# Design and experiment of an online monitoring system for peanut seeding parameters based on IoT

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**Abstract:** Aiming at the problems in the traditional peanut sowing operation process, such as single monitoring mode, lack of online monitoring function, inability to deeply utilize data, and difficulty in tracing the sowing quality, an online monitoring system for peanut sowing parameters based on the Internet of Things (IoT) was designed. The online monitoring system for peanut sowing parameters consists of a peanut seed-metering monitoring device, an on-board monitoring terminal, and an online monitoring cloud platform. The system can monitor parameters such as seed spacing, seeding rate, missed seeding, vehicle speed, temperature, and humidity. It transmits data through RS485 and IoT communication, and supports local interaction and cloud data storage and analysis. The seed-metering monitoring device uses laser opposite reflection and window fiber optic sensors to monitor the missed seeding and seed-metering status in real time. The on-board terminal uses an optoelectronic rotary encoder to collect the rotational speed and calculate the parameters. The operation status is displayed through the human-machine interaction module, and the data is packaged and sent to the cloud server via a wireless network. The online monitoring cloud platform selects the Alibaba Cloud IoT platform, connects with it through the MQTT protocol, and conducts visual development using IoT-studio to achieve data display, analysis, and statistics. Through the test on the simulated test bench, the accuracy rates of the seed spacing, seeding rate, and missed seeding monitoring of the seed-metering monitoring module of the system exceed 98.02%, 98.03%, and 99%, respectively. The field test based on the actual seeder shows that the monitoring effect of the seed spacing of 16 cm and 20 cm is good. The accuracy rate of the 27 cm seed spacing decreases slightly with the increase of the speed but still exceeds 97%. The accuracy rates of the missed seeding and seeding rate monitoring exceed 98%, and the online monitoring module transmits data normally. After testing, each part of the system has good performance, meeting the functional and accuracy requirements of the online monitoring of peanut sowing operation parameters.

**Keywords:** IoT communication, sowing parameters, online monitoring, RS485 communication, data visualization
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## 1 Introduction

Peanuts are a major economic and oilseed crop in China, with the highest total production and export volume in the world[1]. Sowing is a crucial process in peanut production, and the quality of sowing directly affects the yield of peanuts[2-4].

The peanut sowing process is mostly in a closed state, making it difficult for the seeder driver to accurately determine the sowing situation. Therefore, accurate and timely monitoring of the peanut sowing quality is beneficial for promptly detecting and solving sowing problems in real time, ensuring that the peanut seedlings are uniform and robust, assisting in formulating field management strategies, tracing the sowing quality, evaluating the effectiveness of the sowing technology, and promoting the intelligent development of agriculture.

Currently, traditional peanut sowing machines have achieved a high degree of automation, and significant progress has been made in the development of seed dropping detection and intelligent electronic control devices during the sowing process. Zhang et al.[5] utilized laser photoelectric sensors for monitoring seed dropping, achieving a high detection accuracy and demonstrating the feasibility of this method for drop detection. Kostić et al.[6] validated the performance of photoelectric sensors through image and data analysis under experimental simulation conditions. Moreno et al.[7] conducted experiments on the installation position of laser sensors, concluding that when the sensors are installed at the seed guide tube, the monitoring results for corn sowing are most accurate. Therefore, this design combines laser through-beam photoelectric

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sensors with laser window sensors to monitor sowing information.

Liu et al.[8] designed a precise sowing monitoring system based on embedded technology; however, its widespread application may face limitations. Bai et al.[9] developed a seed dropping detection module and a visualization module, enabling the monitoring of parameters such as sowing counts, missed sowing counts, seed drill rotation speed, machine forward speed, and sowing area, although the detection accuracy still needs improvement. Wang et al.[10] developed a miss-seeding detection scheme based on a spatial capacitance sensor with a dual CPU coordinated seed-monitoring and compensation control system architecture. Gao et al.[11] proposed a sowing monitoring and evaluation system based on the CAN bus, developing a real-time monitoring and evaluation upper computer interface based on LabVIEW to monitor sowing quality.

The research finds that there are still some problems in the peanut sowing operation process, such as the lack of a complete monitoring system for sowing parameters[12], incomplete data storage[13], and limited data transmission distance[14,15]. At present, the majority of sowing detection modes are of the type “sowing detection device + monitoring and display terminal”. After the sowing detection device collects the sowing information, it transmits the sowing information to the monitoring and display terminal through cabling, and the sowing information is displayed on the monitoring and display terminal. The sowing monitoring under this mode is a one-to-one mode, and the monitoring content mainly focuses on the statistics of the seeding rate. Not only is the monitoring content relatively simple, but also most of the sowing monitoring information is one-time information. It does not have the function of online monitoring of sowing parameters and does not conduct further statistics on the data[16], which in turn leads to difficulties in tracing the sowing quality.

Aiming at the above problems, this paper adopts the mode of “sowing detection device + monitoring and display terminal + IoT platform for sowing information”. With the help of IoT technology, it breaks through the one-to-one limitation of the “sowing detection device + monitoring and display terminal” mode, and realizes online monitoring of multiple terminals and multiple parameters. It expands the monitoring content, covering parameters such as the sowing time interval and sowing status in addition to the seeding rate. By collecting and transmitting data in real time, it achieves online monitoring of sowing parameters and provides producers with dynamic information. At the same time, it uses data records to accurately trace the sowing quality, helps to improve the peanut sowing quality and management level, and promotes the intelligent development of peanut planting.

## 2 Working principle and overall design of the online sowing monitoring system

The online monitoring system for peanut sowing parameters is mainly composed of a peanut seed- metering monitoring device, an on-board monitoring terminal, and an online monitoring cloud platform. The overall structure of the system is shown in Figure 1. This system realizes the monitoring of sowing parameters such as seed spacing, seeding rate, missed seeding situation, vehicle speed, temperature, and humidity. It transmits data through RS485 and IoT communication. It not only supports local human-machine interaction for parameter setting and alarm display, but also can store and analyze data in the cloud to assist in decision-making.

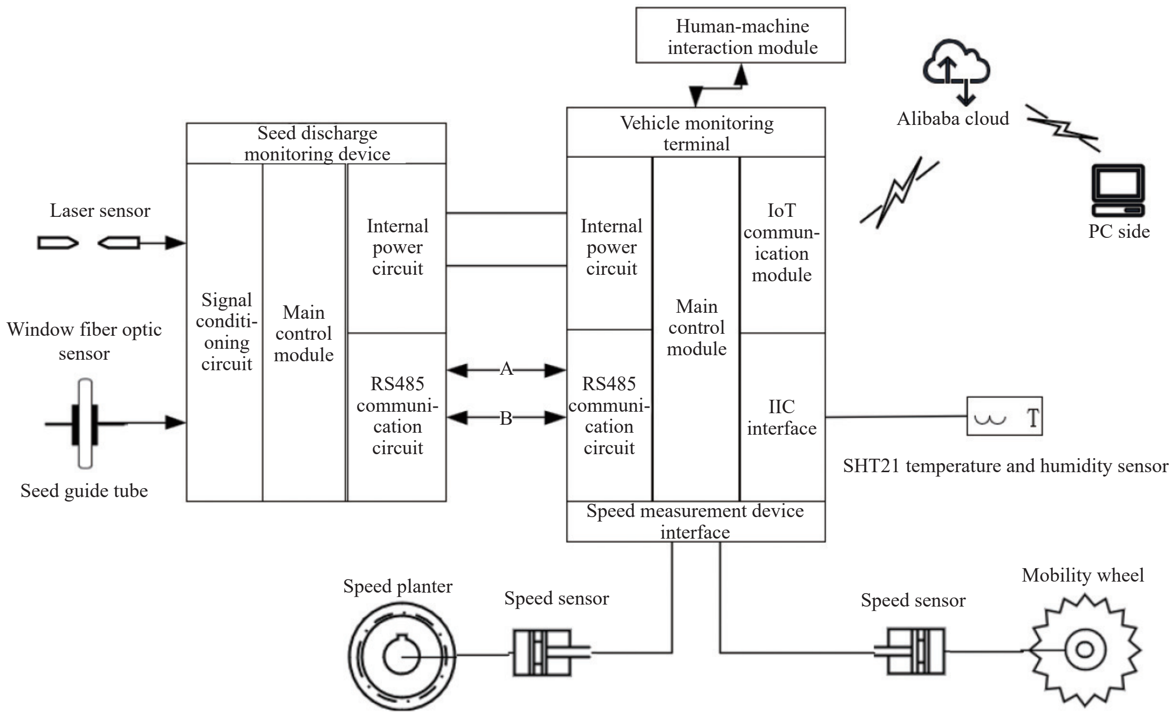



Figure 1 Overall system structure diagram

The peanut seed-metering monitoring device adopts a laser opposite reflection sensor and a window fiber optic sensor with surface detection characteristics to achieve real-time monitoring of the missed seeding situation and the seed-metering status. A set of peanut seed-metering monitoring devices is used for each ridge to monitor the sowing situation[17]. When peanut seeds pass through the distribution monitoring device, they generate pulse signals, which the on-board monitoring terminal uses to identify the seeds through edge detection of these pulse signals.

The optoelectronic rotary encoder installed on the on-board monitoring terminal collects the rotational speeds of the seed-metering disc and the traveling wheels, which are used to calculate the sowing parameters and the advancing speed of the seeder. After data collection is completed, the on-board terminal displays the operational status in real time through a human-machine interaction module for the operator's convenience. It also packages the collected data and transmits the packaged data to the cloud server via a wireless network, thereby enabling online monitoring of the seeder's operational status.

The online monitoring cloud platform utilizes Alibaba Cloud's IoT platform, and the on-board terminal interfaces with the cloud platform using the MQTT protocol. Upon successful connection, IoT-studio (Alibaba Cloud's application development tool) is used for visual development[18], facilitating the display of monitored data information and the analysis and statistics of the data.

## 3 Design of the system hardware

### 3.1 Selection of the system main control module

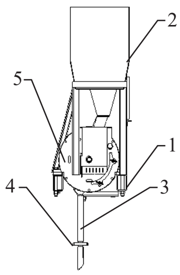
The core part of the system hardware design is the design of the main control module. The operation of the entire monitoring system relies on the control of the main control module, making it essential to choose a suitable main control chip. When selecting a microprocessor, many factors need to be considered, not only from the perspective of hardware interfaces but also regarding the relevant operating systems, supporting development tools, simulation tools, and the engineers' familiarity with the microprocessor and its software support[19].

The online monitoring system for peanut-sowing operation status adopts a master-slave design, with the vehicle-mounted monitoring terminal acting as the master, capable of connecting multiple slave devices (seed-monitoring devices) via an RS485 bus. Based on design requirements, the STM8S003F3P6 was selected as the main control chip for the seed monitoring device. Its internal advanced timer TIM1 has input capture functionality, and the built-in USART interface can be expanded to an RS485 interface, meeting the needs for sensor signal acquisition and communication with the vehicle-mounted monitoring terminal[20]. The main control chip for the vehicle-mounted monitoring terminal is a microprocessor model STM32F103RCT6, which has rich peripheral resources[21]. It can fully meet the functional requirements of the vehicle-mounted terminal and allow for future upgrades and expansions[22].

### 3.2 Hardware design of the seed-sowing monitoring device

The peanut seed-sowing monitoring device is a key component for obtaining seed-sowing information, and it must possess high reliability to adapt to the complex field environment[23]. The peanut seed-metering monitoring device designed in this paper uses a laser window sensor to monitor the acquisition of the key sowing parameter of seed spacing. The detection probe of the laser window sensor is fixed at the tail section of the seed-metering tube and placed at the rear end of the furrow opener. Its installation schematic diagram is shown in Figure 2 below. The transmitting side of the detection probe of the sensor emits strip-shaped infrared light, which can detect opaque objects with a diameter of more than 0.5 mm within the induction area of 20 mm×20 mm. According to the shape of the induction window, a section of square seed-metering tube is specially designed at the installation position of the probe, which is helpful for the dropping of seeds and improves the accuracy of detection.

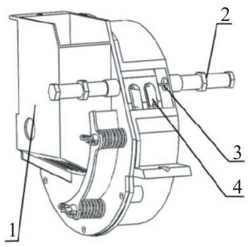
When the seeds falling in the seed-metering tube pass through the detection area of the sensor, due to the shading of the light by the opaque seeds, a certain amount of light shielding is generated, and a sequence of pulse signals representing the seed-metering status is produced. By combining and processing this signal with the advancing speed of the seeder, an important indicator, namely the seed spacing, can be obtained. Moreover, by comparing the amount of light shielding with the set threshold value, the indicators of missed seeding and repeated seeding can be monitored.




1.Frame 2.Seed box 3.Seed guide tube 4.Window fiber sensor 5.Seed dispenser

Figure 2 Installation diagram of laser window sensor

Detecting at the end of the seed-metering outlet using a photoelectric sensor can obtain the important parameter of seed spacing[24]. However, this method has poor accuracy for the missed seeding parameter when the seeder is running at a high speed, and it cannot provide timely feedback[25]. Therefore, in this study, for the missed seeding monitoring, a detection scheme using a photoelectric sensor in the internal cells of the seed-metering disc is further adopted. The transmitting end and the receiving end of the sensor are respectively installed on both sides of the cells of the seed-metering disc. Its installation schematic diagram is shown in Figure 3 below.




1. Seed delivery pipeline 2. Photoelectric sensor 3. Detection hole 4. Seed-metering cell

Figure 3 Installation diagram for missed sowing detection

When the seed-metering disc is in operation, the transmitting end of the opposite-type photoelectric sensor emits an infrared light beam. When the seeds are normally filled, the seeds and the seed-metering disc block the light beam, and there is no signal at the receiving end, with the signal terminal outputting a low level. In the case of missed seeding, the light beam can reach the receiving end, and the signal terminal outputs a high level. By recording the number of times the level is pulled high, the number of missed seeding can be obtained.

### 3.3 Sensor signal acquisition circuit design

The laser opposite reflection sensor and the laser window sensor used in the peanut-sowing operation status monitoring system both output pulse signals, while the temperature and humidity sensor communicates through the $I^2C$ bus.

When the peanut seeds pass through the detection area of the laser window sensor, the signal terminal of this sensor will also output a pulse signal and count to generate a seed-metering time interval sequence. Furthermore, it is integrated with the seed-metering sequence collected by the laser opposite reflection sensor, so as to obtain more accurate seed-metering information. The signal acquisition circuit is shown in Figure 4.

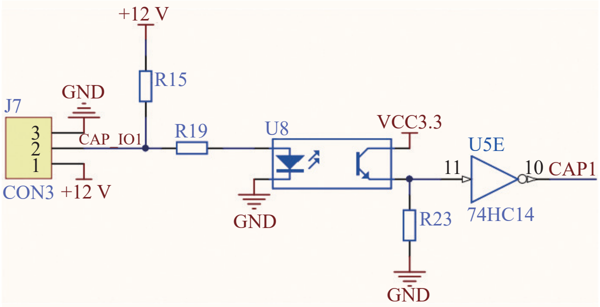



Figure 4 Pulse signal acquisition circuit

During the sowing operation, the transmitting end of the laser through-beam sensor emits an infrared beam. Under normal conditions (when the seed is filled in the hole), the seeds inside the hole completely block the light signal emitted by the transmitting end, and the receiving end of the sensor does not receive the beam signal. As a result, the signal output is low level. After passing through two stages of inversion via the optocoupler TLP281 and the inverter 74HC14, the signal is input to channel 1 pin PC0 of the STM8's advanced timer TIM1. The capture timing period is designed to be 1 MHz, counting the rising edges and measuring the pulse width and frequency through the input capture function. The optocoupler TLP281 can also convert the 12V sensor signal into a signal compatible with the microcontroller's I/O voltage, meeting the level restriction requirements of different main control I/O ports.

### 3.4 Hardware design of the speed measurement and monitoring module

In this design, the incremental Hall effect rotary encoder GTS06-0C-RA1000A-2M from Haide Company is chosen as the speed sensor. It has advantages such as easy installation, low cost, immunity to dust interference, and good stability. The A and B phase outputs of the seed-metering disc speed unit and the traveling wheel speed unit are connected to the STM32 main control I/O port through a pulse signal acquisition circuit. The timer input capture function is then utilized to acquire the pulse signals generated by the encoder's rotation, which are used to calculate the rotational speeds of the seed-metering disc and the traveling wheel.

### 3.5 Design of the human-machine interaction module

The human-machine interaction unit of the on-board monitoring terminal is designed to use the touch screen of Diwen Technology, which can provide users with intuitive sowing data. The human-machine interaction interface of the real-time monitoring system for peanut sowing data is designed through the DGUS software. As shown in Figure 5, the data displayed on the interface includes the advancing speed of the seeder, the seed spacing, the sowing speed, missed seeding information, missed seeding alarms, seed shortage alarms, and other information. Under normal circumstances, the indicator lights for missed seeding and

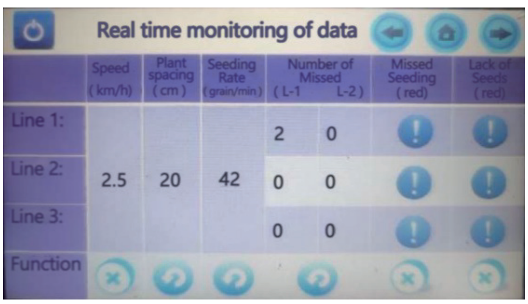



Figure 5 Human-machine interaction interface of the vehicle-mounted terminal

seed shortage are blue. When there is a large amount of missed seeding during sowing or a seed shortage occurs, the indicator lights will turn red.

### 3.6 Selection of wireless communication module

As shown in Figure 6, the wireless communication module serves as the interactive hub connecting the on-board terminal and the cloud platform, making it an essential component of the online monitoring system for the operational status of the peanut planter. It is responsible for facilitating data exchange between the on-board terminal and the remote monitoring platform[26].

The wireless communication module used in this system is the BC35-G module produced by Shanghai Ebyte Communication Technology Co., Ltd. This module is a high-performance, low-power NB-IoT module. It employs power-saving technology, with current consumption as low as 5 $\mu$A in Power Saving Mode (PSM). On one hand, the on-board terminal uploads the collected operational data, environmental parameters, soil parameters, and other information to the remote monitoring platform through this module. On the other hand, commands issued by the user through the remote monitoring platform must also be transmitted to the on-board terminal via this wireless communication module to execute the corresponding actions. As a critical communication hub in the system, the stability of this module's operating status will significantly impact the overall performance of the system[27,28].

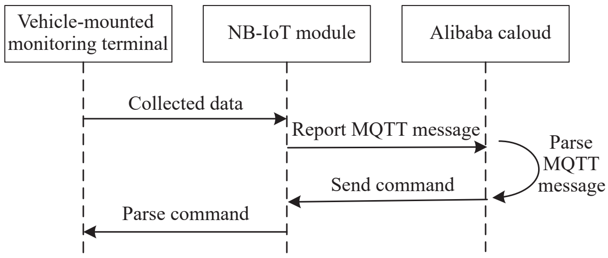



Figure 6 Relationship between vehicle-mounted terminal, NB-IoT module, and Alibaba Cloud platform

## 4 Design of the system software

### 4.1 Overall design of system software

The software design of the monitoring system mainly focuses on the programming of several major functional modules, including the drivers for various peripherals of the system, the collection and processing of sowing operation data, the human-machine interaction interface, and the connection and transmission of the IoT module.

When the system is running normally, the laser opposite reflection sensor and the laser window sensor monitor the sowing operation parameters. When the sensors output detection signals, the main controller needs to quickly recognize these signals and transmit the collected data to the on-board terminal.

The software design of the on-board terminal adopts the programming concept of combining the interrupt mechanism and the timer mechanism, and periodically sends heartbeat packets to the cloud server. The program flow of the monitoring system is shown in Figure 7.

### 4.2 Design of the system seeding monitoring program

The seeding parameters mainly include seeding amount, qualification rate, missed seeding rate, and re-seeding rate, evaluated according to the "GB/T 6973-2005 Test Methods for Single Seed (Precision) Planters".

The seeding monitoring program utilizes the input capture function of a timer to achieve counting and timing functions.

Counting can be used to tally the number of seeds sown, while timing can provide the time interval between two adjacent seeds, allowing for the calculation of the real-time plant spacing based on the tractor's actual forward speed. This helps in determining missed and re-seeding and calculating various parameters. The flowchart of the seeding monitoring program is shown in Figure 8.

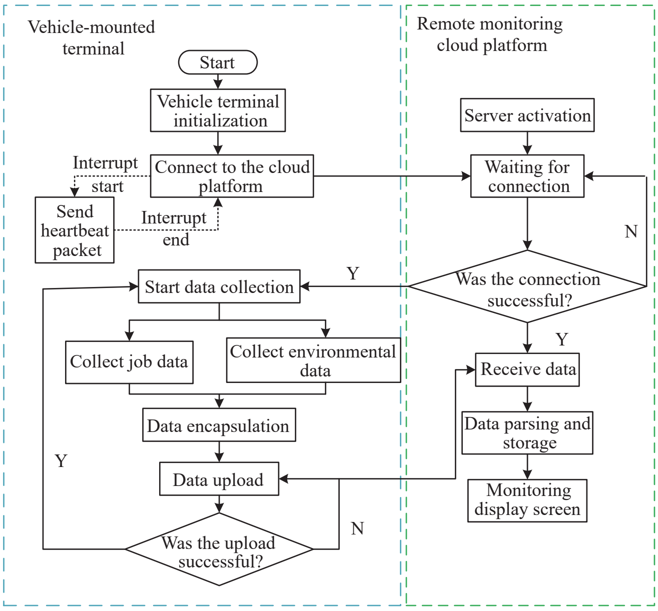



Figure 7 Flowchart of monitoring system program

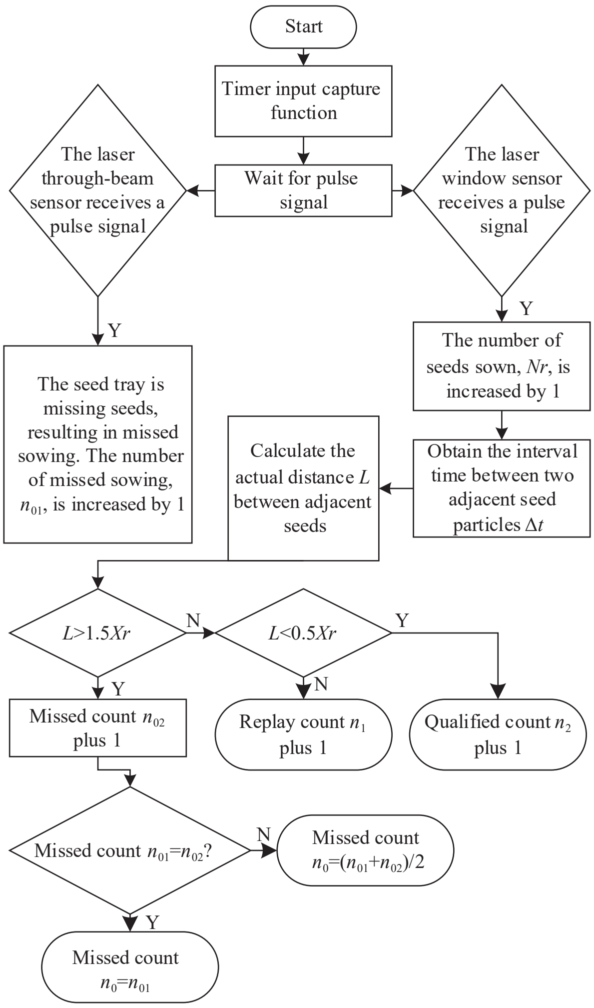



Figure 8 Flowchart of seeding monitoring program

The specific calculation formulas for the missed seeding rate, re-seeding rate, and qualification rate are as follows:

$$M = \frac{n_0}{Nr} \times 100\% \tag{1}$$

$$Q = \frac{n_1}{Nr} \times 100\% \tag{2}$$

$$Y = \frac{n_2}{Nr} \times 100\% \tag{3}$$

where, $n_0$ represents the number of missed seeds; $n_1$ represents the number of re-seeded seeds; $n_2$ represents the number of qualified seeds; and $Nr$ represents the theoretical number of seeds to be sown. The theoretical seed spacing is denoted as $Xr$, and the actual distance between adjacent seeds in the forward direction is $L$. When $L>1.5Xr$, it is considered missed seeding; when $L<0.5Xr$, when $0.5Xr<L<1.5Xr$, it is considered qualified.

### 4.3 Design of seed spacing monitoring program

The speed measurement module mainly includes the seeding disc speed measurement device and the travel wheel speed measurement device. Both devices use the same model of rotary encoder, GTS06-0C-RA1000A-2M. This encoder generates 1000 pulse signals per revolution and has two output pulse signal lines with a phase difference of 90 degrees, referred to as phase A and phase B. The rotation direction is determined by analyzing the phase difference between these signals.

During the speed measurement process, the direction of the encoder is first determined by the phase difference between the two phases A and B. If the direction is correct, the input capture functions of TIM4 and TIM5 are enabled to respectively obtain the pulses output by the walking wheel speed measuring device and the seed disc speed measuring device. A 100 ms timer interrupt is generated using TIM7, during which the received pulses are detected. After accumulating a certain amount of data, the median filtering method is used to remove one minimum and one maximum value, and then the average of this dataset is calculated. This average represents the number of pulses $N$ within the 100 ms period, which is related to the rotational speed $n$ (r/min) measured by the rotary encoder as follows:

$$n = \frac{10N}{1000} \times 60 = 0.6N \tag{4}$$

The working speed of the walking wheel is:

$$v = \pi d \times n/60 = 0.01N \times \pi d \tag{5}$$

Since the sowing disc has 10 seed holes in one rotation, the sowing speed is:

$$V = 10n = 6N \tag{6}$$

where, $v$ represents the working speed of the drive wheel, m/s; $d$ represents the diameter of the drive wheel, m; $V$ represents the sowing speed, seeds/min.

$$\Delta t = \frac{60}{V} \tag{7}$$

The actual distance (cm) between adjacent seeds in the forward direction is:

$$L = 100v \cdot \Delta t \tag{8}$$

### 4.4 Communication module program design

To achieve the online monitoring function of the system, this design uses the NB-IoT wireless communication module to interface with the Alibaba Cloud platform, thereby completing remote communication between the vehicle-mounted terminal and the remote monitoring platform. The wireless communication solution adopted in this design is the BC35-G module. The STM32 microcontroller sends AT commands and data information via Serial Port 3 to implement control and data transmission functions. The communication baud rate between the STM32 and BC35-G is set to 115 200 Bd/s. All AT commands sent by the STM32 start with "AT" and end with "\r\n" (carriage return and line feed). After sending each AT command, the system must wait for a response from the BC35-G module before sending the next command; otherwise, the program flow may become disordered. Therefore, the design of the control program for the BC35-G module adopts a "question-and-answer" programming approach, meaning that after sending an AT command, the response content of that command is parsed, and only after confirming the correctness of the parsing can the next command be sent. The response content from the BC35-G module is line-separated, with each line ending in "\r\n". The end of the response will include either the string "OK" or "ERROR"; "OK" indicates that the command was executed correctly, while "ERROR" indicates that the command was not executed correctly. Some of the AT control commands for the BC35-G module used in this design are listed in Table 1.

**Table 1 Some AT commands used for BC35-G module**

| AT Command | Function |
|---|---|
| AT+CSQ | Retrieve signal strength |
| AT+CGPADDR | Request IP address of the device |
| AT+COPS | Set carrier |
| AT+CGATT | Connect to the base station |
| AT+CIMI | Get IMSI |
| AT+NBAND | Set frequency band |
| AT+NSOCR | Create a TCP or UDP socket |
| AT+NSOSD | Send TCP data |

When controlling the BC35-G module, it is necessary to initialize the module using the corresponding AT commands to facilitate subsequent operations with the cloud platform. First, use the commands "ATE0", "AT+CMEE=1", and "AT+CEREG=1" to turn off the echo mode and specify the format of command responses, making it easier to parse the responses. Then, use the commands "AT+COPS=0", "AT+CSCON=1", and "AT+CGATT=1" for network settings. After that, use the commands "AT+NBAND?", "AT+CSQ", and "AT+CEREG?" to check whether the network status is normal. The specific program control flow for the BC35-G module is shown in Figure 9.

### 4.5 Design of the online monitoring system

After the on-board terminal is connected to the Alibaba Cloud platform, the STM32 main controller packages and sends the collected data to the cloud platform via the NB-IoT module and creates data points in the digital twin model[29,30]. After the platform receives the data, it can perform online monitoring of the device data stream on the Web side in the IoT Studio interface by using the application development editor. The uploaded data is filtered and processed into JSON format by the platform rule engine, and is used to build the online monitoring large-screen interface as shown in Figure 10.

## 5 Monitoring system experimental verification

### 5.1 Experimental equipment and materials

In order to verify the feasibility of the peanut seed-metering parameter monitoring system and the implementation status of each

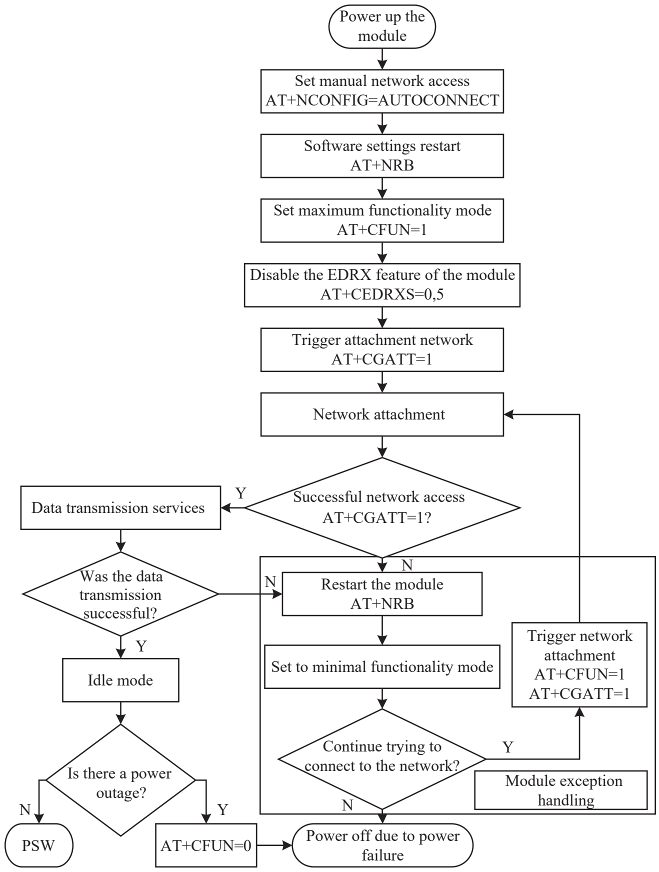


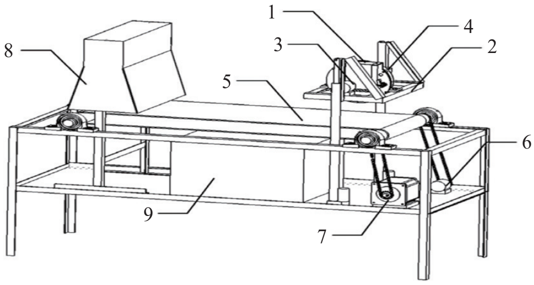

Figure 9 Program control flow of BC35-G module


Figure 10 Data monitoring dashboard of Alibaba Cloud platform

functional module, a peanut-sowing simulation test bench with the structure shown in Figure 11 is designed. The seed-metering disc rotates under the drive of its driving motor to carry out the seed-metering operation. The driving motor of the seedbed belt drives the rotating shaft of the seedbed belt to rotate through a chain, so as to make the seedbed belt move translationally. The test bench simulates the working condition of the seeder during field sowing operation through the relative movement of the seedbed belt. The physical diagram of the test bench is shown in Figure 12, and the experimental effect is shown in Figure 13.

The image acquisition device monitors and counts the peanut seed spacing, missed seeding, and seeding volume, and compares the results with those of the seed-metering monitoring system to verify the accuracy of the sowing parameter monitoring system. The image acquisition effect is shown in Figure 14.

When conducting the sowing parameter monitoring function test, the seed-metering disc, the seedbed belt, and the image acquisition device are controlled through the control panel of the designed upper computer. At the same time, the changes in the running speeds of the seed-metering disc and the seedbed belt are intuitively displayed. The interface of the upper computer of the test bench is shown in Figure 15.




1. Seed distributor 2. Lifting frame 3. Seed-distributing disc speed measurement device 4. Seed-distributing disc drive motor 5. Seedbed belt 6. Seedbed belt speed measurement device 7. Seedbed belt drive motor 8. Image acquisition device 9. Control box

Figure 11 Schematic diagram of peanut seeder simulation test bed structure

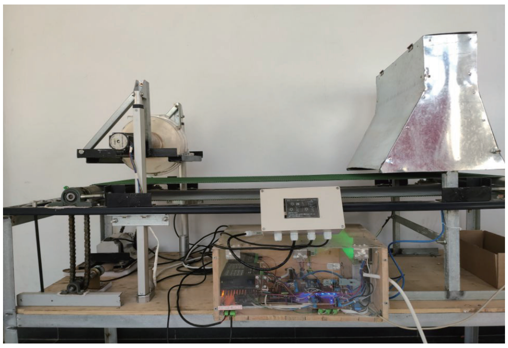


Figure 12 Sowing parameter monitoring test bench

Figure 13 Experimental results of test platform

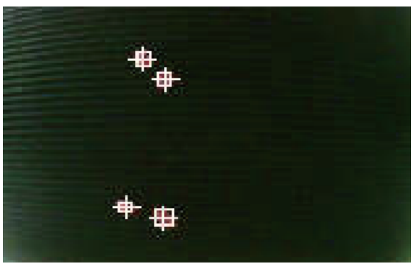


Figure 14 Image acquisition results

### 5.2 Seeding monitoring system experiments and results

For the system test, 200 peanut seeds of the variety "Huayu 16" with a length of 10-15 mm and a diameter of 5-7 mm are used as the test materials. The experimental effect of the test bench simulating the sowing operation is shown as follows.

Considering that the peanut seeder has a certain working speed range during actual sowing operations, seven moving speeds of the seedbed belt are selected to simulate the vehicle speeds of the peanut seeding operation for testing under three different sowing seed spacings of 150 mm, 200 mm, and 250 mm, which are 2 km/h, 2.5 km/h, 3 km/h, 3.5 km/h, 4 km/h, 4.5 km/h, and 5 km/h.


Figure 15 Upper computer interface of test bench

The operation of the seed-metering device is controlled by setting different speed parameters to test the seed-metering monitoring module. The monitored parameters are the seed spacing, seeding volume, and missed seeding situation. The experiment is repeated four times and the data is recorded. After organizing all the experimental data, the experimental results in Table 2 are obtained.

**Table 2 Experimental results of sowing parameter monitoring module of system**

| Speed/ $kg\cdot h^{-1}$ | Set planting spacing/mm | Qualified rate of planting spacing/% | Monitoring accuracy rate/% | Seeding volume monitoring accuracy rate/% |
|---|---|---|---|---|
| 2.0 | 150 | 99.95 | 99.89 | 98.17 |
| | 200 | 98.92 | 99.87 | 98.63 |
| | 250 | 98.80 | 99.95 | 98.68 |
| 2.5 | 150 | 98.33 | 100 | 98.72 |
| | 200 | 99.26 | 100 | 98.78 |
| | 250 | 98.52 | 99.32 | 98.27 |
| 3.0 | 150 | 98.02 | 99.67 | 98.56 |
| | 200 | 98.00 | 99.86 | 98.37 |
| | 250 | 98.90 | 100 | 98.66 |
| 3.5 | 150 | 99.22 | 99.84 | 98.21 |
| | 200 | 98.80 | 99.84 | 98.86 |
| | 250 | 98.55 | 99.62 | 98.15 |
| 4.0 | 150 | 98.21 | 99.87 | 98.22 |
| | 200 | 99.65 | 100 | 98.19 |
| | 250 | 98.80 | 99.85 | 98.52 |
| 4.5 | 150 | 98.71 | 99.96 | 98.44 |
| | 200 | 98.48 | 99.63 | 98.16 |
| | 250 | 98.15 | 99.97 | 98.52 |
| 5.0 | 150 | 98.17 | 99.76 | 98.63 |
| | 200 | 98.57 | 99.95 | 98.56 |
| | 250 | 98.61 | 99.88 | 98.03 |

Through data analysis, it can be concluded that when the working speed of the seeder is between 2 and 5 km/h, the seed-metering monitoring module of the system can maintain the accuracy rate of seed spacing monitoring above 98.02%. The better the monitoring effect is, the minimum accuracy rate of seeding volume detection can be controlled above 98.03%, which shows good monitoring accuracy. The accuracy rate of missed seeding monitoring can reach above 99%, indicating extremely high monitoring precision.

### 5.3 Field test design

In order to further verify the practical application effect of the online monitoring system for sowing parameters, based on the 2MB-2/4X two-ridge and four-row summer peanut seeder, the seed-metering monitoring system is installed on the platform for field tests. At the same time, "Huayu 16" peanut seeds are selected for sowing to carry out field tests, and the field test situation is shown in Figure 16.

Figure 16 Field test photograph

During the field test, the tests are carried out according to the traditional peanut sowing seed spacings of 16 cm, 20 cm, and 27 cm. The advancing speed of the seeder is set in three intervals: 2-3 km/h, 3-4 km/h, and 4-5 km/h. Each group of experiments is repeated three times and the average value is calculated. The actual measurement method of the sowing effect is adopted, as shown in Figure 17. The actual seed spacing of 250 peanut seeds is continuously measured, the seeding volume is calculated, and the missed seeding rate is checked. These are then compared with the measured values of the seed-metering monitoring system to verify the accuracy of the seed-metering detection module. At the same time as the experiment, the implementation effect of the online monitoring module is tested.

Figure 17 Photograph of actual measurement of seed metering

### 5.4 Analysis of field test results

The experimental results are listed in Table 3. When sowing with seed spacings of 16 cm and 20 cm, the sowing effect is relatively good and is less affected by the working speed. The accuracy rate of seed spacing monitoring is around 98%. When the seed spacing is 27 cm, the faster the working speed, the lower the accuracy rate, but it still remains above 97%.

When conducting field tests under the three set seed spacings and working speeds, the accuracy rates of missed seeding detection and seeding volume monitoring decreased slightly, which may be caused by the influence of field vibrations. However, the accuracy rates of missed seeding monitoring and seeding volume detection can still reach above 98%.

**Table 3 Experimental results of sowing parameter monitoring module of system**

| Speed/ $kg \cdot h^{-1}$ | Set planting spacing/mm | Qualified rate of planting spacing/% | Monitoring accuracy rate/% | Seeding volume monitoring accuracy rate/% |
|---|---|---|---|---|
| 2-3 | 160 | 99.04 | 99.35 | 98.68 |
| | 200 | 97.45 | 98.87 | 98.53 |
| | 270 | 97.27 | 99.65 | 98.42 |
| 3-4 | 160 | 98.59 | 100 | 98.37 |
| | 200 | 98.32 | 99.10 | 98.43 |
| | 270 | 97.87 | 99.32 | 98.75 |
| 4-5 | 160 | 98.71 | 98.67 | 98.03 |
| | 200 | 97.95 | 98.86 | 98.27 |
| | 270 | 97.54 | 98.90 | 98.39 |

The data transmission test of the wireless monitoring module is shown in Figure 18. The data acquisition module of the on-board terminal is working normally. The NB-IoT wireless communication module carried by it can accurately realize the data transmission between the on-board terminal and the cloud platform. Moreover, with the help of the Alibaba Cloud platform, the historical data of each digital twin model at any time period can be accurately viewed.

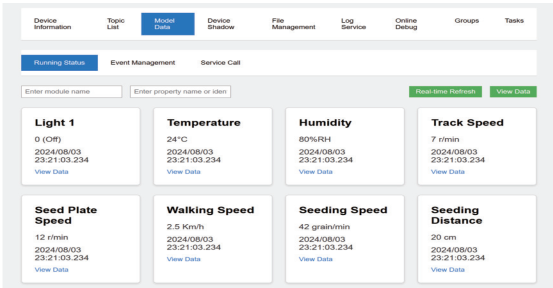



Figure 18 Online monitoring interface of sowing parameters

In summary, through the overall function test of the online monitoring system for the operation status of the peanut seeder, the detection devices such as the designed seed-metering disc speed measurement unit, traveling wheel speed measurement unit, and seed-metering detection unit have good working performance, which can meet the functional requirements and accuracy requirements for monitoring the parameters of peanut seeding operations. Each functional module of the online monitoring system for peanut seeding parameters operates well and meets the application requirements for online monitoring of the operation status of peanut seeding operations.

## 6 Conclusions

1) The online monitoring system for peanut seeding parameters is composed of the peanut seed- metering monitoring device, the on-board monitoring terminal, and the online monitoring cloud platform. It realizes the monitoring of various seeding parameters such as seed spacing, seeding volume, missed seeding situation, vehicle speed, temperature and humidity, etc. Data is transmitted to the online monitoring cloud platform through RS485 and Internet of Things communication, enabling the development of data visualization as well as analysis and statistics.

2) A peanut seeding simulation test bench was set up. Through comparison with the image acquisition device, tests were carried out under different seed spacings and vehicle speeds. The results show that the accuracy rate of seed spacing monitoring of the system's seed-metering monitoring module exceeds 98.02%, the accuracy

rate of seeding volume detection exceeds 98.03%, and the accuracy rate of missed seeding monitoring exceeds 99%.

3) Field tests were carried out based on actual seeders, and tests were conducted according to different seed spacings and speeds. The results show that the monitoring effect is better when the seed spacing is 16 cm and 20 cm. When the seed spacing is 27 cm, the faster the speed, the lower the accuracy rate, but it still remains above 97%. Although the accuracy rates of missed seeding and seeding volume monitoring are slightly reduced due to the influence of field vibrations, they still exceed 98%, and the data transmission of the wireless monitoring module is normal. In conclusion, each detection device and functional module of this system has good working performance, meeting the functional requirements and accuracy requirements for the online monitoring of peanut seeding operation parameters.

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## [References]

[1] Zhao S C, Lyu J L, Xu X P, Lin X M, Luiz M R, Qiu S J, et al. Peanut yield, nutrient uptake and nutrient requirements in different regions of China. Journal of Integrative Agriculture, 2021; 20(9): 2502–2511.

[2] Zhang J L, Yun G, Feng G, Li X G, Wan S B. Research progress on the mechanism of improving peanut yield by single-seed precision sowing. Journal of Integrative Agriculture, 2020; 19(8): 1919–1927.

[3] de Almeida Moreira B R, Marra T M, da Silva E A, de Brito Filho A L, Júnior M R B, dos Santos A F, et al. Advancements in peanut mechanization: Implications for sustainable agriculture. Agricultural Systems, 2024; 215: 103868.

[4] Yu Y, Hu Y, Shang S, Diao L, Ge R, Zhang X. Design of motor-driven precision seed-metering device with improved fuzzy PID controller for small peanut planters. Int J Agric & Biol Eng, 2023; 16(1): 136–144.

[5] Zhang X, Yi K. Monitoring and performance analysis of seed sowing using photoelectric sensing. Journal of Nanoelectronics and Optoelectronics, 2022; 17(3): 418–26. doi: 10.1166/ jno.2022.3209

[6] Kostić M, Rakić D, Radomirović D, Savin L, Dedović N, Crnojević V, et al. Corn seeding process fault cause analysis based on a theoretical and experimental approach. Computers and Electronics in Agriculture, 2018; 151: 207–218.

[7] Moreno FG, Zimmermann G G, Jasper S P, da Silva Ferraz R, Savi D. Sensors installation position and its interference on the precision of monitoring maize sowing. Smart Agricultural Technology, 2023; 4: 100150.

[8] Liu X, Wang Z, Wu G, Zheng Y. Monitoring and controlling system of maize precision sowing and fertilization based on embedded technology. Proceedings of the 2017 ASABE Annual International Meeting, 2017. doi:10.13031/aim.201700783

[9] Bai S, Yuan Y, Niu K, Shi Z, Zhou L, Zhao B, et al. Design and experiment of a sowing quality monitoring system of cotton precision hill-drop planters. Agriculture, 2022; 12(8): 1117.

[10] Wang G P, Yang X P, Sun W, Liu Y, Wang C J, Zhang H, et al. Potato seed-metering monitoring and improved missseeding catching-up compensation control system using spatial capacitance sensor. Int J Agric & Biol Eng, 2024; 17(4): 255–264.

[11] Gao Y Y, Wang X, Yang S, Zhai C Y, Zhao X G, Zhao C J. Development of CAN-based sowing depth monitoring and evaluation system. Transactions of the CSAM, 2019; 50(12): 23–32.

[12] Zhao X, Chen L, Gao Y, Yang S, Zhai C. Optimization method for accurate positioning seeding based on sowing decision. Int J Agric & Biol Eng, 2021; 14(3): 171–180.

[13] Zhang C, Xie X, Zheng Z, Wu X, Wang W, Chen L. A plant unit relates to missing seeding detection and reseeding for maize precision seeding. Agriculture, 2022; 12(10): 1634. doi:10.3390/ agriculture12101634

[14] Swapnil T, Kasturi M, Girish P, Rajkumar P. Development and test of an electric precision seeder for small-size vegetable seeds. Int J Agric & Biol Eng, 2019; 12(2): 75–81.

[15] Yin Y, Chen L, Meng Z, Li B, Luo C, Fu W, et al. Design and evaluation of a maize monitoring system for precision planting. Int J Agric & Biol Eng, 2018; 11(4): 186–192.

[16] Chen K K, Zhao B, Zhou L M, Wang L L, Wang Y H, Yuan Y W, et al. Real-time missed seeding monitoring planter based on ring-type capacitance detection sensor. Inmateh-Agricultural Engineering, 2021; 64(2): 279–288.

[17] Fan Y Q, Yu Y, Shang S Q, Gu T Y, Hu Y R, Diao L S, et al. Development of the peanut precision fertilization control system based on threshold velocity algorithm. Int J Agric & Biol Eng, 2022; 15(5): 116–122.

[18] Xu M X, Yang L, Wang Y, Gao C X, Wen L F, Xu G Y, et al. Practice of Alibaba cloud on elastic resource provisioning for large-scale microservices cluster. Software: Practice and Experience, 2024; 54(1): 39–57.

[19] Kumar P, Ashok G. Design and fabrication of smart seed sowing robot. Materials Today: Proceedings, 2021; 39: 354–358. doi:10.1016/j.matpr. 2020.07.43

[20] Qu X L, Liu S Z, Fu S, He H, Hu Y, Xiao L Y. Design and implementation of wireless environment monitoring system based on STM32. Scientific Programming, 2021; 2021: 6070664.

[21] Yang F, Wei Q. Design of smart home control system of internet of things based on STM32; proceedings of the Journal of Physics: Conference Series, F, 2021. IOP Publishing. doi: 10.1088/1742-6596/1972/1/012002

[22] Patrik J, Matej B, Irena K, Ján M, Tibor V, Jozef D, et al. Remote IoT education laboratory for microcontrollers based on the STM32 chips. Sensors, 2022; 22(4): 1440.

[23] Nardon G F, Botta G F. Prospective study of the technology for evaluating and measuring in-row seed spacing for precision planting: A review. Spanish Journal of Agricultural Research, 2022; 20(4): e02R1–eR1.

[24] Liu J, Shi Y, Meng D S, Liu Z F. Design and performance analysis of monitoring system for seed metering and fertilization of precision seeder based on photoelectric sensor. Journal of Nanoelectronics and Optoelectronics, 2023; 18(8): 971–977.

[25] Tang H, Xu C S, Wang Z M, Wang Q, Wang J W. Optimized design, monitoring system development and experiment for a long-belt finger-clip precision corn seed metering device. Frontiers in Plant Science, 2022; 13: 814747.

[26] Prakash C, Singh L P, Gupta A, Lohan S K. Advancements in smart farming: A comprehensive review of IoT, wireless communication, sensors, and hardware for agricultural automation. Sensors and Actuators A: Physical, 2023; 114605. doi:10.1016/j.sna.2023.114605

[27] Huan J, Li H, Wu F, Cao W J. Design of water quality monitoring system for aquaculture ponds based on NB-IoT. Aquacultural Engineering, 2020; 90: 102088.

[28] Valecce G, Petruzzi P, Strazzella S, Grieco L A. NB-IoT for smart agriculture: Experiments from the field. In: Proceedings of the 2020 7th International Conference on Control, Decision and Information Technologies (CoDIT), 2020; IEEE. doi:10.1109/CoDIT49905.2020. 9263860

[29] Ping H, Wang J H, Ma Z H, Du Y F. Mini-review of application of IoT technology in monitoring agricultural products quality and safety. Int J Agric & Biol Eng, 2018; 11(5): 35–45. doi:10.25165/j.ijabe.20181105. 3092

[30] Mohamed T M K, Gao J M, Tunio M. Development and experiment of the intelligent control system for rhizosphere temperature of aeroponic lettuce via the Internet of Things. Int J Agric & Biol Eng, 2022; 15(3): 225–233.