iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: IV Month of publication: April 2026

DOI: https://doi.org/10.22214/ijraset.2026.81623

Design and Development of a Dual-Row Liquid Fertilizer Micro-Doser

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***Abstract:** The evolving nature of India's agricultural sector presents persistent challenges in operational efficiency, particularly for small-scale agrarian communities. Conventional manual fertilizer application is labour-intensive and physically demanding, often leading to operator exhaustion and sub-optimal crop nourishment.*

While high-end motorized or tractor-trailed equipment exists, the associated capital costs remain prohibitive for marginal farmers. This research presents the engineering of a manually operated, dual-row liquid fertilizer micro-doser.

Utilizing purely mechanical principles, the system ensures precise nutrient delivery directly to the root zones. The device is constructed on a stable four-wheel mild steel chassis.

An eccentric crank-driven assembly automates an internal pressure pump, drawing from a 16L HDPE reservoir to provide continuous discharge without reliance on batteries or fossil fuels.

Initial field trials indicate that the prototype effectively doubles application capacity with significantly reduced human effort, making it a sustainable and cost-efficient tool for rural deployment.

***Keywords:** Dual row fertilizer doser, Manual agricultural sprayer, Eccentric crank mechanism, Low-cost farming tool, Ground wheel transmission, Sustainable precision agriculture.*

I. INTRODUCTION

In developing agricultural economies, the convergence of rising input expenses and a dwindling labor pool has necessitated the adoption of precision farming techniques. Conventional fertilization methods, primarily involving manual knapsack sprayers, are not only inefficient in terms of speed but also present severe ergonomic risks, such as chronic back and shoulder pain. For many small-scale farmers, industrial-grade motorized sprayers are economically out of reach and difficult to scale for fragmented landholdings.[6] This project introduces a purely mechanical, dual-row liquid micro-doser designed as a viable alternative for effective crop nourishment. The primary objective was the development of a user-friendly machine that minimizes human exertion and eliminates fuel dependency. By integrating a ground-wheel transmission with an eccentric crank actuation system, the device maintains a pressurized delivery flow during movement. This specialized design addresses the specific needs of the Indian agricultural landscape, offering a high-efficiency solution where skilled labour is scarce and low-cost mechanization is required. [5]

II. PROBLEM STATEMENT

The sustainability of Indian small-scale farming is currently threatened by the inefficiencies of manual nutrient application, which impacts both crop yields and the physical well-being of the farmer. A targeted field survey (n=14) revealed that 100% of local small-scale operators rely on knapsack sprayers, which 57.1% of respondents identified as the primary cause of severe musculoskeletal distress. Despite these health concerns, 64.3% of the stakeholders continue to avoid motorized alternatives due to their high acquisition and maintenance costs. Consequently, there is a clear need for a purely mechanical, wheeled chassis system that eliminates the need for carrying heavy loads. Our design utilizes an automated pressure pump driven by an eccentric crank to provide a cost-effective technological intervention aimed at improving both farming outcomes and operator welfare.

III. LITERATURE SURVEY

1) Manual Knapsack Sprayers: These tools remain a staple in Indian agriculture due to their low cost, though they necessitate continuous hand-pumping to maintain tank pressure. While versatile, the manual effort required leads to rapid fatigue and often results in inconsistent application pressure, causing uneven nutrient distribution across the field. This technical gap necessitates a more ergonomic and automated approach for smallholder farmers. [1, 8]

2) Motorized Backpack Sprayers: Engine or battery-powered sprayers provide a more consistent fluid atomization and faster coverage compared to manual versions. These systems are beneficial for larger orchards or high-value cash crops; however, the reliance on electricity or fossil fuels makes them economically inaccessible for the average marginal farmer. [8]
3) Tractor-Mounted Boom Sprayers: Designed for large-scale industrial farming, these implements offer high pressure and massive field coverage. Despite their efficiency, their physical dimensions and high capital requirements make them impractical for the small, fragmented land plots typical of the Indian subcontinent. [9]
4) Crank Actuated Mechanisms: Mechanical crank systems provide a durable solution for automated actuation without requiring an external power source. By mounting an eccentric crank on a drive axle, rotational energy is converted into a reciprocating motion to drive pump levers. These linkages offer a reliable and sustainable dosing alternative for rural machinery where ease of maintenance is critical. [4]
5) Pressurized Delivery Systems: Ground-driven pressurized systems utilize the machine's forward motion to drive fluid delivery, ensuring a consistent application rate. This mechanical integration allows for steady multi-row spraying, bypassing the flow inconsistencies associated with simple gravity-fed designs. Such systems improve soil penetration and minimize fertilizer wastage. [2], [3]

IV. OBJECTIVES

1) To engineer and fabricate a budget-friendly mechanical implement for row-wise liquid fertilizer delivery.
2) To evaluate diverse fertilization techniques and the specific operational hurdles faced by local farmers.
3) To create an automated prototype featuring an eccentric crank drive and a 16L HDPE storage capacity.
4) To ensure the machine can simultaneously treat two crop rows, thereby optimizing labour and time efficiency.

V. METHODOLOGY

1) CAD Layout: The initial structural layout and component synchronization were modelled to ensure proper crank and transmission alignment.
2) Engineering Analysis: Calculations were performed to verify shaft strength, frame rigidity, and the torque requirements of the transmission system.
3) Part Acquisition: Standard components—including 16L HDPE tanks, nylon wheels, and fasteners—were selected based on their durability and regional availability.
4) Custom Fabrication: Specific elements such as the mild steel chassis and the eccentric crank assembly were manufactured in a specialized facility.
5) System Assembly: Fabricated and off-the-shelf parts were integrated into a single cohesive unit.
6) Field Testing: The finalized prototype underwent farm trials to assess steering, movement, and dosing accuracy, followed by minor technical refinements.
7) Results: The doser was able to dose the liquid fertilizer and balance itself to move and steer.

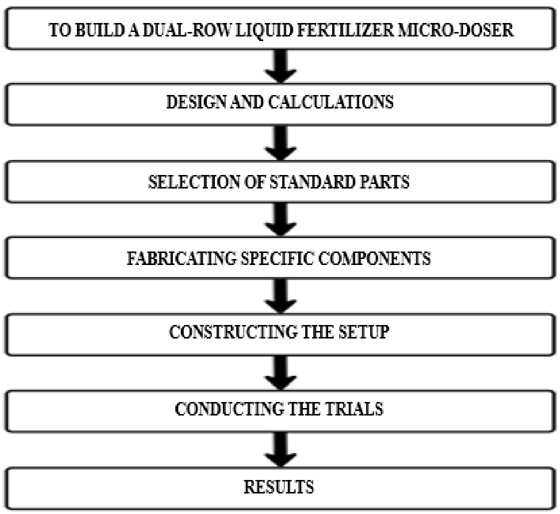

Fig 1: Methodology

VI. DESCRIPTION OF COMPONENTS

1) Structural Frame: The primary mild steel chassis provides the structural foundation for all integrated components and facilitates the transfer of force from the operator to the drive system.
2) 16L HDPE Reservoir: A high-density polyethylene tank provides durable storage and acts as the intake source for the pressure system.
3) Ground Drive Wheels: These wheels convert human pushing force into the rotational energy required to drive the internal axle.
4) Crank Assembly: An eccentric crank is fixed to the axle to provide continuous mechanical actuation of the pump lever during transit.
5) Internal Pressure Pump: A specialized cylinder that is pressurized by the crank mechanism to ensure a powerful, atomized spray at the nozzles.
6) Transmission: A robust chain and sprocket assembly manages the transfer of rotational motion to the drive axle.
7) Nozzle Boom: A dual-row assembly designed to deliver liquid nutrients directly to two parallel crop rows simultaneously.

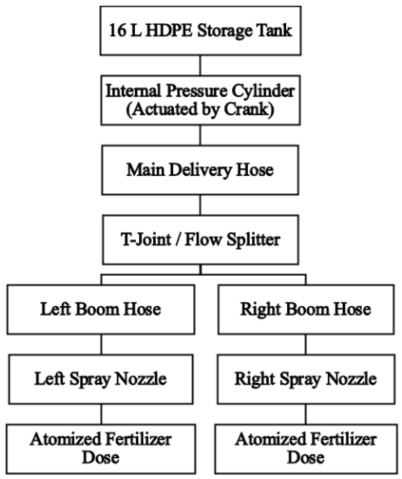

Fig 2: Block Diagram illustrating the pressurized fluid distribution path.

VII. MATERIAL SELECTION FOR DESIGNING

Selection criteria were prioritized based on operational efficiency and manufacturing cost. For the initial prototype, Mild Steel (MS) was selected due to its excellent weldability, high availability, and low cost. For commercial versions, high-strength stainless steel and advanced plastics are recommended for enhanced corrosion resistance against chemical fertilizers. All critical fasteners utilized in the build are made from stainless steel to prevent oxidation. [10]

VIII. KINEMATIC AND STRUCTURAL CALCULATION

All the formulae and data in this section are from K. Mahadevan and K. Balaveera Reddy's "Design Data Handbook" (4th Edition). [11]

Base Frame:

- Length = 500 mm
- Width = 400 mm
- Material = Mild Steel Square Tube (20 x 20 mm, 2 mm Thickness)
- Axle Diameter = 20 mm

Tank Dimensions (16L Nominal Capacity):

- Base Width = 350 mm
- Height = 500 mm
- Maximum density of liquid fertilizer (ρ) = 1400 kg/m^3
- Maximum mass of fluid (m_f) = 1400 x 0.016
- m_f = 22.4 kg

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

Ground Wheel Kinematics:
- Diameter of the ground wheel = 300 mm = 0.3 m
- Circumference of the wheel (C) = π x D
- C = 3.1416 x 0.3
- C = 0.942 m
- Therefore, distance covered in one complete revolution = 0.942 m

Pump Stroke Frequency:
- Transmission ratio (Wheel to Crank) = 1:1
- Target field distance = 10 m
- Number of wheel revolutions (N) = Distance / C
- N = 10 / 0.942
- N = 10.61 ≈ 11 revolutions
- Since the eccentric crank completes one stroke per wheel revolution, the mechanism delivers approximately 11 continuous pressure strokes per 10 meters of travel.

Structural Load Calculation:
- Maximum mass of fluid (m_f) = 22.4 kg
- Estimated mass of MS frame (m_{fr}) = 12 kg
- Total Mass (M) = $m_f + m_{fr}$
- M = 22.4 + 12 = 34.4 kg
- Total Weight (W) acting on axle = M x g
- Where, g = Acceleration due to gravity = 9.81 m/s^2
- W = 34.4 x 9.81
- W = 337.46 N
- The selected 20 x 20 x 2 mm MS square tubing can safely withstand this maximum static load

IX. PROTOTYPE FABRICATION AND ASSEMBLY

Fig 3: Initial fabrication of the mild steel chassis.

Fig 4: Integration of the 16L tank and ground-driven crank linkage.

Fig 5: Final assembly showing the dual-nozzle boom.

X. RESULT

1) Dosing Efficiency: The mechanical drive successfully achieved an output of approximately 84 ml of fertilizer per 10 metre row cycle.
2) Ergonomics: By supporting the fluid weight on a wheeled platform, the prototype eliminated the back and shoulder strain associated with traditional backpack sprayers.
3) Economic Viability: The fabrication cost of ₹14,000 demonstrates that the system is a scalable and affordable option for rural Indian agrarian communities.

XI. ACKNOWLEDGEMENT

We express our sincere thanks to the following people without the presence of whom it would have not been possible for us to complete this project. Therefore, we consider ourselves very lucky as we were provided with an opportunity to be a part of it. We are also grateful for having a chance to meet so many wonderful people and professionals who led us through this project period. We express our deepest sense of gratitude towards our JSS Science and Technology University, SJCE, Mysuru, for providing us an opportunity to carry out a project during the academics, which we consider as a best opportunity to have an exposure to the industry at the right time and for granting the permission to complete our final year project in collaboration with a local industry facility. We would like to thank Prof. Santhosh C who guided us in completing this report with his technical and moral support to complete our project without any hassles. We would also like to thank our Prof. & HOD, Dr. Savitha M, Dept. of Industrial & Production Engineering, for her expert advice and counselling from time to time. We would like to express our gratitude and sincere regards for his kind approval of the project and encouragement throughout. It is our privilege to express gratitude to all those who inspired us and guided us to complete the project program. This work has remained incomplete without the direct and indirect help of many people who have guided us in the success of this project.

We are grateful to all of them. We consider this opportunity as a big milestone in our career development. We will strive to use gained skills and knowledge in the best possible way and will continue to work on their improvement to attain desired career objectives. Hope to continue cooperation with all of you in the future.

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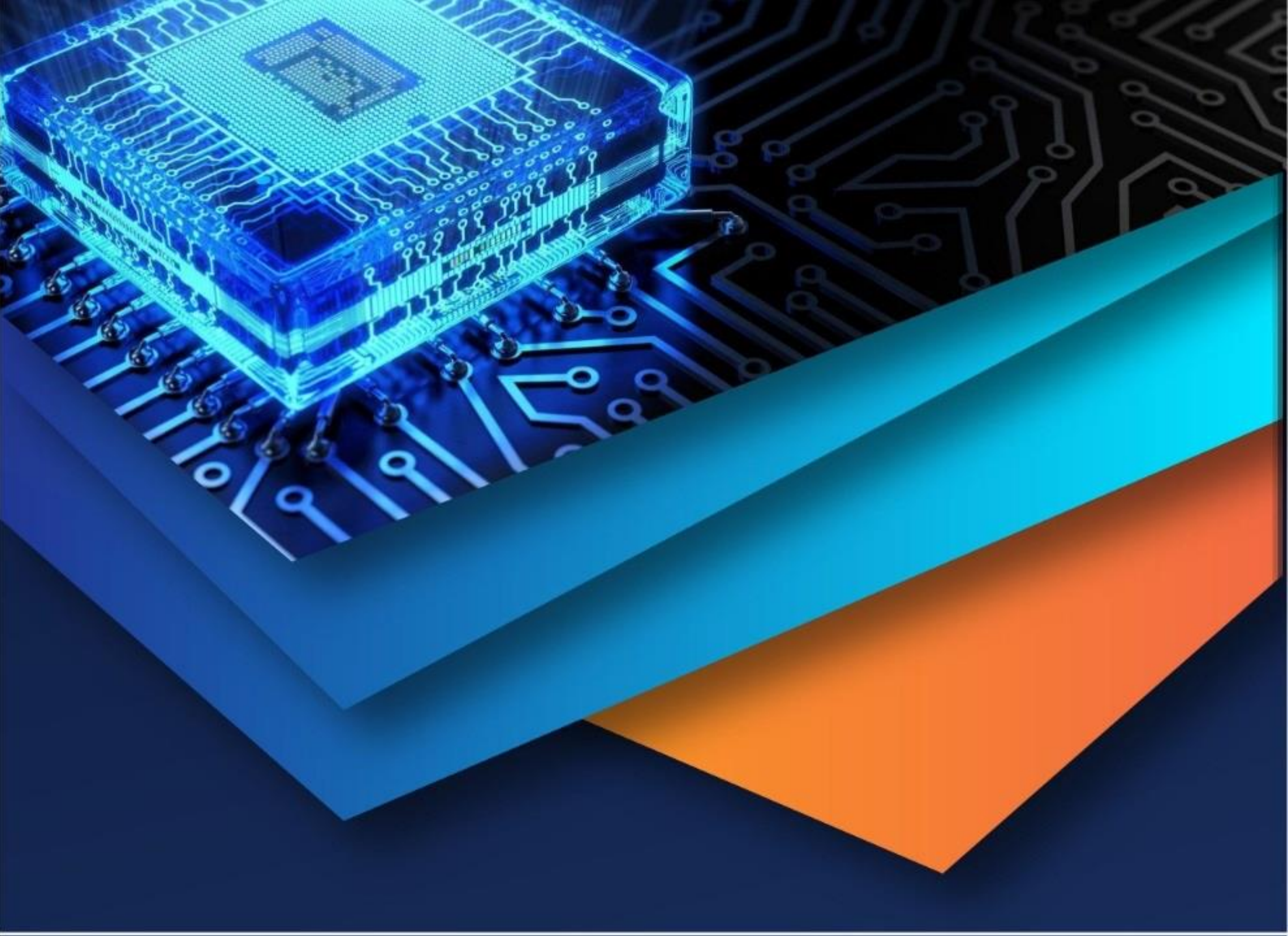

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