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Design and Implementation of a Small-Scale Intelligent Precision Pea Seeder

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Abstract: To address low efficiency in manual pea seeding and poor adaptability of large machinery in China, a small-scale intelligent precision pea seeder suitable for small farmlands was designed. Integrating automated control and Internet of Things (IoT) technology, this device enables integrated operations of precise seeding, watering, fertilizing, and soil covering. Through a three-rail seeding mechanism, a dial-type precision seed metering device, and remote control via a smart APP, it solves problems such as uneven seeding spacing, high seed damage rate, and insufficient intelligence in traditional seeders. Test results show that the seeder significantly improves the efficiency and quality of pea seeding, providing an effective solution for mechanized pea cultivation in hilly and small-scale farmlands.
Keywords: Pea seeder; Precision seeding; Intelligence; Small-scale agriculture; Integrated operations

I. Introduction

In the modernization of agriculture, automation and intelligent technologies have become core drivers for breaking through bottlenecks in traditional agricultural production. As a key link in agricultural production, the mechanization and precision of seeding directly affect crop yield and quality. Intelligent agricultural machinery, by integrating automated control, IoT, and artificial intelligence, achieves full-process digital management from planting to crop management, significantly improving agricultural efficiency and resource utilization. This has become an important support for promoting agricultural modernization and rural revitalization.

Pea, as a major edible legume crop in China, has dual values as a food, vegetable, and deep-processing raw material. Its nitrogen-fixing rhizobia also play a vital role in soil improvement. However, current pea seeding relies mainly on manual labor or large-scale general machinery. The former is inefficient, while the latter suffers from issues such as non-adjustable seeding spacing, high seed damage rate (15%–20%), and poor adaptability to small farmlands. Given China's fragmented cultivated land—with over 60% of farmland areas smaller than 5 hectares—there is an urgent need for specialized seeding equipment adapted to small-scale planting.

Existing research shows that precision seeding technology can increase crop yields by 10%–15% and reduce seed waste by 30%. However, due to the light weight of pea seeds (1000-seed weight: 200–300 g) and their sensitivity to seeding depth (3–5 cm), traditional machinery struggles to meet agronomic requirements, with furrow depth control errors (±1 cm) and seed metering accuracy (single-grain rate <80%) falling short. To address this, this study proposes a miniaturized device integrating mechanical precision seeding and intelligent monitoring, achieving efficient and precise pea seeding through structural innovation and intelligent control.

II. Materials and Methods

A. Overall Design Objectives

(1) Based on agronomic requirements for pea planting (row spacing: 30–40 cm, plant spacing: 5–10 cm, 3–4 seeds per hole), the device must meet the following:
(2) Seeding precision: Single-grain delivery accuracy ≥95%, hole spacing error ±0.5 cm;
(3) Functional integration: Integrated operations of furrowing, seeding, watering, fertilizing, and soil covering;
(4) Adaptability: Body width ≤80 cm, passable on field ridges≥30 cm wide, load ≤50 kg;
(5) Intelligence: Remote control via APP for travel path, watering volume (0–500 mL/mu), and seeding frequency (5–20 holes/min).

B. Mechanical Structure Design

(1) Overall Structure

The small-scale intelligent precision pea seeder consists of a precision seeding mechanism, watering mechanism, fertilizing mechanism, soil-covering mechanism, power system, and traveling mechanism. An

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aluminum square tube framework supports these components, ensuring light weight, high efficiency, and simple operation. The power system provides sufficient power and torque for driving the machine; the seeding system precisely controls seeding spacing for uniform distribution; and the watering, fertilizing, and soil-covering mechanisms ensure optimal conditions for seed growth. Designed for three-row simultaneous seeding, this structure aims to enhance both the efficiency and quality of pea seeding.

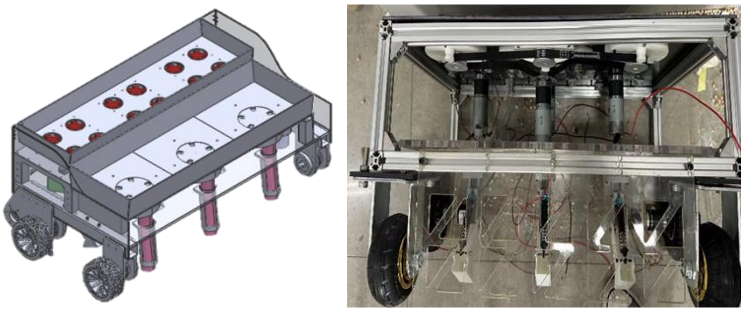
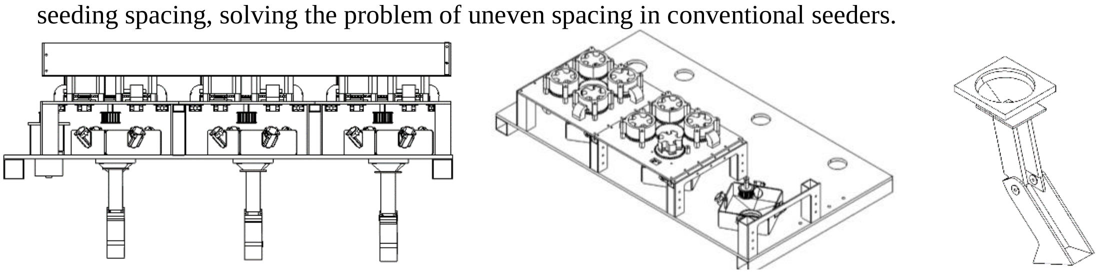


Fig.1Overall Structure

(2) Core Seeding Mechanism

The core seeding mechanism includes a seed hopper, dial-type metering device, planting conduits, and seeding drive unit, adopting a three-rail parallel design with a dial-type seed metering (Fig. 2). The seed hopper (Fig. 2 (a)) stores pea seeds, while the metering device (Fig. 2 (b)), composed of four rotating wheels synchronized by a timing belt, ensures uniform seed spacing via speed control by a stepper motor. The planting conduit (Fig. 2 (c)) is equipped with a 30° plow-shaped furrow opener at the front, creating shallow furrows of 4±0.5 cm depth to meet seeding depth requirements. The drive unit, consisting of a motor, timing belt, and pulleys, powers the metering device.

During operation, the motor drives the pulleys and rotating wheels, which use smooth circular grooves to capture single seeds. Guided by the planting conduits, seeds are dropped into the soil. Since pea seeding typically requires 3–4 seeds per hole, four wheels work in unison to deliver multiple seeds, which converge into a single conduit via a four-way collector. This mechanical design ensures precise control of seeding spacing, solving the problem of uneven spacing in conventional seeders.



(a) The seed hopper (b) The metering device (c) The planting conduit

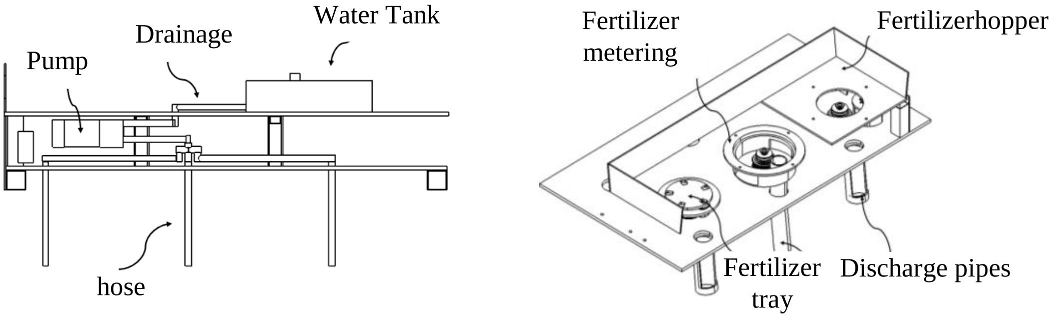
Fig.2 The seeding mechanism

(3) Integrated Operation Mechanism

The integrated system synchronizes watering, fertilizing, and soil covering with seeding to optimize the growth environment (Fig. 3). The watering mechanism (Fig. 3 (a)) includes a water tank, mini pump, rechargeable battery, and hoses, mounted on the back of the load-bearing plate. The pump draws water from the tank and distributes it into three furrows via hoses for quantitative irrigation.

The fertilizing mechanism (Fig. 3(b)) comprises a fertilizer hopper, drive unit, fertilizer tray, and discharge pipes. As the motor rotates the tray, fertilizer is released when the tray's outlet aligns with the discharge pipe, achieving five fertilizations per 360° rotation.

The soil-covering mechanismincludes a toothed soil plate hinged to the frame, smoothing furrows behind the seeding, watering, and fertilizing units to ensure seed-soil contact.



(a) The watering mechanism (b) The fertilizing mechanism

Fig.3 The Integrated Mechanism

C. Electrical and Intelligent Control System

The electrical system uses an STM32F103ZET6 microcontroller as the core, integrated with four motor drivers to control rollers and axles, minimizing space and simplifying wiring. Chassis and stepper motors are driven by RZ7899 and TB67S109A chips, respectively, with all components powered by 24V DC. Servos and relay-equipped push rods connect directly to the STM32, enabling centralized control.

Intelligent control is achieved via a custom smart APP, allowing remote start/stop, direction control, and real-time monitoring of seeding density, speed, and area. Data are transmitted to the cloud via a communication module for remote management and optimization.

III. Seeding Performance Testing

Tests on sandy loam with 20% moisture content showed:

(1) Seeding spacing accuracy: At a set plant spacing of 8 cm, the measured average was 8.2 cm, significantly better than traditional machinery;
(2) Seed damage rate: Mechanical friction caused <2% damage during single-grain delivery;
(3) Operational efficiency: Three-rail simultaneous seeding increased daily productivity by over 10 times compared to manual labor.

IV. Conclusion

This study presents a small-scale intelligent precision pea seeder that overcomes adaptability issues in traditional machinery for small farmlands through mechanical optimization and intelligent control. Field testsshow superior seeding precision, efficiency, and integration compared to similar devices, providing a viable solution for mechanized and intelligent pea cultivation. Future work will focus on optimizing the electrical system's heat dissipation and integrating soil moisture sensors for dynamic irrigation adjustment, enhancing environmental adaptability.

V. Acknowledgements

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