and width) and plant mowing equipment. It is designed to spray pesticides directly on crops with minimum wastage, making it cost-effective and environment-friendly. With an adjustable chassis, it is suitable for many crop fields. Alternatively, it can also be used for watering gardens, maintaining lawns, and in pandemic situations like COVID-19 for the spraying of sanitizer in hospitals. [4]
- ***A.M. Kassim, M. F. N. M. Termezai et al,*** Designed and developed an autonomous pesticide sprayer for the chili fertigation system, which intends to implement a flexible sprayer arm to spray the pesticide under the crop's leaves. This study involves the development of an unmanned pesticide sprayer that can be mobilized autonomously. This is because the pesticide is a hazardous component that can affect human health in the future if it is exposed during manual spraying, especially in a closed area such as a greenhouse. [5]
- ***Vinay Gowda, Rohith V., et al,*** Designed and developed an autonomous robot for pesticide spraying in agriculture, aimed to enhance both the efficiency and precision of pesticide application. Traditional spraying methods can lead to uneven coverage and excessive chemical use, causing environmental harm and health risks. The robot's effectiveness will be evaluated through field tests, focusing on its precision, efficiency, and overall impact on crop health and yield. [6]
- ***Kumar, S. et al,*** Presented a detailed design of a skid-steering mobile platform with four wheels, along with a Cartesian serial (PPP) manipulator. This design aims to enable the platform to perform various tasks in the agricultural process. The parallel manipulator design can handle heavy materials in the agricultural field. An experimental robotic harvesting scenario was conducted using parallel manipulator-based end-effectors to handle heavy fruits such as watermelons or muskmelons. The conceptual and component design of the different models was carried out using the Solid Works modeling package. [7].

3. System Modelling:

It should be noted through the previous research, that such systems are primarily suited for use on engineered surfaces, such as vertical farming setups or greenhouses, as they are hindered by the presence of passive rollers in their wheels. Similarly, very few attempts were made with track-based mobile bases. Considering these factors, and in pursuit of a modular and cost-effective solution, we propose employing a simple four-wheel skid-steering mobile base for our envisioned work. Further, the proposed agriculture robot is designed to meet specific requirements and achieve its objectives reliably and efficiently. A system development stages and conceptual diagram of project work are shown in Figures 1 and 2 respectively. Figure 2 illustrates the overall structure and key components of the agricultural spraying robot, offering an overview of its design and functionality.

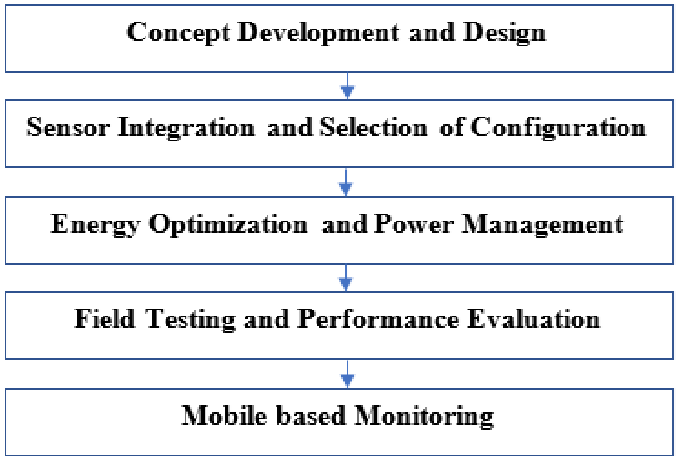


Fig. 1: System Development Stages of AgroMax

The AgroMax platform has been specifically designed to address challenges encountered in various terrains, including slippery ground. To ensure strong traction and pulling capability, the platform incorporates a skid-steering mobile base. This configuration enhances the vehicle's stability and maneuverability. The mobile platform ensures that even when traversing difficult and irregular terrains, the car remains stable without tipping over. Achieving precise motion and tracking control in parallel manipulators requires controllers. This AgroMax robot consists of several key modules that are interconnected to perform various functions. At the heart of the system is the ESP32 microcontroller board, which controls all operations and communicates with the Android application via Wi-Fi. The Android application is responsible for sending control signals to the ESP32, allowing the user to operate the robot remotely. The motor driver module (L298) controls the four DC motors used for the robot's movement. These motors are connected to the wheels, allowing the robot to navigate the field. The servo motors (MG995) control the rotation of the spray nozzles, mounted on a T-shaped pipe arrangement. These nozzles are powered by two 12 V submersible pumps that supply water from a 2-liter tank. The water is used for spraying liquid fertilizer or pesticides. The 12 V relay modules are used to switch the power for the pumps and the grass cutter on and off. Additionally, the ESP32 camera module captures live video footage, which is streamed to a webpage for real-time monitoring. The robot is powered by a 12V lithium-ion battery pack, which ensures a reliable power supply for all components. The on/off toggle switch controls the overall power of the system. The system is designed for ease of use, with the Android app providing a simple interface to control and monitor the robot's operations, while the ESP32 handles all the internal control and communication.

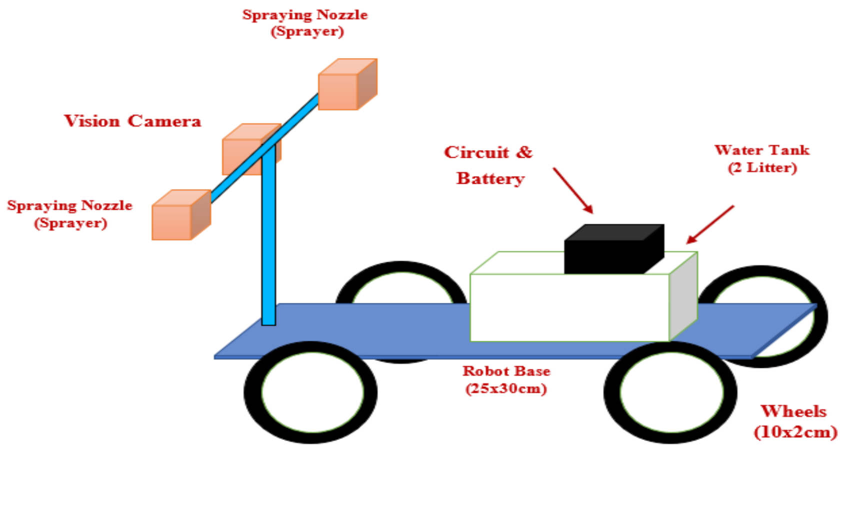


Fig. 2: Conceptual AgriMax Spraying Robot

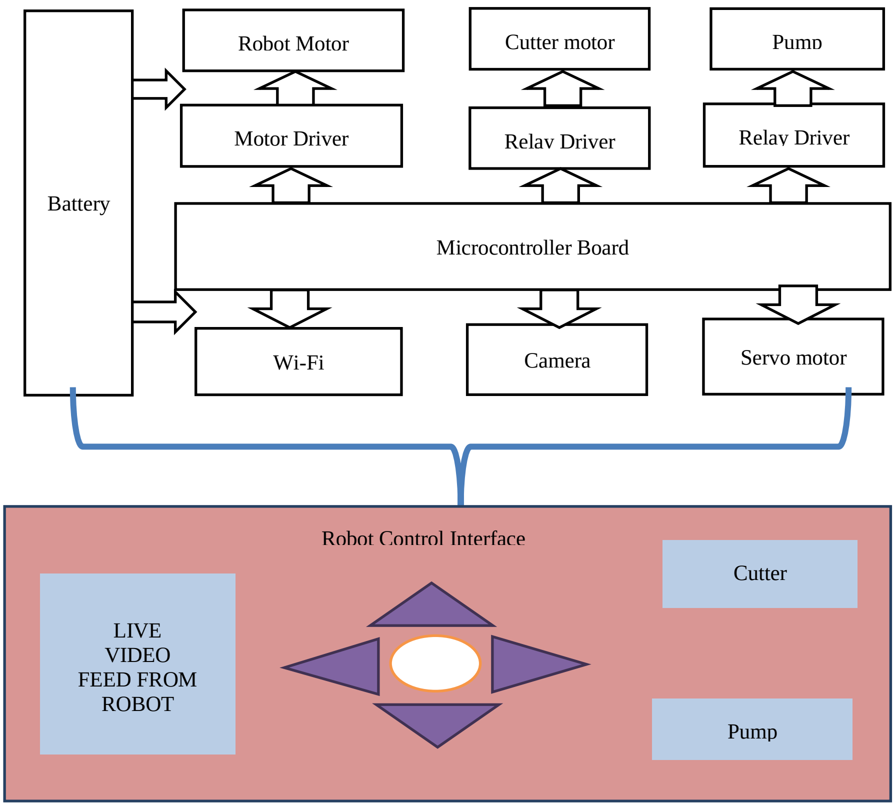
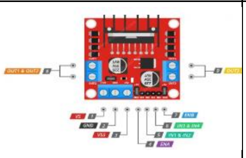


Fig. 3: Block Diagram illustrating system configuration

Table 1 – AgroMax: Components Details.

S.N.	Component used	Brief Specification	Function
1	 **MG995 Servo Motor1**	Model Number: MG995 Operating Voltage: 4.8V – 7.2V Current Consumption: 500mA (idle), 1.5A (running) Torque: 9.4 kg.cm (at 6V) Rotation Angle: 0° to 180° Communication: PWM signal Pins Required: 1 PWM pin per servo	It controls the rotation of the spray nozzles, ensuring uniform spraying of fertilizer or pesticide. A servo motor operates using a closed-loop control system, where a PWM signal determines the angle of rotation.
2	 **Submersible Water Pump**	Operating Voltage: 12V Current Consumption: 500mA – 1A Flow Rate: 3–5 L/min Pins Required: 1 GPIO for relay control	The pumps draw liquid fertilizer/pesticide from the 2-liter tank and supply it to the spray nozzles. A submersible pump operates by pushing liquid using an impeller, creating a pressure difference that forces the liquid through the nozzles.
3	 **12 V Grass Cutting Motor**	Type: DC gear motor with permanent magnet stator Operating Voltage: 12V Current Consumption: 0.2A-0.4A (depending on load) Connector: Flange coupling for blade attachment Torque: High torque for cutting applications Speed: 1000 RPM Pins Required: 1 GPIO for relay control	This DC motor powers the metal cutter blade at the rear of the robot, enabling efficient grass-cutting. A DC motor works on the principle of electromagnetic induction. When current flows through the windings, a magnetic field is generated, causing the motor shaft to rotate.
4	 **Robot Wheels**	Type: Circular wheel Size: 10cm x 2cm Made of: Plastic Comes with a rubber grip 6mm ID hole to attach with motor	For a robot, 10cm diameter, 2cm width plastic wheels are used. Wheels come with a rubber grip to maintain the ground contact. It also has a 6 mm mounting hole to attach the motor directly.
5	 **L298 Motor Drive Module**	Model Number: L298N Operating Voltage: 5V logic, 12V motor supply Current Handling: 2A per channel Communication: Direct GPIO control Pins Required: 4 GPIO for direction, 2 PWM for speed control Protection Features: Built-in fly-back diodes for motor protection	The L298 motor driver is used to control the movement of the robot by driving the four DC motors attached to the wheels. It enables the ESP32 to control motor speed and direction efficiently.

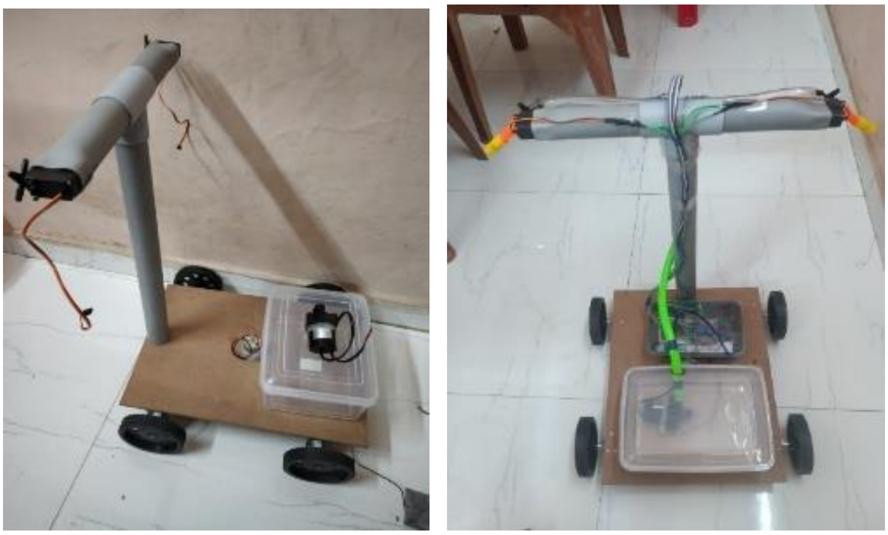


Fig.4: AgroMax Spraying Robot

The robot operates by receiving control signals from the Android application, which communicates with the ESP32 microcontroller. The user can operate the robot manually or set it to automatic mode. The DC motors move the robot, enabling it to navigate across fields. When the user triggers the spraying function, the submersible pumps draw water from the tank and feed it to the nozzles. The MG995 servo motors periodically rotate the nozzles to ensure an even distribution of the liquid. When grass cutting is required, the user activates the 12V DC motor, which powers the metal blade at the back of the robot. The camera module continuously streams live video to the user, allowing them to monitor the progress in real-time. The system is powered by a 12V lithium-ion battery, which ensures enough energy for the entire robot to operate for extended periods. The relay modules control the switching on/off of the pump and cutter, and the L298 motor driver regulates the movement of the robot's wheels.

4. Performance Analysis and Testing:

Table 2 – Performance Testing of AgroMax Spraying Robot.

S. N.	Parameters	Observations/Results
1	Mobility and Navigation Testing	Tested the four-wheel-drive system on various terrains (soil, grass, uneven surfaces). Speed on the plain surface: 0.8 m/s Speed on grass: 0.6 m/s Climbing capability: 15-degree incline Turn radius: 40 cm
2	Spraying Mechanism Testing	Activated submersible pumps to check the liquid flow rate. Flow rate: 1.2 L/min Nozzle spray coverage: 50 cm width Rotation angle: 0° to 90° (servo-controlled) Spraying range: 1.5 meters
3	Grass Cutting Efficiency	Tested the 12V DC motor with the metal cutter blade on different grass densities. Cutting speed: 3000 RPM Effective cutting width: 20 cm Time to cut 1 sq. meter: 40 seconds Motor temperature after 30 min: 38°C
4	ESP32-CAM Video Streaming Test	Checked real-time video streaming via Wi-Fi. Video resolution: 640x480 px Latency: 0.5 seconds Wi-Fi connectivity range: 30 meters
5	Battery Performance Analysis	Battery capacity: 12V, 3Ah lithium-ion Discharge rate under full load: 0.8A/hour Runtime (continuous use): 3.5 hours Recharge time: 2.5 hours
6	Software and App Testing	Tested the Android app's ability to send commands via Wi-Fi. Response time for movement: 0.2 seconds Response time for spraying and cutting: 0.5 seconds Connectivity loss rate: <1% in 1 hour of testing

Fig. 5: Mobile Interface for Robot Control and Live Video

5. Conclusions:

The agriculture industry is highly resource- and labor-intensive. As such, farmers are increasingly turning to technology and automation to address this issue. However, agricultural robots are far too complicated, slow, and costly to be made publicly available. As a result, the agriculture sector still lags in integrating modern technologies. Through this project work, we developed a cost-effective, scalable solution adaptable to different crop types and farm layouts. The outcomes of this project work are summarized below;

[1] The AgroMax agriculture spraying robot provides an innovative solution to the challenges faced in modern farming.

[2] Automating the tasks of pesticide/fertilizer spraying and grass cutting reduces the dependency on manual labor, increases efficiency, and promotes sustainability in agriculture.

[3] The robot's integration with an Android application and live video streaming also enhances ease of operation and remote monitoring.

Overall, this robot has the potential to revolutionize agricultural practices by improving productivity and reducing costs. The developed agricultural robot offers a labor-saving solution by automating routine tasks such as pesticide and fertilizer application, as well as grass cutting. It enhances operational efficiency through uniform spraying, reducing chemical wastage, and incorporates real-time monitoring via a live camera feed for remote supervision. Powered by a rechargeable battery, the robot promotes sustainability while offering versatility in performing multiple field operations. However, limitations such as restricted operational range due to battery capacity, difficulty navigating uneven terrain, and extended battery recharge times may affect continuous use. Despite these challenges, the system presents a valuable application in modern farming by improving productivity, reducing manual labor, and supporting precision agriculture practices.

REFERENCES

1. Ghafar, Afif & Hajjaj, Sami & Gsangaya, Kisheen, Hameed Sultan, Mohamed Thariq, Mail, Mohd Fazly bin & Lee, Seng Hua. (2021), "Design and development of a robot for spraying fertilizers and pesticides for agriculture", Materials for Today: Proceedings. 81. 10.1016/j.matpr.2021.03.174.
2. V. A. Aher, Nibe Nikita, Kakade Priyanka, Shinde Sakshi (2023), "Design and Development of Agricultural Pesticide Spraying Robot", International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), Volume 3, Issue 15, ISSN (Online) 2581-9429.
3. Vaishali Raut, Hitesh Patil, Aniket Shidore, Rohit Gotefode (2023), "Design and Development of Agriculture Robot", International Research Journal of Innovations in Engineering and Technology (IRJIET), Volume 7, Issue 5, pp 357-361, ISSN (online): 2581-3048.
4. Abhishek More, Nikhil Kemble, Shatrughan Javir, Suraj Jadhav, Umesh Kamble, D.A. Sawant (2022), "Design and Development Of Solar Operated Pesticide Spraying Vehicle", Journal of Emerging Technologies and Innovative Research (JETIR), Volume 9, Issue 8, ISSN-2349-5162).

5. A.M. Kassim, M. F. N. M. Termezai, A. K. R. A. Jaya, A. H. Azahar, S Sivarao, F. A. Jafar6, H.I Jaafar, M. S. M. Aras, (2020), "Design and Development of Autonomous Pesticide Sprayer Robot for Fertigation Farm", International Journal of Advanced Computer Science and Applications, Vol. 11, No. 2, 2020
6. Vinay Gowda, Rohith V, Sharan K, Vinay Bhushannavar (2024), "Agriculture pesticide spraying robot", International Journal of Innovative Research in Electrical, Electronics, Instrumentation, and Control Engineering, Vol. 12, Issue 7, ISSN (P) 2321-5526.
7. Kumar, S., Mohan, S., & Skitova, V. (2023). Designing and Implementing a Versatile Agricultural Robot: A Vehicle Manipulator System for Efficient Multitasking in Farming Operations. Machines, 11(8), 776. https://doi.org/10.3390/machines11080776.
8. Kanna, P Rajesh & Ragunath, Vikram. (2020). Agricultural Robot -A pesticide spraying device, International Journal of Future Generation Communication and Networking, Vol. 13, No. 1, (2020), pp. 150-160
9. Zhang, Y., et al. (2019). Design and development of an autonomous agricultural robot for pesticide spraying. Computers and Electronics in Agriculture, 157, 241-253.
10. Roldán, J. J., et al. (2018). Robotic system for pesticide spraying in greenhouses. Biosystems Engineering, 166, 137-147.