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Research status and prospects of potato seed-metering device

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ABSTRACT

Potato has been widely planted, and China's potato planting area and total output have become the first in the world. As an important part of the whole mechanization technology, potato planting mechanization directly affects the quality and yield of potato. As the core component of potato planter, the performance of seed metering device directly affects the operation quality of planter. In recent years, with the continuous efforts of researchers and manufacturers at home and abroad, the types and research technology of seed metering device are constantly innovating and improving. This paper mainly introduces the key technologies and types of seed metering devices used in the main models in China and abroad, as well as the existing problems and future development direction of different types of seed metering devices.

Keywords: Potato; Seed metering device; Problems; Key technology

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Introduction

As one of the main crops in the world, potato can be used for both food and vegetable. It has rich nutrition, good yield and strong environmental adaptability. It is the fourth major grain crop besides wheat, corn and rice. In 2015, the state put forward the development strategy of potato staple food. In February 2016, the Ministry of agriculture officially issued the guiding opinions on promoting the development of potato industry, which means that the development of potato industry in China has entered the fast lane, and the development of potato planting mechanization plays a crucial role in promoting the development of potato industry¹⁻². In 2010, China has become the world's largest production country, nearly 75 million tons. By 2013, according to statistics, China's potato planting area has reached 5.77 million hm², the total output has reached 90 million tons, and the single output is 15.4t /hm². Both the planting area and the total output are the world's first, but the per unit output is 18.5% lower than the world average level. There are many reasons for the low level of per unit yield. The main reason is that in many areas of our country, semi artificial, semi mechanical or purely manual operation is still used. Some studies have shown that the rate of potato machine sowing in our country is only about 23%³⁻⁴. The research of potato seeder in China started lately, which led to the backward technology of potato seeder and the lack of wide application of seeder. In fact, the research abroad started as early as 1880, and there are mature technologies and products abroad. It is predicted that the planting area of potato will reach 6.67 million hm² by 2020. It is more urgent for the research and development of key technologies of potato planter.

1 Research status at home and abroad

1.1 Domestic research status

Potatoes are root crops, and the seeds are different from wheat, corn and other crop planting machinery. Potato planting is to machine seeds that have been cut in advance or whole potatoes through a seed meter. The structure of potato seeding device is divided into two types: mechanical type and air suction type. Among them, common mechanical seed metering devices include spoon type, needle type and finger clip type. Among these different types of seed metering devices, needle metering and finger clip type are used for cutting and seed sowing of potato. The spoon seed metering device has strong adaptability, which can be used for cutting and seed sowing of potato or sowing of whole potato. Spoon type seed metering device (as shown in Figure 1) is the most widely used type of seed metering device in potato seeder, and also the most researched seed metering device in domestic universities, scientific research institutes and relevant machinery companies. Its working principle is that when the seed spoon passes through the seed box, it will scoop out the potato seeds, which will be driven by the chain, turn around the highest part of the driven sprocket end and enter into the potato guide barrel. At the same time, the potato blocks will fall on the back of the previous seed spoon and continue to move downward with the seed spoon, until the seed spoon in the seed feeding area does not support the potato blocks to complete the seed protection and transportation, and the potato blocks will fall into the seed ditch under the gravity to complete the seeding operation. In the 2CMF-2 potato fertilizing planter developed by Lv Jinqing et al. In 2008, the seed metering device adopts scoop sowing, and is equipped

with disc seed guiding mechanism and electronic vibration on the seed box and belt wheel respectively, which greatly reduces the rate of replanting and missing seeding. At the same time, the machine can complete many operations such as trenching, side deep fertilization, seeding, covering soil and pressing in one operation, with working state Stability, etc⁸. In 2012, Gao Mingquan⁹ pointed out in the design of key components of 2CM-2 potato planter that the seeding mechanism is the core component of the potato planter, and the seeding device is required to ensure that the seeding device does not hurt the seed, the rate of missed seeding and reseeded is low, and the operation is stable. The

seed bowl design is reasonable, the plant spacing is uniform and adjustable. In 2CM-2 type potato seeder, the belt type seed feeding bowl structure is adopted, and the cross feeding and taking method is applied. Two feeding bowls are arranged on one belt for cross seed taking, and a vibrator is used for auxiliary work, so as to ensure that each seed bowl has one potato, realize precise seeding, reduce missed seeding and reseeded⁷. In 2013, the chain spoon seed metering device was used in the single row potato fertilizing seeder studied by Li Chengsong of Shihezi University, which increased the artificial reseeded, although it reduced the missed seeding rate, the intensity of manual work was increased¹⁰.

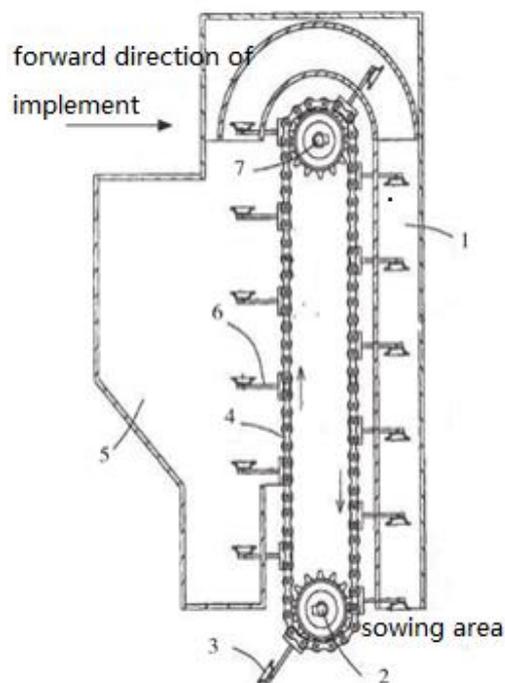


Figure 1 Working process of spoon potato seed metering device 1. Seed metering tube 2. Drive sprocket 3. Seeding spoon 4. Drive chain 5. Seed box 6. Handle 7. Driven sprocket

The operation process of the air suction seed metering device (As shown in Figure 2) can be divided into two parts: one is suction of potato seeds under negative pressure, and the other is

positive seeding. When the seeder starts to work, the air distribution valve can be divided into negative pressure chamber and positive pressure chamber. When the suction seeds arm rotates to

the negative pressure chamber, it is connected with the suction pipe interface. The negative pressure suction arm formed by the fan will suck the potato seeds from the seed box and carry it to rotate. When the suction seeds arm rotates to the positive pressure chamber, the negative pressure disappears into the positive pressure, and the potato seeds fall into the seed groove under the combined action of positive pressure and self gravity sowing process. At the same time, different types of suction nozzles at the end of suction arm can also be changed to adapt to the sowing of cut potatoes and micro potatoes, and the seed sowing device has good adaptability. The air suction seed metering device realizes the seeding operation through the switch of negative and positive pressure. The technical parameters of negative pressure are required to be higher when the air suction seed sowing device is used, and the negative pressure will affect the seeding quality. When the negative pressure of seed suction is small, the adsorption force of seed suction nozzle will also be reduced, which can not overcome the friction caused by the gravity of the potato seeds itself, and the phenomenon that the potato seed can not be sucked or falls off in the transportation process will cause the missing sowing. When the negative pressure is large, although the seed carrying stability can be improved, at the same time, there will be a phenomenon that a seed suction nozzle sucks multiple potato seeds, and the probability of reseeding will increase. The characteristics of the air-suction seed metering device are the high precision of the seeding operation and the high price. It is common on foreign models and requires high reliability of the seeder. Air-suction seeder is the main research direction of potato seeder in the future because compared with mechanical seeder, the advantages are reseeding, low sowing rate, fast operation speed and no

damage to potatoes. 2CMQ2 air suction potato seeder developed by the potato machinery research team of Northeast Agricultural University in China. The machine adopts three-point suspension, which is suitable for small plot operation, and the supporting power is more than 90kw. According to the team experiment, the rate of reseeding and miss-seeding is low, and the performance is stable. On the basis of this machine, Lv Jinqing and others optimized the performance of the zero-speed seeding of the positive-pressure seeding device of the air-suction seeding device, and proposed to use the positive pressure air flow as the falling potato seed to accelerate in the reverse direction of the seeder to achieve zero-speed seeding. According to the optimization of the regression model parameters, when the seeding positive pressure is 15kPa, the seeding angle is 57°, and the seeding speed is 35r/min, the qualified index, reseeding index, miss-seeding index and difference coefficient of the seed metering device are 95.22%, 3.51%, 1.27% and 9.42% respectively, which can meet the requirements of potato planting¹¹.

1.2 Research status abroad

Some foreign companies, such as the 9-500 series potato planter of double L company in the United States, the GL Series of Grimme company in Germany and the SP series of standen company in the United Kingdom, are all using the chain spoon seed metering device. Grimme's GL series include GL440, GL420, GL660, GL860, etc. taking GL860 as an example, it is an eight row seeder equipped with a specially developed plow-share opener and spoon type seed metering device. The machine is equipped with a hydraulic control system and an electronic monitoring system. The driver can directly control the spacing of seeding plants through the cab operation terminal and can control and drive each row of seeding

units by sections and by hydraulic pressure, which can adapt to the requirements different working environment. When it is not working, the width and side of the folding machine are narrow after folding through the folding system, which is convenient for transportation. The 9500 series potato seeders produced by double L company in the United States are all chain spoon seeders. Take the 9560 potato planter as an example, its planting rows are 6 rows, which are pulled by a tractor, the supporting power is 128kw, the planting spacing is 71~101cm, the planting spacing can be adjusted and controlled directly in the cab. Each planting unit all can be individually controlled by hydraulic drive, which can complete trenching, pesticide application, sowing, fertilization, ridge formation and soil covering at one time. At the same time, the maximum capacity of the

seeds box is 6.6t, which can reduce frequent land entry; the hydraulic and mechanical drive system adopts electronic control, and the trencher has the function of automatic obstacle crossing, which can automatically climb over hard foreign matters such as stones¹²⁻¹⁴. Buitenwerf H et al. Studied the spoon type potato seed metering device, kinematically analyzed the working process of the seeder, and established a mathematical model of the seed potato movement during the seeding process, taking the movement speed of the seeding belt and the shape of the seed potato as the experimental factors an experimental study was conducted and the results showed that there was a positive correlation between the movement speed of the seeding belt and the uniformity of the seed pitch, and the shape of the seed potato did not affect the seeding quality¹⁵.

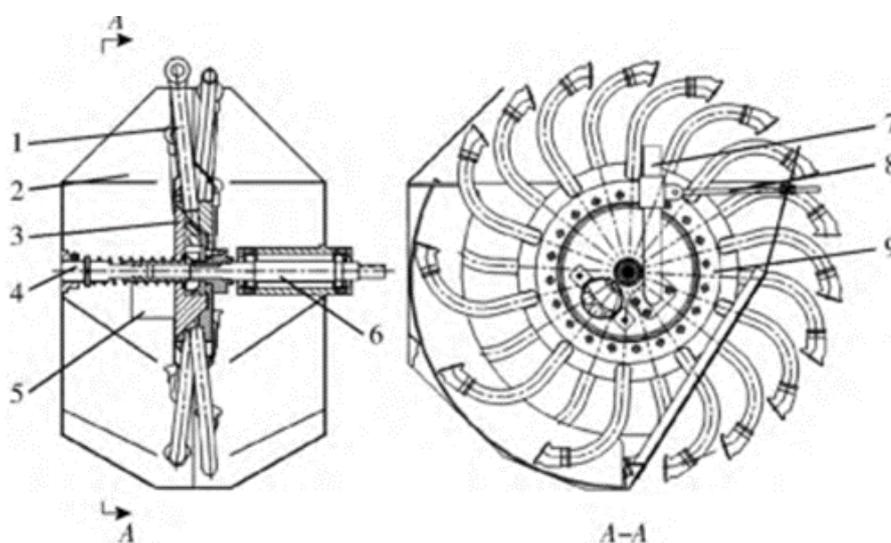


Fig. 2 Air suction potato seed metering device 1. Suction arm 2. Seed box 3. Air distribution valve 4. Static shaft 5. Pipette 6. Axis of rotation 7. Blowpipe interface 8. Adjusting screw 9. Cover

The characteristics of the air-suction seed metering device are the high precision of the seeding operation and the speed of the operation, which require high reliability of the seeder. The technol-

ogy of this type of seeder planter is relatively mature abroad. The most representative model is the 60-type potato planter produced by Lockwood in the United States. Taking the 606p potato planter as an example, the air-suction type seeder is

used. The power of tractor traction operation is 134kw, the body weight is 5T, which can realize high-speed operation, and the operation speed can reach 11.2km/h. This machine can be completed at one time trenching, sowing, fertilization, drip irrigation, soil covering and suppression¹⁶.

The working principle of the finger clip potato seed metering device (as shown in Figure 3) is similar to that of the small grain crop. When the lower part of the seed metering tray reaches the seed tank, the finger clip is normally closed under the action of the finger clip spring. With the rotation of the seed metering tray, the fingers will open to pick up the potato seeds. When the seeds are carried to the seed feeding area under the action of the fingers spring, the fingers will touch the guide again, and the fingers will open. At the same time, the

potato seeds carried will also fall into the seed ditch under the action of gravity to finish sowing. The finger clip seed metering device has higher requirements on the size and shape of seeds, but there are different shapes and sizes of potato blocks, so the seed metering device will lead to a higher rate of miss-seeding. This kind of seed metering device is often used in the seed metering device of small grain crop seeder in China, such as corn, wheat and other crop seed metering devices. Among the foreign potato planter manufacturers, only the 500 series produced by Lockwood use finger clip seed metering device. Taking the Lockwood 506p potato planter as an example, the number of rows is 6, and the fertilization device can be arranged before and after the planter. The seed box capacity is 4.1T, and the operation speed can reach 10.5km/h¹¹.

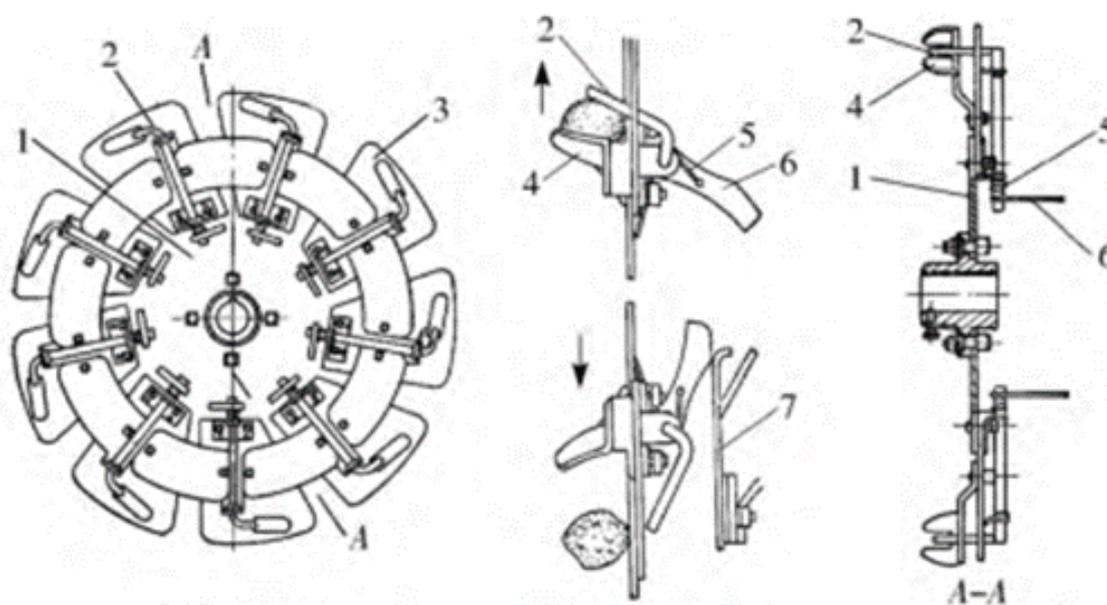


Fig. 3 Finger clip seed metering device 1. Planter plate 2. Clip 3. Seed tray 4. Spoon 5. Spring 6. Inflective arm 7. Guide rails

The needle type seed metering device (as shown in Figure 4) is through the seeding arm with needle needle to continue to penetrate into the potato seeds for seeding (as shown in Figure 5.b), at this

time, the movable arm and the fixed arm are closely combined, and the needle is exposed to the fixed arm carry out seed collection and seed

carrying operations. When the sowing arm carrying potato seeds rotates to the seeding area, the rotation of the cam on the sowing arm will drive the lancet movement on the sowing arm, so that the lancet will no longer be exposed outside the sowing arm (as shown in figure 5.a), separating the needles between the fixed arms will lose control of the potato pieces, and the potato seeds carried on the needles fall from the seeding arm to the bottom of the ditch to complete the seeding process. In the 1990s, this kind of seed metering device was mainly studied in the United States. Its overall structure is simple and it can adapt to

different sizes and shapes of potato blocks. However, it is limited by its own mechanical structure and there is no effective removal of excess seeds and its missed and replayed are serious. Another disadvantage of this kind of seed metering device is that repeatedly stabbing into the potato blocks will lead to the mutual spread of pathogens and affect the horse bells quality of potato. Taking the 6200-4100 potato planter produced by Lockwood company of the United States as an example, the machine works in 4 lines, and is pulled by tractor. The supporting power is 75kW, the seed box capacity is 1.8T, and the operation speed can reach 9.6km/h¹⁷⁻¹⁹.

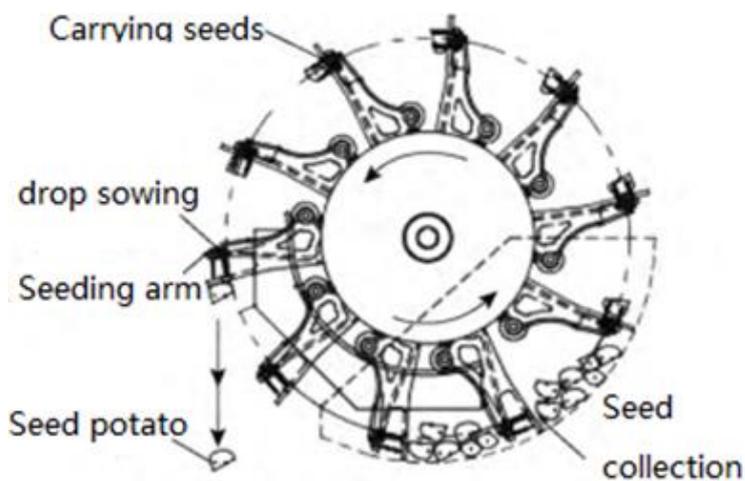


Fig. 4 Needle type potato seeds metering device

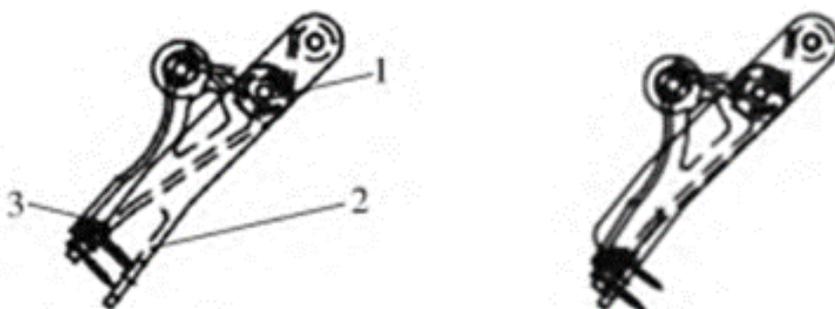


Figure.5 Different working states of needle (a) Seeding status (b) Holding(taking) states

1.Cam mechanism 2. Fixed arm 3. Boom 4. Pneumatic seed metering device

3. Problems

3.1 Problems of spoon type seed metering device

According to the analysis of the research status of different types of seed metering device of potato planter, the spoon type seed metering device is the most widely used seed metering device on the potato planter, and the air suction seed metering device is the most potential seed metering device. There are many advantages of spoon type seed metering device, such as simple structure, low cost, suitable for small and medium-sized plot operation; however, its disadvantages are obvious, such as the operation speed is limited by the operation quality, and the phenomenon of repeated and missed sowing caused by vibration is serious.

3.1.1 Problems in optimization parameters of key components

At present, when the three problems exist in the spoon seeder, the complementary operation speed is limited by the phenomenon of repeated and missed sowing, so the operation speed of the seeder is relatively low. In view of the shortcomings of the spoon type seed metering device, domestic scholars have also done a lot of research, design and experimental analysis. These research designs can be divided into two categories. One is to design and optimize the parameters of key components in the first type of research results, which can reduce the rate of re-seeding and improving the efficiency of single seed rate of spoon potato planter, But in the original working speed, the sowing quality of the planter has been improved, and the speed of the potato planter has not been improved.

3.1.2 Problems in intelligent reseeded system

The other is to add intelligent control device to solve the problem of missing sowing on the basis

of the spoon seeder. In this type of research results, most of them use infrared photoelectric sensor to detect the missing sowing signal and add a seeding device to detect the missing sowing. Firstly, the infrared photoelectric sensor detecting the missing sowing signal will be affected by the poor working environment of the seeder, and the accuracy of the detection signal will be affected due to the characteristics of short time and relatively fixed angle, the fuselage of the seeder will vibrate when it works in the field, which is easy to cause deviation of the detection results in addition, the adverse working environment of the seeder will affect the detection signal, including dust, fog, rain and sunlight during the operation, which will weaken the infrared red signal transmission in the air. The second is to add a special supplementary seed system, which will complicate the structure of the planter, and the reliability of the planter needs to be tested. Finally, this kind of research is still in the stage of research and design system and experiment, which has not been applied in potato planters.

3.2 Problems of air suction seed metering device

The air suction seed metering device has the advantages of low reseeded rate, no damage to seeds and strong adaptability to seed size. However, if we want to make full use of the advantages of the air suction seed metering device, we need to solve the unique key technical problems of the air suction seed metering device. First, through the analysis of the working principle of the air suction seed metering device, we can see that the performance of the fan is very important. Whether the air volume pressure of the fan can meet the requirements of the seed metering device and whether the output power of the tractor can match the driving force of the fan; the second is that the air suction seed metering device should

have the characteristics of no damage to seeds and strong adaptability to seed size, the installation angle of seeding arm and the opening of seed suction nozzle. Size, shape and material are key parameters to be considered.

3.2.1 Problems of fan

The fan is the key component to ensure the operation quality of the air suction potato planter. One of the good working conditions of the air suction potato planter is that the fan can provide appropriate wind power. In recent years, air suction seeders have developed rapidly, which can not only realize precision no tillage sowing, but also adapt to different operating requirements in different areas and different environments. However, these seeders are only used in planting corn, soybean, wheat and sugar beet. Potato tubers are several times or even dozens of times larger than corn and soybean, which need to be equipped on the seeder to meet the requirements of high speed, large flow and high wind pressure. On the one hand, the existing air suction seeder fan can not meet the suction pressure required by potato sowing, on the other hand, when the high-speed fan works, it needs the matching motor drive or tractor output shaft drive. When considering that the fan can provide enough air pressure, it is also necessary to consider whether the driving speed of the fan can match the output speed of the tractor, and whether the power supply voltage required by the motor can meet the requirements.

3.2.2 Problems of seed suction mouth anastomosis

At present, domestic and foreign scholars, research institutes on the suction nozzle parts research results are relatively scattered. The working object of the seed suction nozzle is that the seed directly acts on the potato seed, and the

seed suction nozzle also affects the operation effect. The influencing factors include the material, size angle and type selection of the seed suction nozzle. When the seed suction nozzle contacts with the potato seed, there are two working surfaces: curved surface and plane. When the material, size, angle and shape of the suction nozzle are selected reasonably, the seed taking and carrying work will be stable. Potato seed can be divided into whole tuber and cut potato. In the current research results, the whole potato suction nozzle and the cut potato suction nozzle are separated from each other in the design. In the later stage of operation, it is necessary to stop the machine and replace the seed suction nozzle when sowing different potato seeds, which increases the workload and delays agricultural time. Therefore, a seed suction nozzle suitable for both whole potato and block potato is designed.

4. Conclusion

With the continuous expansion of the potato planting area, there is still a lot of room for the potato planter to develop in the direction of mechanization, precision, and intelligence. Based on the analysis of the research status of potato planters in China, most of them still stay in mechanical operations. Most foreign potato planters use electronically controlled mechanical drive and hydraulic drive technology. my country's potato planter needs to develop towards intelligence and automation. The application of machine, electricity, liquid, gas and other technologies to the potato planter can improve the quality and precision of the planter's operation, and at the same time reduce the labor intensity of manual planting operations. At present, most of potato seeders use chain spoon metering device. The mechanical structure of this metering device is simple, and the simple mechanical structure needs more stable working state to improve the reliability of the

seeder. Although the degree of automation and intelligence of foreign potato planters is higher than that of domestic planters, most of them are not suitable for potato operation environment in China. Therefore, in our country, the potato planter in the development of automation and intelligence, but also to adapt to and meet the potato production area planting environment, agronomic requirements and other conditions.

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