AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 04 (April, 2026)
Available online at http://www.agrimagazine.in

Design and Development of a Sensor-Based Fertiliser Dispensing Machine

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Agriculture is undergoing a gradual transformation with the integration of engineering, electronics, and automation. While crop varieties and irrigation technologies have improved significantly, fertiliser application practices in many parts of the world—especially in developing countries—remain inefficient and outdated. Fertilisers play a crucial role in enhancing crop yield and soil fertility; however, their indiscriminate and excessive use has led to serious environmental and economic concerns. Traditional fertiliser application methods such as broadcasting and manual placement often result in non-uniform distribution, nutrient losses, and poor fertilizer use efficiency. These practices increase cultivation costs and contribute to soil degradation and groundwater pollution. Precision agriculture has emerged as a promising solution to these problems by enabling accurate, site-specific, and need-based application of agricultural inputs. The present work focuses on the design, development, and testing of a sensor-based fertilizer dispensing machine, which aims to automate fertilizer application using low-cost sensors and microcontroller technology. The system is specifically designed to be affordable, simple, and suitable for small and medium-scale farmers.

Need for Sensor-Based Fertilizer Application

Fertilizer efficiency in conventional agriculture is often low due to uniform application regardless of plant spacing or crop requirement. Excess fertilizer not absorbed by plants is lost through leaching, runoff, or volatilization, resulting in environmental pollution and economic loss. Sensor-based fertilizer application systems allow fertilizers to be applied only where plants are present and only in the required quantity. Such systems reduce wastage, improve nutrient uptake, and promote sustainable farming. The integration of sensors and automated control mechanisms in farm machinery represents a key step toward smart agriculture.

Objectives of the Study

The major objectives of this study were:

- To design and fabricate a sensor-based fertilizer dispensing machine.
- To integrate electronic sensors with mechanical dispensing systems.
- To reduce fertilizer wastage and improve application accuracy.
- To develop a low-cost and user-friendly prototype.
- To evaluate the performance of the system under controlled conditions.

System Description

The developed fertilizer dispensing machine consists of five main subsystems:

1. Sensing unit
2. Control unit
3. Fertilizer dispensing mechanism
4. Power supply system

5. Supporting frame and mobility unit

1. Sensing Unit: An ultrasonic sensor (HC-SR04) is used to detect the presence of plants. The sensor emits ultrasonic waves and calculates the distance based on the time taken for the reflected signal to return. When a plant is detected within a predefined distance, the sensor sends a signal to the control unit. Ultrasonic sensors were selected due to their low cost, ease of use, and suitability for short-range detection in agricultural environments.

2. Control Unit: The control unit is based on an Arduino Uno microcontroller, which processes sensor signals and controls the fertilizer dispensing mechanism. The Arduino executes a programmed logic that triggers fertilizer release only when a plant is detected. The microcontroller-based system ensures precision, repeatability, and reduced operator dependency.

3. Fertilizer Dispensing Mechanism:

The fertilizer dispensing unit consists of:

- Fertilizer hopper
- Gate-type outlet
- Servo motor (SG90)

When triggered by the control unit, the servo motor opens the outlet for a fixed duration, allowing a measured quantity of fertilizer to be dispensed. After dispensing, the outlet closes automatically, preventing over-application.

4. Power Supply System: The system is powered by a 9V rechargeable battery, making it portable and suitable for field use. A voltage regulation unit supplies stable power to the microcontroller, sensor, and servo motor.

5. Frame and Mobility System: The supporting frame is fabricated using iron pipes to provide strength and stability. The system is mounted on two wheels to allow smooth movement along crop rows.

Methodology

The methodology followed in this project included:

- Literature review on precision fertilizer application.
- Conceptual system design.
- Component selection and CAD modelling.
- Fabrication and assembly.
- Programming and system integration.
- Laboratory and simulated field testing.

CAD modeling using SolidWorks helped visualize the system layout and optimize component placement before fabrication.

Working Logic

START
↓
Initialize System
(Arduino UNO, Servo Motor, Ultrasonic Sensor)
↓
Set Threshold Distance (e.g., plant detection range)
↓
Ultrasonic Sensor Sends Signal
↓
Measure Distance to Object (Plant)
↓
Is Distance ≤ Threshold?
↓ ↓
YES NO

↓ ↓
Activate Servo Keep Servo Closed
Motor (Open Gate) ↓
↓ Continue Scanning
Dispense Fertilizer
↓
Delay (for required quantity)
↓
Close Servo Motor
↓
Move to Next Position
↓
Repeat Process
↓
END (or Continuous Loop)

Advantages of the Developed System

1. Reduced fertilizer wastage.
2. Improved nutrient use efficiency.
3. Lower environmental impact.
4. Reduced labor requirement.
5. Simple design and low cost.
6. Suitable for smallholder farmers.

Limitations

1. Limited to granular fertilizers.
2. Sensor performance affected by dust and reflective surfaces.
3. Manual operation and limited battery life.

Future Scope

Future enhancements may include:

1. Integration of soil nutrient sensors.
2. GPS-based variable rate technology.
3. IoT-based monitoring and data logging.
4. Solar-powered operation.
5. Autonomous mobility.

Conclusion

The sensor-based fertilizer dispensing machine developed in this study successfully demonstrates the application of low-cost sensor and microcontroller technology in agriculture. The system offers a practical solution for precise fertilizer application, reducing wastage and environmental impact while improving crop productivity. This project highlights the potential of interdisciplinary approaches combining agricultural engineering, electronics, and automation. With further refinement, the developed system can play a significant role in advancing precision agriculture and sustainable farming practices.

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