Development and test of an electric precision seeder for small-size vegetable seeds

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Abstract: An electric seeder for small-size vegetable seeds was designed based on the power drive and the optical fiber detection technology. The seeder is driven by electric power during the sowing process. At the same time, using the fiber sensor technology to monitor the sowing condition, the seeder is more efficient with high seeding precision in terms of different seed sizes. In order to achieve the precision seeding for the 2-10 mm seeds, the driving motor is equipped in the rear crackle. The power drive reduces pollution and dyeing. Also the other components of the electric seeder were modularly designed. The seeder was designed with buckle, which could be quickly disassembled on the sowing machine to replace the sowing wheel. It can quickly adjust row spacing and sowing depth during sowing process to meet the requirements of agricultural planting. Field test was carried out for coriander, pakchoi, and radish on the accuracy and monitoring of the system, respectively. The results showed that during the field operation, the sowing precision of the sowing machine was 95%. When the seeder worked at the speeds of 3 km/h and 4 km/h, the relative error of the monitoring precision of the system was less than 6%. This system can meet the real-time monitoring requirements of the seed metering device and improve the quality of the sowing work.
Keywords: precision seeding, electric seeder, nest eyed sowing wheel, electric power drive, field test, vegetable seed
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1 Introduction

Small seeds usually refer to seeds with an average diameter of less than 3 mm, including most of the seeds of vegetables, flowers and rape, such as tomatoes, chili, radish, carrot, and other vegetable seeds, with flattened and villous surfaces. The seeds of rape are approximately spherical in average diameter of 1.8-2.0 mm. After drying, the seed epidermis has wrinkles, high oil content and easy to break. The reason for its inconvenient sowing is due to the small diameter, small weight and irregular shape of the vegetable seed. Therefore, it is difficult to develop the precision seeder of small grain seed. According to the agricultural requirement, precision seeding can ensure the most rational distribution of seeds in the field. The precision of seed sowing, the uniform spacing of the plant, the same sowing depth, and the best conditions for the growth and development of the seeds, can save a lot of seeds and ensure the stable yield and high yield of the crops.

In view of the problem that small seeds vegetable seeds are not easy for mechanized sowing at present, an electric sowing machine is designed in this paper. By using the matching sowing wheel according to the diameter of different seed, the seed sowing is realized for small grain seeds such as vegetables. On the other hand, the field test is conducted to validate the seeding precision and quality of the seeding machine. The machine improves the quality of field operation and improves the monitoring accuracy of seeding effect.

Some experts and scholars have adopted high and new technology such as satellite positioning system, geographic information system and remote sensing technology in the development of precision seeder. It has made full research on sowing device, and can realize automatic, intellectualized and informational[1-4] of the sowing machine in turn. Kim et al.[5] uses photoelectric sensors, infrared light emitting diodes to monitor seeding leakage. The photoelectric detection cost is low, the system is simple and widely used, but it is difficult to detect seeds with diameter less than 4 mm by traditional photoelectric detection technology. Maleki et al.[6] studied the improvement of the seed uniformity of the mechanical seeder with a composite spiral device. Meanwhile, the depth, width, outer diameter and angular velocity of the spiral slots were studied. The best combination parameter is obtained by test, which solves the problem of uneven seed flow pulsation. The Gaspardo V20 and MaterMacc series seeder in the United States is designed for small seed crops[7]. It can be used for direct seeding of small and irregular vegetable seeds, including carrots, onions, and gamma rays. And the single grain sowing can be realized. Anantachar et al.[8] established the model of sowing speed, seed spacing and seed damage rate and proposed the use of artificial neural network to predict the performance parameters of seed metering device. The result showed that the artificial neural network model could better predict the performance parameters of the seed metering device than the statistical model. Grewal et al.[9]

studied the performance of the six rows inclined ring-inlet onion seeder at different rotational speeds and the number of slot holes. The replay rate, the leakage rate, and the seed qualification rate were validated as the index. The feasibility of the machine was verified by field test. Karayel et al.[10] detected the uniformity of the seed arrangement and the speed of the seed falling in the room by high speed camera system, which achieved good results compared with the results of the canvas belt detection method. In further research, automated image processing will play more important roles. Abdolahzare et al.[11] determined the relationship between the most important operating parameters and the physical properties of the seeding machine. The regression model obtained by the GP algorithm has a higher determination coefficient compared with the conventional regression model. Singh et al.[12] studied the influences of seed disc speed, vacuum degree and shape hole shape on seed spacing, seed variation coefficient, leakage rate, and qualified rate. The regression equation of the rotation speed and vacuum degree of the disks was further iterated and optimized, and the similarity of the iteration results was verified by test. Zhan et al.[13] used mean shift algorithm and high-speed camera system to analyze the movement of seed. The uniformity of seed metering was optimized by changing the working parameters of the seed metering device. The trajectory of the rape seed is simulated by CFD soft, and the reliability of the numerical analysis is verified by test. Al-chanatis et al.[14] developed a high resolution optical system for detecting the performance of the seeder. The point and distance of the seed can be transmitted to the computer online by the image acquisition card and the linear scanning camera. The distribution parameters of the seeds can be calculated and displayed online, and the optical system is compared with the results of the canvas belt detection. The results of the two tests were similar. Chen et al.[15] identified the structural parameters of the belt type seeding device through the structural design and theoretical analysis of the belt type seeding device. The seeding quality and performance indexes were calculated respectively. The primary and secondary factors affecting the quality of seed metering were obtained through test, and the optimal combination parameters were determined. Cong et al.[16] designed a kind of rapeseed-wheat combined pneumatic seeder. Through the replacement of seed disks, the precision sowing of two kinds of crops can be realized. Through test, the influences of the rotation speed of the seed disks, the negative pressure in the seed suction area and the positive pressure of the planting area on the seed metering performance were obtained. Liu et al.[17] designed a kind of sensor without blind area detection. By comparing the results of sensor detection and artificial detection, the sensor can detect the performance of seed metering accurately. Zhang et al.[18] used piezoelectric principle to count seeds and detect seedling leakage by using ceramic slices, and selected suitable polymer materials and installation methods, transformed the short-term impact of seeds into a single peak voltage signal, and completes the accurate counting of seeds. However, under complex field conditions, it cannot achieve better monitoring effect. Chen et al.[19] studied the performance of seed metering using high speed camera technology through the detection of the position of the seed centroid and area, it is close to the result of artificial detection. Huang et al.[20] studied the performance index and the real-time monitoring of the operation situation based on the physical characteristics of piezoelectric film sensor. By analyzing the performance indexes of the seed metering device, Liao et al.[21,22] carried out the single factor tests and orthogonal tests on the speed of the seed disks and the speed of the seed belt. Finally, the optimal

parameter combination of the best performance of the seeder was achieved. Zhou et al.[23] used capacitance method to detect the sowing state, and realized the function for seeding quality detection through the conversion of charge signals.

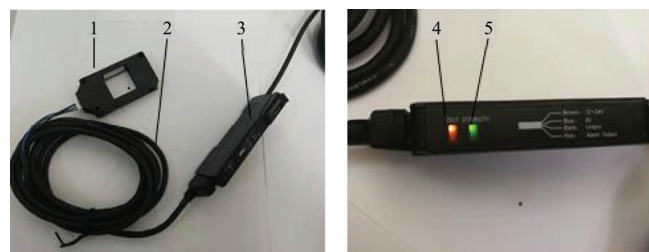## 2   Monitoring system design

The optical fiber monitoring technology has been used in sowing quality monitoring system, which has the function of leakage alarm and sowing counting. It is suitable for monitoring sowing machine of small seeds such as cilantra, cabbage, and radish. The sowing quality monitoring system is mainly composed of Holzer speed measuring sensor, sowing monitoring fiber sensor, upper computer and etc.

2.1   Holzer velocity measurement sensor

In order to obtain the speed of the sowing work accurately, Holzer sensor and the matching magnetic steel were used to realize the speed measuring function of the system. The Holzer velocity sensor is installed near the drive shaft rack, and a magnet is installed in the drive shaft. When the Holzer sensor and the magnetic steel are close, the pulse signal is generated, which is formed through the inside of the controller. The rotation speed of the seed shaft is calculated and the speed of seeding operation is obtained.

2.2   Sowing monitoring sensor

In view of the small seed diameter, the sowing monitoring sensor used optical fiber sensor, and the detection area is 4 cm×4 cm. The feature of the surface coverage can realize the function of the pass detection and effectively detect the small grain seeds. Through the adjustable amplifier, the sensitivity of the seeds with different diameters can be monitored and the sensor detection can be increased. The detection range was 1.5-5.0 mm, and the response time is 200 us, as shown in Figure 1. The sowing monitoring sensor mainly consists of the detection head, the amplifier and the transmission line. The detection head is mainly used for the detection of the passing of the seeds. The pulse signal (action) indicating lamp will be scintillation, and the green lamp is stable indicating lamp. The amplifier mainly transfers the detection signal to the controller. In the process of signal transmission, the seed dropping is monitored by the sensor and the pulse signal is received. The signal is converted by the controller and transmitted to the host computer to realize the counting function. The sensor is installed at the seed metering port of the lower end of the seeder, fixed in the inner side of the ditch opener, and passes through the sensor detection head with a transparent PVC tube, so as to facilitate the detection of seed dropping.

1. Detection head   2. Signal transmission line   3. Amplifier   4. Pulse alarm lamp   5. Power supply lamp

Figure 1   Sowing quality monitoring sensor

2.3   Computer system design

The host computer software mainly includes two parts: the main program flow and the system process. The main program flow includes communication parameter setting, initial parameters, preset, pulse area calculation, seed metering statistics, missing broadcast

judgment and display. The calculation of row spacing is achieved by searching 2 adjacent peak intervals and multiplying the speed of the machine. Peak detection is used to complete 2 adjacent pulses peak search and time detection. The algorithm mainly detects the peak point of pulse, because it passes through the maximum value of the increment and descending increment in the pulse waveform. The main program flow is shown in Figure 2. When the system initializes the setting, it begins to receive the data of the controller and makes a judgment. If the alarm code for the leak alarm is executed, the alarm display is executed. If the seed flow pulse signal is triggered, the traveling distance is calculated through the pulse. The leakage is judged according to the actual particle distance and the theoretical grain distance, and the normal sowing amount is counted.
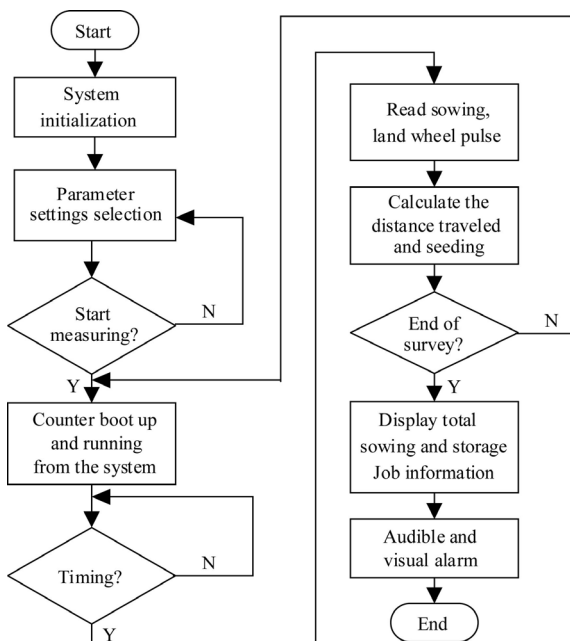

Figure 2　Flow chart of master system software

From the system software process, as shown in Figure 3, it is mainly to transfer the detection process. First, after the initialization of system, it waits to receive the instruction information from the host computer and sends out commands. The microcontroller starts the work of each detection sensor, and the selection of the data information. The work of each controller is detected circularly. When a seed is passed in the pipework, the pulse signal is transmitted, and the counting and monitoring of the leakage are started. When a seeder is missed, the sound and light alarm is triggered by the single chip microcomputer. The microcontroller will respond to the serial interrupt in time, and the display subroutine information is collected in the interrupt program. The fault pipework and the fault information are displayed.

The monitoring system (as shown in Figure 4) can realize the functions of operation control of seeding machine starting or stopping, selection of sowing wheels for different seeds by using intelligent recognition. First, the diameter of different seeds and the sowing wheel are matched to be stored inside the system. When sowing, the seeding wheel should be identified when sowing to different seeds. When the sowing wheel is working, the seed type of the wheel can be displayed, The system can display the seeding conditions for different seeders, including seeding counting and zero clearing functions. The detection of missing seeding is equipped with alarm function. When missing seeding occurs, the indicator lights flicker and the seeding pipes display. and the system can also

display the sowing condition, including leakage monitoring and sowing number. The system structure is humanization design, and easy to use.
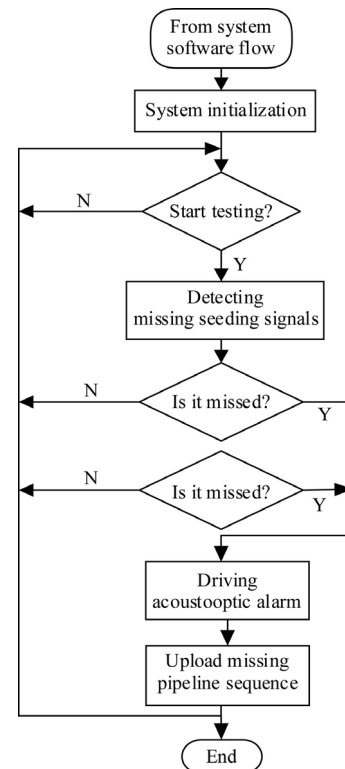

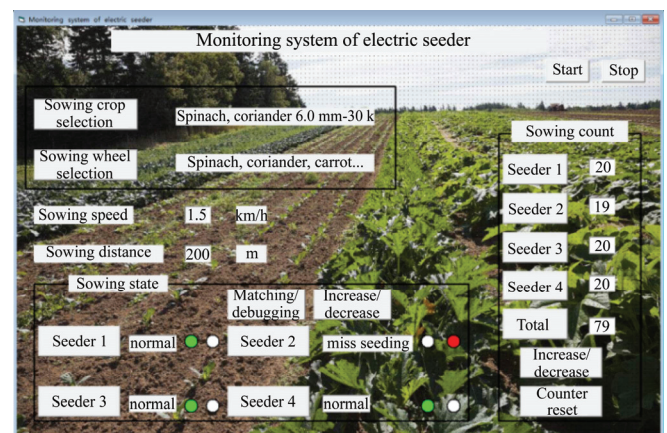Figure 3　Flow chart of the slave system

Figure 4　User interface of the monitoring system

## 3　Structure composition and working principle

As shown in Figure 5, the electric seeder is mainly composed of rack, front and back repression wheel, seeder, power supply box, trench opener, earth cladding device, speed regulation controller, etc. The front roller is connected with the sowing drive shaft by the chains to drive the seeder chains to rotate. The internal frequency conversion motor can adjust the walking speed by the governor. The seeder includes the box, the sowing wheel, the drive shaft, etc. It is fixed on the bottom case. The power supply box is located on the sower to place a 48 V battery, which is the power for the electric seeder and the monitoring system. The ditching device adopts a boot type ditching device, which is located at the lower end of the seed outlet and can facilitate seeds to fall into the ditch. The cladding is located at the rear end of the ditching device, and is fixed on the overall structure of the trenching device. The speed regulation knob is located at the upper end of the rack

handrail.

The machine uses a powerful brushless DC power motor. The motor is installed in the rear wheel through the rear axle and bushing, and it can adjust the moving speed to provide the running power for the whole machine to save labor and improve the efficiency. The seeder can be installed on the drive shaft for easy movement according to the grain spacing of different crops. The trenching device can adjust the depth of the ditch flexibly according to the requirements. Repressing rubber wheel is used to cover the earth back. Electric seeding machine and seeding quality monitoring system can realize precision seeding and monitoring seeding quality of seeds with different diameters, respectively. In the course of operation, the gully, seeding, soil covering and suppression can be completed at one time. At the same time, the optical fiber sensor is used as the detection sensor to monitor the sowing quality. Electric seeder system block diagram is shown as Figure 6.

Main technical parameters are power supply 48 V, sowing line number 1-6 line, row distance 80-450 mm, sowing depth 0-6 cm, diameter 1.5-12 mm nest wheel, external dimension (long × wide × high) 57 cm ×48 cm×90 cm, operation speed 1-8 km/h.
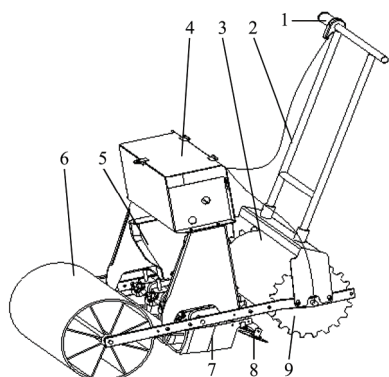
a. Overall structure sketch

b. Overview of prototype

1. Speed governing knob   2. Rack   3. Rear repression wheel   4. Power supply box   5. Seeder   6. Front pressing wheel
7. Ditching device   8. Earthing device   9. Built-in drive motor

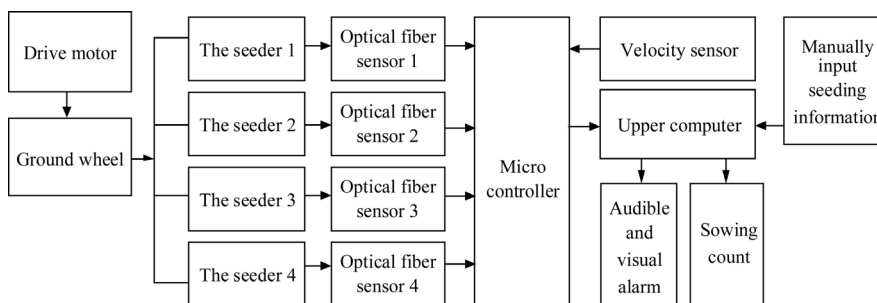Figure 5   Electric precision seeder for small vegetable seeds

Figure 6   Block diagram of electric seeder system

3.1   Working principle

When the electric seeder is working, the speed of the machine can be adjusted quickly by the governor on the walking frame. The motor drives the repressing wheel forward, while the seedling shaft is driven by the front wheel. The former wheel will suppress the soil and the soil will be compacted. The front section of the trench opener is completed. The seed sowed by the machine will fall into the field accurately. The drive shaft drives the rotation of the seeding sprocket. The seeding wheel shaft transfers the power to the seeding device through the gear drive, drives the seeding device shaft to rotate, and completes the seeding operation. The earth-covering device covers the seed-ditch, and the second suppression of the seed sides is carried out after the second repressing of the seed. The two sides of the seed are in full contact with the soil, and the upper soil of the seed remains soft, which is beneficial to the emergence of the seed. After the compaction is over, repressing wheel completes the whole operation of ditching, seeding, soil covering, and suppression. When the seeding monitoring device works, the system can be started by the host computer first. During the seeding process, the monitoring sensor can count the seeds, and when the missing seeding occurs, the monitoring system can display the seeding situation and seeding number, and complete the entire monitoring function.

3.2   Sowing ditching and cladding soil device

As shown in Figure 7, the sowing and furrow soil covering device is mainly composed of a connecting frame, a boat type ditching device, a soil covering plate, an adjustable furrow, a deep shallow column, etc. The trenching device is fixed mainly through the active bolt in the front of the seeder rack front beam. The cladding plate is installed at the back end of the ditch opener. The two parts together make up the sowing machine to cover the soil. In order to make the structure of the machine more compact, the trenching and covering devices are integrated. The appearance and structure are lighter.
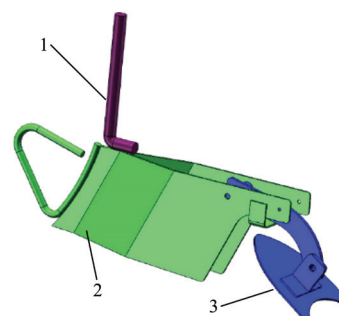
1. Ditching depth adjustment column   2. Ship type opener   3. Cover plate

Figure 7   Drenching and overlaying equipment

The planter can be used for sowing different vegetable grains. The trench opener can adjust the different depth to better adapt to the sowing depth for different crops. By fastening bolts and scale to position, seeding depth can be in 0-60 mm. The triangle frame is installed in the front section of the trench opener, which can effectively prevent the twining of weeds in the field. The rear end can be installed with movable soil clad plate, which can be used to adjust the soil strength.

3.3 Sowing unit

The seeding unit of electric seeder mainly consists of seeding device, seeding axle, and movable bottom case.

3.3.1 Structure of seeder

As shown in Figure 8, the seeding device is mainly composed of seedbox, Shaft-holding piece, fixing pin, drive shaft, and butterfly bolt.

a. Sower device   b. Sowing wheel

c. Different type of seeds available for sowing   d. Seeds in the sowing wheel
1. Seed box   2. Shaft-holding piece   3. Fixed pin   4. Seeder clasp   5. Bottom case   6. Butterfly shaped bolt   7. Trigger for ditching depth   8. Sowing drive shaft

Figure 8   Socket wheel seeder

The electric seeder uses the hole wheel type seeding wheel to carry on the seeding operation to the small seed, because the seed size is different, may choose the different size seeding wheel, realizes the matching seeding. as shown in Figure 7. The machine only sows seed when driving forward, and not sowing when backward, which reduces the waste of seeds. The power is transmitted through the drive shaft to the sowing wheel, and the seeding wheel is driven to sow. There are several grooves on the seeding wheel, which were designed according to seed diameter. When the wheel rotates, the seeds fall into the grooves. At the same time, the seed grain rotates with the seeding wheel and falls into the planting area through gravity. In the process of sowing, the seeding wheel is the most important part of the machine. Not only can the size of the grooves be adjusted according to the seed size, but also the seeding wheel can be changed, and the seeding operation of different seeds can be realized. At the same time, it can effectively reduce the redundancy sowing phenomenon. When the seed metering device is rotated, the seed enters the nest with its own gravity and collision force. After the brush clearance, the seeds enter into the protection area, and the seed falls from the hole after the protection board leaves the protection area.
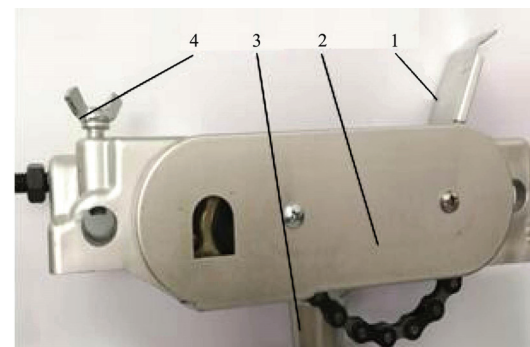
3.3.2 Bottom case of seed metering device

The front and back ends of the seed metering device base are mounted on the rack through the front bracket shaft and the rear drive shaft of the rack. The bottom of the base is designed as conical shape as shown in Figure 9. It can make the seed fall into the seeding orifice effectively and sow accurately. The sowing spacing can be adjusted between 1 and 4 rows according to requirements, with minimum of 6 cm. The seeding wheel shaft is mounted inside the seeding wheel of the seeding apparatus. The seeding wheel shaft is mounted on the rack through the housing. The salve seeding sprocket is mounted on one end of the sowing wheel shaft to drive the slave transmission chain box which is fixed with the bottom case. The main sprocket is connected with the seeding sprocket to drive the rotation from the sprocket, which turns the drive wheel mounted on the metering device.
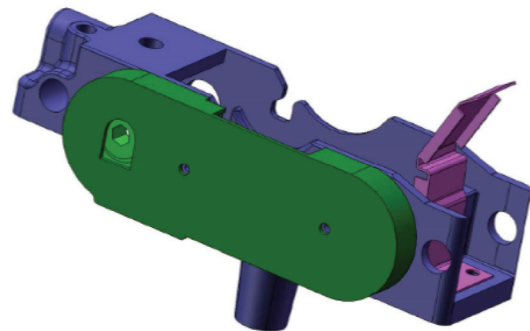
a. 3D design drawings

b. Bottom case of seed metering device
1. Sowing box buckle   2. Sowing chain box   3. Sowing hole   4. Fixed nut
Figure 9   Bottom case of seed metering device

4 Test and result analysis

4.1 Test condition

The field test was carried out at a farm in Luoyang, Henan, on April 2018. The test field was flat. The area for test was 3 hm^2. The photo of the machine is shown in Figure 10. The machine is equipped with 48Vbattery to provide power supply input. The coriander, Chinese cabbage, and radish were used to test the sowing quality. At the same time, the seeding effect and seeding quantity of seeding wheel on seed were tested by using paired seeding wheel.

4.2 Test method

In order to verify the overall performance of the machine, three kinds of representative small seeds were selected to carry out field sowing experiments on coriander, Chinese cabbage, and radish. Through four rows of sowing, test data were collected using the feeder bags respectively. The length of sowing was 35 m. The electric seeder was sowing on fixed speed mode, and the depth of the ditch was set to 3 cm. The test data was collected in the 5 m range after the beginning of sowing and 5 m before the end of sowing. The sowing count and leakage sowing of the soil opener were detected. The sowing quality of different seeding machines was tested by different seeding wheels.

Figure 10   Field test of electric seeder for small seed

4.3   Test results and analysis

4.3.1   Test of seeding precision

In order to obtain the seeding accuracy of different seeds with different sowing wheels, the sowing wheel for seed with different sizes of carrot, Chinese cabbage and radish were selected. At the same time, the theoretical seeding value is calculated by the distance from the diameter of the sowing wheel and the distance from the diameter of each sowing wheel. The seed sew by the machine is collected by a bag. The actual number of seed sew by the machine is checked and counted. The experiment was carried out 5 times for each group, and the theoretical seeds number was compared with the actual value. The test data is shown in Table 1.

Table 1   Results of sowing precision test

| Grain type | Serial number | Type of sowing wheel | | Actual value/grain | Theoretical value/grain | Sow accuracy |
		Diameter /mm	Grooves number of sowing			
Coriander	1	6	30	30	30	100
	2			39	40	97.5
	3			48	50	95.9
	4			58	60	96.6
	5			67	70	98.6
Chinese cabbage	1	3.5	20	34	35	97.1
	2			45	45	100
	3			53	55	96.3
	4			63	65	96.9
	5			74	75	98.7
radish	1	5.5	6	35	35	100
	2			73	75	95.9
	3			62	65	95.2
	4			49	50	98.0
	5			93	97	95.7

For the different size, the sowing spacing requirements are different. Table 1 shows that through the design of the sowing wheel, it can meet the requirements of sowing for seeds with different size, and realize the precision sowing. The precision of sowing is up to 95%, which meets the seed sowing requirements in the field. Analysis of the reasons: During the sowing process, due

to the uneven size of seeds, the quality and effect of operation can meet the requirements of agronomic planting. Test shows that the seeding machine can effectively solve the problem of small seed sowing in the field, improve the efficiency of field operations, and achieve precision seeding.

4.3.2   Sowing number detection test

In order to obtain the actual number of seed sew by the machine, a bag is installed at the end of the seed metering port. The seeding machine with different diameters is used to sow three kinds of crops, to test the precision and density of the sowing. The machine was set at fixed speed of 3 km/h and 4 km/h. The seeding monitoring system was reinstated and the electric seeder was powered up to carry out seeding test. The number of seeding was detected by the vehicle computer terminal. At the same time, the bag was taken off and counted by manual observation. Three groups of test were repeated for three crops. The test data of each group were shown in Table 2.

Table 2   Results of sowing count

Walk speed	crop type	Number	Actual Particle number	Testing Particle number	Absolutely error	Relative Error/%
3 km/h	Coriander	1	110	113	3	2.7
		2	130	132	2	1.5
		3	141	144	3	2.8
	Chinese cabbage	1	90	89	1	1.1
		2	130	133	3	2.2
		3	150	145	5	3.3
	radish	1	87	87	0	0
		2	120	124	4	3.3
		3	160	165	5	3.1
4 km/h	Coriander	1	147	153	4	4.0
		2	137	141	4	2.9
		3	109	109	0	0
	Chinese cabbage	1	125	130	5	4.0
		2	126	129	3	2.3
		3	70	70	0	0
	radish	1	123	127	4	3.2
		2	133	139	6	4.5
		3	119	126	7	5.8

Table 2 shows that under the conditions of 3 km/h and 4 km/h, sowing count monitoring test for three seeds of coriander, Chinese cabbage and radish, the monitoring accuracy is up to 94%. Sowing test Most of the deviation is due to the different diameters of seeds, which can be calibrated by adjusting the appropriate detection range. Test shows that during the field operation, the system improved the accuracy of the seed counting, enhanced the effect of sowing monitoring, and effectively resisted the effect of the field mechanical vibration and dust.

5   Conclusions

(1) An electric seeder for small-size vegetable seed was designed, which consists of the boot type furrow opener, the back press wheel, and the driving motor. The sowing wheel was designed with different diameters and sizes to satisfy the demand for different sizes of seed sowing. At the same time, the design of the traditional trench opener was improved, and the adjustable depth of seeding was realized by adopting the trench opener. The small grain vegetable seed electric seeder and sowing monitoring system can realize precision sowing and real-time monitoring the quality of sowing, and can complete the functions of furrow, sowing and repression at a time.

(2) The seeder adopts the nest eye wheel sowing wheel, which can carry out the precision seeding function to the diameter of 2-10 mm seed. Through the buckle design, the seeder and the sowing wheel is easy to install and disassemble. Field experiment was carried out on the seeding quality of the seeder by selecting suitable sowing wheel for three seeds of coriander, pakchoi and radish. The results showed that for the carrot, Chinese cabbage and radish, the sowing precision is over 94%, and the working quality meets the requirements of agronomy, when using the 30-hole sowing wheel with a diameter of 6 mm, the 20-hole sowing wheel with a diameter of 3.5 mm, and a 6-hole seeding wheel with a diameter of 5.5 mm, respectively.

(3) The sowing amount of different seeds was monitored. When the speed of the seeder is at 3 km/h and 4 km/h, respectively, the field experiment shows that the monitoring accuracy of the system is more than 94%. The monitoring of the system has a strong ability to suppress interference. The vibration of the seeder has no significant effects on the monitoring accuracy of the system.

Acknowledgements

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