International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 13 Issue 4 ǁ April 2025 ǁ PP. 121-125

Automatic Fertilization Cart for Double-Ridge Furrows in Plastic-Mulched Fields

Peng Qiyuan, Zhang Ruiyang, Guan Bofei, Zhang Chengyu, Zheng Lihui
School of Mechanical and Automotive Engineering, Shanghai University of Engineering Science, Shanghai, China
Corresponding Author: Zheng Lihui

Abstract:
To meet the agronomic requirements of fully plastic-mulched double-ridge furrow planting, an automatic fertilization cart was designed for plastic-mulched double-ridge furrow fields. The cart primarily consists of a mobile control device, a hole-forming device, a fertilizer-feeding device, and a traveling device. During operation, the cart performs fertilization while moving. By adjusting the speed and direction of the hole-forming device relative to the cart body, the hole-forming device remains stationary relative to the ground during hole creation and fertilizer application. This mechanism prevents film tearing or lifting, thereby extending the service life of the plastic mulch and reducing agricultural investment costs.

Keywords: *automatic fertilization cart; fully plastic-mulched field fertilization; double-ridge furrow*

Date of Submission: 01-04-2025 Date of acceptance: 11-04-2025

Ⅰ. INTRODUCTION

The fully plastic-mulched double-ridge furrow planting technique, developed for arid agricultural regions, significantly enhances land productivity in dryland farming and has become a critical technology for promoting agricultural economic growth and ensuring food security in these areas. To reduce agricultural costs and mitigate residual film pollution, the "two-year use of one film" model has emerged as an extension of this technique. However, challenges such as sub-film fertilization and topdressing have hindered its widespread adoption [1-2]. Existing fertilization machinery predominantly targets non-mulched open fields, featuring bulky designs and relying on broadcast fertilization or seed-fertilizer separation furrow openers attached to seeders [3-5]. These systems are incompatible with fully plastic-mulched double-ridge furrow planting. Although handheld point fertilizer applicators enable fertilization on mulched fields, they suffer from high labor intensity and low efficiency. To address these limitations, an automatic fertilization cart tailored for plastic-mulched double-ridge furrow fields was developed.

Ⅱ. OVERALL DESIGN

The automatic fertilization cart comprises a mobile control device, a hole-forming device, a fertilizer-feeding device, and a traveling device. The mechanical structure of the cart is illustrated in Figure 1.

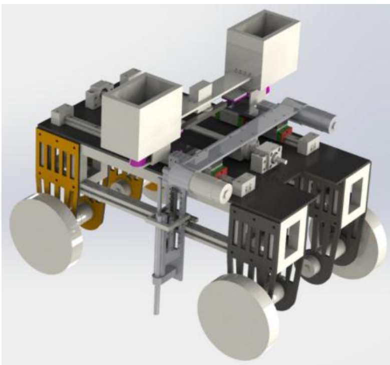

Figure 1: Schematic diagram of the mechanical structure of the automatic fertilization cart

The mobile control device is designed to control the reciprocating horizontal motion of the fertilizer-feeding device and hole-forming device along the longitudinal direction. By adjusting their movement speed relative to the cart body to match the cart's ground travel speed in magnitude but opposite in direction, the hole-forming device maintains relative stillness to the ground during operation. This ensures that no film-damaging phenomena (e.g., tearing or lifting) occur during hole formation and fertilization in plastic-mulched double-ridge furrow fields, as illustrated in Figure 2.

Upon completing fertilization at a target position, when the hole-forming device is idle, the mobile control device reverses the motion direction of the fertilizer-feeding and hole-forming devices relative to the cart. This allows both devices to return to the front end of the cart at a speed synchronized with the cart's travel direction, preparing for the subsequent hole-forming and fertilization cycle. Consequently, the cart achieves continuous fertilization operations without film damage during uninterrupted cart movement.

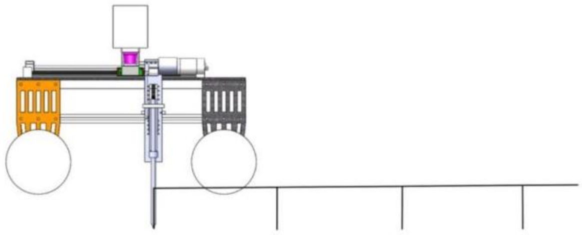

Figure 2: Schematic diagram of the working trajectory of the automatic fertilization cart

Ⅲ. Working Principle of the Automatic Fertilization Cart

3.1 Mobile Control Device

The primary function of the mobile control device is to enable reciprocating horizontal motion of the fertilizer-feeding device and hole-forming device along the longitudinal direction, dynamically synchronizing their movement with the cart's travel speed. This ensures that the drill bit of the hole-forming device remains stationary relative to the ground during operation, thereby preventing film tearing [6]. The mobile control device comprises motor 4, ball screw 8, bearings 5, lead screw slider 7, slide rails 2, slide rail sliders 6, and a slider connector 1, as illustrated in Figure 3. The slider connector rigidly couples the lead screw slider and slide rail sliders, with the fertilizer-feeding and hole-forming devices mounted on the slider connector. The motor drives the rotation of the ball screw, enabling controlled forward and backward motion of the devices.

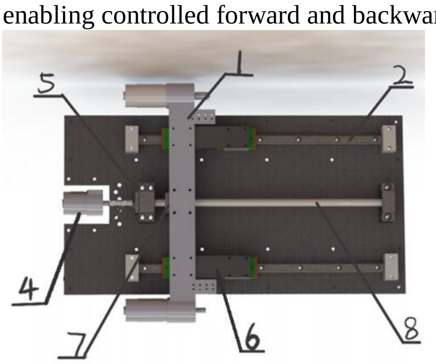

Figure 3: Schematic diagram of the mobile control device structure

3.2 Fertilizer-Feeding Device

The fertilizer-feeding devices are symmetrically installed on both sides of the automatic fertilization cart. During operation, they extract a predetermined amount of fertilizer from the hopper and deliver it to the hole-forming device via a flexible fertilizer delivery hose for subsequent field application. The fertilizer-feeding device primarily consists of a quantitative device 11, fertilizer hopper 12, fertilizer baffle 13, motor 14, and gear rack 15, as shown in Figure 4. A circular opening is positioned at the bottom of the fertilizer hopper, allowing fertilizer to pass through under gravity into the quantitative device's aperture and then into the delivery hose.

The quantitative device acts as a switch by horizontally shifting between positions. When aligned as depicted in Figure 4, its plate blocks the hopper's bottom opening, halting fertilizer discharge. When moved to the right, the hopper's opening aligns with the quantitative device's aperture, enabling fertilizer flow into the hose. The horizontal motion of the quantitative device is controlled by a motor-driven gear rack mechanism.

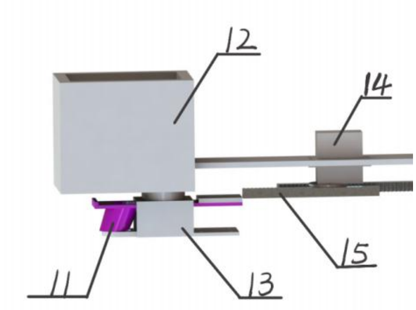

Figure 4: Schematic diagram of the fertilizer-feeding device structure

3.3 Hole-Forming Device

The hole-forming device primarily comprises motor 17, crank 18, connecting rod 19, gear set 20, fixed rack 21, movable rack 22, and drill bit 23, as shown in Figure 5. The motor shaft is rigidly connected to the crank, driving the gear set (linked to the connecting rod) to reciprocate vertically. The gear set engages with the fixed rack on one side and the movable rack on the other. The drill bit, attached to the lower end of the movable rack, performs vertical motion via the crank-slider mechanism when motor 17 rotates. Simultaneously, the drill bit is driven by a micro-motor to generate rotational motion, creating fertilization cavities in the soil. During this process, steering gear 14 controls the horizontal displacement of quantitative device 11, enabling fertilizer to flow through the delivery hose into the cavities, thereby completing the fertilization cycle.

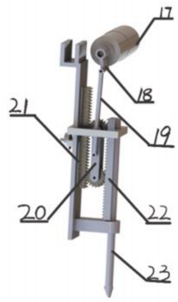

Figure 5: Schematic diagram of the hole-forming device structure

3.4 Traveling Device

The traveling device primarily consists of frame 9, motors 10, and wheels 24, as illustrated in Figure 6. To ensure stable travel without rollover in rugged inter-ridge environments, the cart employs thick rubber wheels with tread patterns to enhance traction. Each of the four wheels is connected to an independent motor via a coupling, forming a four-wheel-drive system. This configuration provides sufficient power and improves adaptability to uneven terrain during operation.

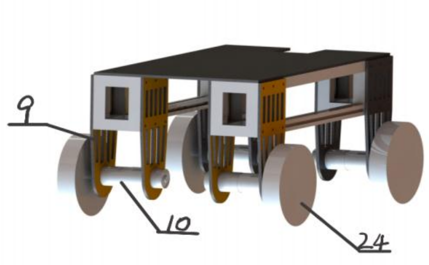

Figure 6: Schematic diagram of the traveling device structure

3.5 Electronic Control System

The system employs an STM32F103C8T6 microcontroller as the core controller for the fertilization cart [7-8]. Programming was implemented using the Keil MDK5 development environment with the C language, and hardware drivers were developed utilizing the STM32 Standard Peripheral Library. A configurable TIM timer generates PWM waves with adjustable duty cycles to regulate DC motor speeds, while GPIO ports generate high/low logic level combinations to control motor rotation direction. Compared to traditional software-based delay speed regulation methods, this hardware-driven PWM control strategy achieves superior precision and stability, ensuring functional reliability while minimizing hardware resource consumption. The custom-designed hardware circuit board is illustrated in Figure 7.

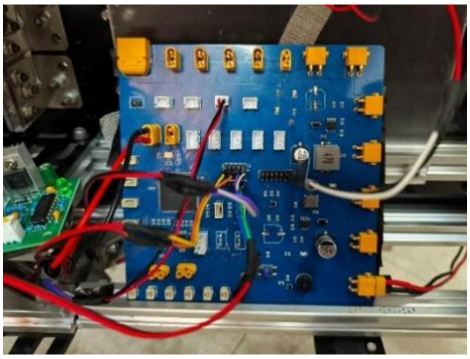

Figure 7: Hardware circuit board of the automatic fertilization cart

Ⅳ. Application Prospects Analysis

Dryland farming, internationally referred to as "rainfed agriculture," relies entirely on natural precipitation and employs drought-resistant crop varieties. Globally, dryland farming accounts for 81% of cultivated land. The fully plastic-mulched double-ridge furrow planting technique represents an innovative advancement tailored for arid agricultural systems. The automatic fertilization cart, designed for plastic-mulched double-ridge furrow fields, integrates fertilizer extraction, hole formation, and precise fertilization. The hole-forming device is engineered to accommodate varying fertilization depths required by different crops by selecting cranks of varying lengths.

This cart addresses the limitations of existing handheld point fertilizer applicators, such as low efficiency and high labor intensity, by enabling sub-film fertilization in double-ridge furrow systems. Its operational design eliminates film tearing or lifting, ensuring prolonged film durability. These features position the cart as a promising solution for sustainable fertilization in fully plastic-mulched double-ridge furrow fields, with significant potential to enhance operational efficiency and reduce agricultural costs in arid regions. The experimental prototype of the automatic fertilization cart is shown in Figure 8 below.

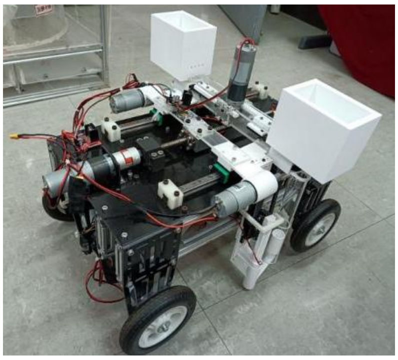

Figure 8: Experimental prototype of the automatic fertilization cart

V. CONCLUSION

An automatic fertilization cart tailored for plastic-mulched double-ridge furrow fields was designed, incorporating a mobile control device, fertilizer-feeding device, hole-forming device, and traveling device. This system enables efficient sub-film fertilization in double-ridge furrow systems, effectively addressing the limitations of handheld point fertilizer applicators, such as high labor intensity and low operational efficiency. The cart features a simple structure, low cost, and high efficiency, demonstrating practical value for sustainable agricultural practices in arid regions. Its design ensures minimal film damage during operation, further enhancing its applicability for fully plastic-mulched cultivation systems.

REFERENCES

[1]. Huan Deng. (2024) “Simulation Experiment on Mechanized Fertilization and Water and Fertilizer Transport under the Full Film Double Ridge Ditch "One Film for Two Years"”, Gansu Agricultural University, pp.1-92.

[2]. Fei Dai, Wuyun Zhao, Bugong Sun, etc. (2018) “Design of picking hole fertilize mechanism with “one film used for two years” pattern of corn whole plastic - film on double ridges”, Agricultural Research in the Arid Areas, Vol. 36, No.1, pp. 274-280.

[3]. Kun Li, Wensheng Yuan, Wenyi Zhang, etc. (2017) "Research Status and Development Trend of Corn Fertilizing Technology and Fertilizing Machine", Journal of Agriculture Mechanization Research, Vol. 39, No.1, pp. 264-268.
[4]. Yakai He, Xueguan Zhao, Cuiling Li, etc. (2021) "Research Status and Analysis on Fertilization Technology of Corn Topdressing Machinery", Journal of Agriculture Mechanization Research, Vol. 43, No.7, pp. 1-9.
[5]. Liang Wu, Yan Wu, Qiang Yan, etc. (2020) "Design of Fertilization Robot Structure and Control System", GUANGXI NONGYE JIXIEHUA, No.3, pp. 29-30.
[6]. Shuangwei Jing, Fugui Zhang, Xue Chen, etc. (2019) "Study on Tearing Characteristics of Plastic Mulch Under Different Single-track Tensile Speeds", JIANGSU AGRICULTURAL SCIENCES, Vol. 47, No.1, pp. 225-230.
[7]. Hongwei Tong, Liping Zhang, Jingshuang Shen, etc. (2019) "Control system of BLDC based on STM32", Transducer and Microsystem Technologies, Vol. 38, No.7, pp. 79-81.
[8]. Xi Zhang, Dihui Zeng, Yongli Wang, etc. (2013) "BLDCM Control System Based on STM32", Instrument Technique and Sensor, No.9, pp. 68-69.