A Monitoring and Reseeding Device for Potato Sower

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Abstract. To solve the problem of artificial detection and replanting in a potato planter, we provide laser sensor-based seeding detection method. In addition, this paper adopts a method for the detection of seeding by designing a monitoring and reseeding device for a potato sower. We also test the performance of the seeding detection and the automatic filling performance of the device. The device adopts the two pairs of laser correlation sensor and contact-travel switch sensor to detect the leak air scoop seeding location. To achieve precise seeding, the proposed device relies on the step motor to drive the seeding device. The experimental result shows that when the working speed is 2–5 km/h, the original average seeding rate of the seeding machine is 91.35%, the average successful replanting rate of the replanting device is 82.17%, and the comprehensive seeding rate is less than 1.5%. In addition, the total seeding rate is 98.5%. The seeding rate and the seepage rate obviously decreased when the line speed is less than 0.5 m/s. The method for seeding detection proved to be accurate, and the effect of the automatic seeding device is highly apparent. The method not only adapts to different sowing speeds and potato sizes, but also provides a theoretical basis for the intelligent design of a potato planter.

1. Introduction

According to the Chinese Ministry of Agriculture, potato ranks fourth after rice, wheat, and corn, making it one of the most important crops in the country. The potato planting industry has grown in recent years, but the mechanization level remains relatively low. Potato planter is critical to the development of the potato industry. Specifically, the seeding quality of potato planters directly affects the growth and yield of potato and depends on the seed-metering device. A spoon-chain seed metering device is widely used in potato planters because of its low price, minimal risk of injury, and adjustable distance. Due to the limits of the seed-taking method, seeds may easily leak when sowing. At present, the empty spoons are reseeded by human beings, but such reseeding is difficult, expensive, and slow.

At present, many studies on monitoring seeding have been conducted. However, in China, only a few studies have proposed monitoring and reseeding devices for potato sowing. For example, Sun and Liu designed a monitor and reseeding system of a chain spoon seed-metering device with atmega16 at the core and Hoare’s sensor localization. Niu designed and proposed a leakage detection method based on the accurate measurement of capacitance value and a capacitance leakage detection sensor. Zhu examined the seeding of large grain crops to solve the problem of seeding of grain crops in large grain crops, whereas Zhang designed an automatic compensation system of a potato planter based on an
infrared photoelectric sensor. Monitoring is mainly conducted in ways, including multigroup photoelectric switch, Hoare’s sensor, and empty spoon detection by high-speed camera. Although these approaches are relatively accurate, the structures are complex and the accompanying costs are usually high. To solve the problem, in this paper, we design an automatic reseeding machine for potato seeding. The machine combines seeding and reseeding to ensure high-quality seeding, simplify the structure, and improves the stability and automation level.

2. Overall design

2.1. Overall structure

Based on single-row and twin-row spoon-chain potato sowers, we design an automatic reseeding machine for potato seeding. The machine contains a reseeding box, reseeding slide way, outer-fluted feed seed meter, and laser beam sensor, and travel switch, as shown in Figure 1. The reseeding machine contains a reseeding box, outer-fluted feed seed meter, and reseeding slide way. We also design an outside slot round sower based on the average size of potato seed.

2.2. Operating principle

In the operating process, when the spoon moves from the bottom to top, the spoon blocks up a pair of laser beam sensor A1 underneath. The signal triggers the cycle judgement system of the control program. Then, the spoon continues to move up and blocks a pair of laser beam sensors A2 above. The judgement system detects whether the pair of laser beam sensors A1 is immediately blocked by a signal. If the A1 signal is blocked, the height of the spoon is greater than the distance of installation, and thus, a seed is in the spoon. If the A1 signal is not blocked, the height of the spoon is less than the distance of installation; thus, no seed is in the spoon. When the machine detects no seed and the spoon touches the switch on the top, the control system sends a signal to control the actuator. Then, the stepper motor is driven to work and the outer-fluted seed meter in reseeding box twirls. The reseeding seed will fall into the bottom of the front spoon to attain automatic reseeding.

3. Control system design

3.1. Composition of the control system

The control system consists of an information collecting system, information handling system, information outputting system, and power source, as shown in Figures 2 and 3.
3.1.1. Information collecting system. The system includes two parts: one that detects leaking and another that detects location. The first part comprises two pairs of laser beam sensors. Based on a predefined distance, the sensor location is confirmed. The sensor is installed in the bracket wall upright. Two pairs of sensors measure the passing spoons. The presence of a seed is determined by the height difference of the spoon. The component that determines location monitors the spoon’s location for the travel switch, which is installed in the top of the bracket. The spoon touches the travel switch, and the stepper motor begins operation.

Figure 2. Block diagram of system

Figure 3. Principle diagram of system

3.1.2. Information handling system. The system comprises an information-handling component, an input–output interface, and single chip microcomputer (SCM) minimum controlling system. The information-handling component addresses the date that is gathered by the sensor and travel switch. The input–output interface sends the data handled by the information-handling component to the SCM minimum controlling system and then sends the signal of the SCM minimum controlling system to the information output system. The SCM minimum controlling system is the basic SCM part of controlling and handling information.

3.1.3. Information output system. The system consists of the automatic compensation component and the alarm and input component. The SCM minimum controlling system, which is connected to a stepper motor driver, controls the signal output interface. The stepper motor runs as its output shaft connects with the outer-fluted feed seed meter’s shaft. The SCM minimum controlling system connects the working indicator light and acousto-optic alarm sensor with the status output interface. When the system operates properly, the indicator light is turned off, and the acousto-optic alarm sensor is active. The SCM minimum controlling system connects the input keyboard and display by a human–machine interface; the system sets and modifies planting speed and planting row-spacing parameters through an input keyboard. The display shows the quantity of mis-seeding. The power system uses a 12 V battery.

3.1.4. Function of the empty spoon and ensuring reseeding location. We use two pairs of laser beam sensors to determine an empty spoon and choose the contact travel switch to determine the reseeding spoon’s location and the reseeding start time. The control system is shown in Figure 4.

3.2. Seeding absence monitor

The seeding absence monitor uses two pairs of laser correlation sensors. The sensor comprises a transmitting terminal and receiving terminal. Two pairs of sensors are installed on two opposite side of the bracket based on the distance measured. The sensor measures the passing spoon. When the spoon with a seed passes the seed aisle, it can block the light of the sensors and the system does not work.
When the spoon is empty, it cannot block the light; thus, the system controls the reseeding part to reseeding. The low-cost laser correlation sensor (M18-1212NO, Shanghai Electric Appliance Electron Company) has strong anti-interference ability. The sensor’s inductive mood is the blocking type, the reaction time is less than 3 ms, the laser wavelength is 650 nm, the laser beam’s divergence angle is less than 6°, the receiving terminal’s acceptance angle is less than 8°, and the range of work temperature is between –25°C and 55 °C.

![Figure 4. System control flow chart of main program](image)

The operating speed of the chain-spoon potato sower is in the range of 2–5 km/h, the minimum distance between one spoon with another is 140 mm, the seeding sprocket wheel completes one revolution with 12 seeds. To achieve zero-speed row, the sprocket rotation speed is computed as follows:

\[
\begin{align*}
n &= 60 \times \frac{V_0}{12 \times d} \\
\omega &= 360 \times \frac{n}{60} \times \frac{\pi}{180}
\end{align*}
\]

where \( n \) represents sprocket speed, r/min; \( V_0 \) represents the speed of the planter, m/s; and \( d \) represents sowing distance, m.

Based on Equations (1) and (2), \( n = 19.84–49.60 \) r/min and \( \omega = 2.078–5.194 \) rad/s, respectively. The line speed of the transmission chain is given by,

\[
V_r = \omega \times r \times 10^3
\]

where \( V_r \) represents the linear speed of the transmission chain, mm/s, and \( r \) represents the sprocket radius, mm. Based on Equation (3), \( r = 95 \) mm and \( V_r = 194.41–493.43 \) mm/s.

Given that the response time to a selected projective laser sensor is <3 ms, sufficient response time exists for the laser dual sensor to pass the chain with a spoon. The response time is calculated based on 3 ms; thus, the response height is obtained using the equation

\[
h = V_r \times t \times 10^{-3}
\]

where \( h \) is the sprocket radius response height, mm, and \( t \) is the sprocket radius response time, ms.

Based on Equation (4), \( h = 0.58–1.48 \) mm. The height difference between a scoop and no seed is greater than 5 mm, and the response time accuracy of the dual-laser sensor meets the design requirements.

### 3.3. Reseeding location monitoring and reseeding

The travel switch actuating arm is installed in front of the top spoon; there is also a spoon distance between the arm and laser beam sensor. When the spoon is working and touches the travel switch, the actuating arm sends a signal and the information handling system acquires the signal. By this way, the
system can assess the location of the spoon. If the spoon is empty, the information handling part uses the travel switch signal to drive the stepper motor, and the reseeding meter finishes the reseeding work.

4. Performance testing

4.1. Materials and method

On the basis of the aforementioned theory, we develop a monitoring and reseeding device of potato test table. The device contains an adjustable-speed motor, spoon-chain, and a monitoring and reseeding automatic potato sower device. We change the speed of the motor to simulate reseeding situations at different speed levels. The spoon mounting position can adjust the location in the wide belt and simulate different distances of spoon. The laser beam sensor is installed on the connector of the test table.

The planting effect and reseeding quality of the potato sower is affected by potato size, shape, and sowing speed. When sowing speed is fast, the spoon cannot easily take a seed, resulting in mis-seeding. Moreover, the seeding rate declines, the time for reseeding is short, and the reseed effect is not high. Whether the seed easily falls off will be affected by the shape and size of the seed. To verify several factors and their impact on reseeding result, we performed orthogonal testing using three factors: potato size, planting speed, and potato shape. By using combinations of different factors to determine whether the reseeding device can finish the monitoring and reseeding in different conditions, the test provides a theoretical basis for the optimization and improvement of the proposed automatic reseeding potato sower.

The operating speed is in the range of 2–5 km/h. The speed by which the spoon obtains seeds on the test table is 0.194–0.493 m/s. The speed levels of the test are set at 0.3, 0.5, and 0.7 gears. We choose the seed and entire potato size between 25–35, 26–45, and 46–55 mm. We conduct the test eight times under every factor. During the tests, we control the planting quantity between 100–150, and measure all data of the test, including the quantity of double seeding $B$, the quantity of normal seeding $N$, the quantity of reseeding $R$, and the quantity of mis-seeding $L$. We also calculate and assess the test figures, including the rate of mis-seeding $H$, the rate of normal seeding $H$, the rate of double seeding $P$, the rate of reseeding $V$, and the rate of whole seeding, as follows:

$$H = \frac{N}{N + L} \times 100\%$$  \hspace{1cm} (5)

$$T = \frac{L}{N + L} \times 100\%$$  \hspace{1cm} (6)

$$P = \frac{B}{N + L} \times 100\%$$  \hspace{1cm} (7)

$$V = \frac{R}{L} \times 100\%$$  \hspace{1cm} (8)

$$M = \frac{N + R}{N + L} \times 100\%$$  \hspace{1cm} (9)

| Level | Potato size/mm | Sowing speed/m·s$^{-1}$ | Potato shape          |
|-------|----------------|-------------------------|-----------------------|
| 1     | 25–35          | 0.3                     | whole potato          |
| 2     | 35–45          | 0.5                     | part of the potato    |
| 3     | 45–55          | 0.7                     | -                     |

Table 2. Factors and levels of test
After the test, we assess the data of eight tests and averaged the target to ensure data accuracy. The factors and levels are listed in Table 2.

### 4.2. Test results and analysis

Our analysis of the test results indicates that the speed of obtaining seeds has the greatest impact on the rate of seeding and reseeding. When the speed is 0.5 m/s, the effect on seeding and reseeding is the best, whereas when the speed is 0.7 m/s, the effect on seeding and reseeding is the worst.

The different sizes of potato seeds also affect the reseeding result: the tests prove that when the size of seeds is in the range of 35–45 mm, the effect on seeding and reseeding is the best. It is influenced by the shape of spoon and the size of the outer-fluted feed seed meter. Whether part of potato seeds or a whole potato is used has almost no effect on the rate of seeding and reseeding.

According to Equations (5)–(9), to conduct further processing, the operating speed is in the range of 2–5 km/h, the rate of normal seeding of the device is above 90%, the average rate of successful reseeding is 82.17%, the rate of mis-seeding is less than 1.5%, and the whole seeding rate is above 98.5%. The test results show that our device can quickly monitor mis-seeding in different conditions and reseed the empty spoon, thereby reducing the rate of mis-seeding and achieving the expected effect.

The monitoring and reseeding automatic potato sower device is designed based on the relative parts of potato sower. Thus, our results prove that our reseeding device can automatically reseed; moreover, the sower can replace humans in reseeding and improve the degree of automation.

### Table 3. Poor analysis

| Test number | A Potato size/mm (1) | B Sowing speed/m•s⁻¹ (2) | C Potato shape (4) | Test index |
|-------------|----------------------|--------------------------|-------------------|------------|
|             |                      |                          |                   | Seeding rate (%) | Reseeding rate (%) |
| 1           | 1 (25–35)            | 1 (0.3)                  | 1 (whole)         | 90.55       | 81.25           |
| 2           | 1                    | 2 (0.5)                  | 2 (diced)         | 92.16       | 83.22           |
| 3           | 1                    | 3 (0.7)                  | 3 (whole)         | 91.55       | 82.43           |
| 4           | 2 (35–45)            | 1                        | 2 (whole)         | 91.13       | 82.12           |
| 5           | 2                    | 2                        | 3 (whole)         | 92.56       | 83.82           |
| 6           | 3                    | 3                        | 1                 | 91.23       | 82.20           |
| 7           | 3 (45–55)            | 1                        | 3                 | 90.03       | 80.08           |
| 8           | 3                    | 2                        | 1                 | 92.05       | 83.02           |
| 9           | 3                    | 3                        | 2                 | 90.89       | 81.40           |

**H_i**

- (k1j)1 19.142
- (k2j)1 19.64
- (k3j)1 90.99
- (Rj)1 0.65

\[ \sum_{i=1}^{9} H_i = 822.15 \]

**V_i**

- (k1j)2 82.30
- (k2j)2 82.71
- (k3j)2 81.50
- (Rj)2 1.21

\[ \sum_{i=1}^{9} V_i = 739.54 \]



### 5. Conclusion

In this study, we designed an automatic monitoring and reseeding potato sower device.

(1) The result of the study shows that when the speed of the device is in the range of 2–5 km/h, the average rate of successful reseeding is 82.17%. The reseeding device increases the average rate of
seeding by another 7.15%, and the entire rate of seeding reaches 98.5%. Therefore, the detection method has high accuracy and high reseeding time.

(2) The test results of combining device properties indicate that the device can adjust to different seeding speeds and potato shapes, thereby increasing the seeding rate of the potato sower.

Our automatic monitoring and reseeding potato sower device can effectively improve the mis-seeding and the seeding rate, thereby establishing a solid foundation for intelligent potato sowers now and in the future.

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