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Minireview Article

Research Status and Development Trend of Intelligent Mechanized Pepper Harvesting

ABSTRACT

Since the reform and opening up, the mechanization level of China's agricultural production has been significantly improved; and intelligent mechanization of agricultural production is an inevitable trend of future social development, which will be based on intelligent equipment, data, and knowledge as the core elements, so that modern science and technology and agriculture are deeply integrated to achieve digital perception, intelligent decision-making, precise operation and intelligent management of the whole process of agricultural production, and further significantly improve Labor productivity, land output rate, and resource utilization rate are further improved. This paper introduces the development status of agricultural production at homeand abroad with pepper harvesting ~~as an example~~, analyzes the necessity of changing China's agricultural production to intelligent mechanized production, summarizes the opportunities and challenges ~~facing the development of China's agricultural production to~~in intelligent mechanization, and accordingly puts forward the development direction and development route of China's agricultural production. To promote the transformation of China's agricultural production mode from mechanization to wisdom, this paper puts forward countermeasure suggestions such as strengthening the construction of agricultural machinery equipment R&D and innovation system, strengthening the construction of agricultural machinery promotion system, strengthening the construction of agricultural machinery socialization service system, and accelerating the construction of wisdom agriculture demonstration area.

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Keywords: agricultural production, pepper harvesting, ~~agricultural~~ Farmmechanization, intelligent farm machinery~~, the wisdom of agricultural production~~

1. INTRODUCTION

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Chili pepper is one of the important vegetables of the eggplant group and is the 3rd largest vegetable crop in the world after beans and tomatoes [1]. As a green food rich in nutritional elements, chili pepper can be consumed not only alone but also as a flavoring agent for other foods and has always occupied an important position in the human diet structure. China is the largest producer and major consumer and exporter of chili peppers in the world, and the planted area accounts for about 40% of the world's chili planted area [2]. At present, chili peppers are generally picked by hand, and with the continuous increase of chili planting areas and labor shortage in China, the cost of chili pepper picking accounts for an increasing proportion of the production cost of chili peppers, and the cost of picking accounts for 38%-40% of the selling price of chili peppers, and the problems of tight picking time, labor intensity, harsh picking environment, and

low picking efficiency have seriously restricted the healthy development of chili pepper industry [3]. Therefore, the mechanization of pepper picking has become an inevitable development trend.

Recently, intelligent information technology is developing rapidly, along with the combination of industrial production, medical care, education, and many other industries with intelligent information technology. China has officially entered into the era of intelligent information technology [4]. The current combination of various types of intelligent systems and related fields perfectly solves the problems of insufficient manpower and insufficient efficiency. China is a large agricultural production country, and to move from a largely agricultural country to a strong agricultural country, the development of agricultural mechanization and intelligent information technology is the way to go [5-6]. Agricultural mechanization and agricultural machinery intelligence is an important basis for transforming the agricultural development mode and enhancing agricultural development. Precision and intelligence empower the whole process of agricultural production and open a new era of intelligent agriculture for China's agriculture [7]. Intelligent mechanized pepper harvesting technology is a research hotspot in the field of intelligent agriculture in recent years, and at present, the design research of intelligent mechanized pepper harvesters in China is much later compared with developed countries such as Europe and the United States and is basically at the stage of manual picking or semi-mechanized picking [8]. The use of intelligent technology to automatically adjust the pepper picking speed according to the maturity of peppers and reduce the loss rate and breakage rate of peppers lacks systematic and in-depth research.

2.TRENDS IN THE LEVEL OF DEVELOPMENT OF FOREIGN TECHNOLOGY IN RELATED FIELDS

2.1 Foreign mechanized pepper harvesting technology research status

Foreign-developed countries have earlier research on pepper harvesting machines, and the major pepper countries, mainly the United States, have been studying the mechanization of pepper harvesting since the 1970s. In 1967, the first commercial mechanized harvesting of bell-shaped peppers was carried out in the United States [9]. 1976, McClendon Pepper Company independently developed and produced the Peter Piper spreading double spiral pepper harvester [10]. In 1998, in cooperation with Bucknell University, Pik-Rite, USA, modified the pepper harvester with good harvesting results, and the development of pepper harvesters has since achieved a milestone [11]. Yung-Etgar Institute of Agricultural Machinery, Israel, developed two- and four-row self-propelled pepper harvesters with tilting and unfolding double-spiral mechanisms as the picking device [12].In 2008 Funk PA and Walker S J years tested five picking mechanisms for five varieties in two fields in Sego State, New County The results surface that the tilting and reversing double-opening spiral design of the pepper picking device with low relative tip speed had the highest harvesting efficiency and lowest breakage rate [13].

In 2016, Kyuno-Sik Kang et al. developed a spiral picking head for a self-propelled pepper harvester, testing the spiral type, spiral release winding direction, and spiral rotation speed to obtain optimal operating conditions. The best total harvesting efficiency was obtained at a speed of 400 rpm. However, operating the equipment at this speed resulted in overall equipment vibration [14].

Maturity assessment is an important feature of selective robotic harvesting. HarelB and KurtserP et al. studied the

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Comment [A4]: Modi RU, Manjunatha K, Gautam PV, Nageshkumar T, Sanodiya R, Chaudhary V, Murthy GRK, Srinivas I and Rao CS. 2020. Climate-smart technology based farm mechanization for enhanced input use efficiency. In: Srinivasarao C. et al., (Eds). Climate Change and Indian Agriculture: Challenges and Adaption Strategies. ICAR-National Academy of Agricultural Research and Management, Hyderabad, Telangana, India. Pp-325-357.

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maturity assessment of the color camera of a bell pepper robotic harvester. Based on the maturity assessment derived from the color camera of the bell pepper robotic harvester, the number of viewpoints required to determine the level of bell pepper maturity and the optimal single viewpoint was evaluated for different color and morphological characteristics of bell pepper maturity [15-16]

The United States is a leader in research on mechanized pepper harvesting. In the global market, the main companies producing pepper harvesters are Boes Harvester Company, Crown Agricultural Systems, Massey Spice Harvester Limited Joint Stock Company, McClendon Pepper Company, Limited, Pik Rite Company, Ten Square Company, Oxbo Company in the United States, and Yung-Etgar Agricultural Machinery Institute in Israel In 2005, Massey Pepper Harvesters, Inc. developed a self-propelled three-row pepper harvester that could be on a defined track path, with a picking table that uses a tilting long-bar comb-finger mechanism and provides a field sorting function to transport the harvested pepper fruit to an adjacent trailer. Figure 1 shows Massey's three-row self-propelled pepper harvester.

Fig. 1.Massey's three-row self-propelled pepper harvester

McClendon's harvesting machine adopts the tilting spiral and rubber finger picking mechanism and produces two-row, four-row, and six-row self-propelled pepper harvesters, the spiral type for picking green peppers and the rubber finger type for picking dried red peppers, relying on pneumatic conveying and clearing, with a card-type submersible picking device on the machine. Figure 2 shows McClendon's four-row self-propelled dry red pepper harvester.

Fig. 2.McClendon four-row self-extracting dry red pepper harvester

2.2Current status of foreign pepper harvesting picking device research

The picking device is a key component of the pepper harvester, and the picking effect of the picking device determines the adaptability of the pepper harvester. Due to the diversity of pepper varieties and the great degree of differences in physiological characteristics among pepper varieties, such as the length-to-diameter ratio, shape, and specific gravity of peppers, peppers of different varieties and uses also have different requirements for picking conditions.

At present, foreign picking devices are mainly divided into the following categories according to the different picking mechanisms; spread double spiral wire type, rod comb finger type, strip comb finger type, and roller finger popping type.

The working principle of the unfolded double spiral wire type is: when the pepper harvesting machinery works along the pepper monopoly row forward, the pepper stems enter the spiral beating type picking device, and the rotating spiral rod continuously knocks the pepper basal culm, and the spiral rod knocks the fruit off the basal culm to realize the

separation of fruit and stems [19-20]. The spreading double spiral type is further divided into inclined and vertical types. Numerous studies have shown that this picking form is rated as the most popular picking mechanism in the U.S. The tilted unfolded spiral-type picking mechanism is better for peppers with large-bodied fruits such as green peppers and dried red peppers, and the picking mechanism is less damaging to peppers.

The working principle of the bar comb finger type is; when the pepper harvesting machine works along the pepper monopoly row, the pepper stems enter into the multiple comb fingers equipped on the bar, and the rotating bar or vertical movement by the comb fingers strokes the pepper stems several times to realize the separation of fruits and stems [21-22]. The bar comb finger type picking device is mainly used for picking green and red peppers, which requires a larger diameter of peppers and is not widely used because of the lower picking rate as well as the higher breakage rate.

Belt comb finger type working principle: When the pepper stem enters between the two picking belts, the spring finger on the picking belt is inserted into the pepper stem, and the picking belt drives the spring finger to move from the bottom to the top, which compulsorily strokes and drags the pepper fruit down from the stem. This mechanism is currently used in the Pik Rite pepper harvester to pick up peppers that have fallen from the ground [23].

Finger-roller working principle: When the picking drum is driven by the tractor along the pepper monopoly rows, the fingers on the rotating picking drum push the pepper fruits off the stems to separate the fruits from the stems, and the picked pepper fruits are carried to the conveyor belt behind the drum to complete the pepper picking process [24].

2.3 Domestic mechanized pepper harvesting technology research status

Because the development of foreign pepper harvesting machinery has entered a stage of steady development, more mature products on the market, while I am still in the research and exploration stage of the trapped pepper harvesting machine, has developed a variety of pepper harvesting machine, to fill the gaps in the field, but for the core components of the research. There is still a big gap with a foreign advanced level. Domestic scholars ~~and scientific research institutions~~, scientific research institutions, and enterprises have conducted in-depth research on self-propelled pepper harvesters, pepper-picking devices, and cleaning devices.

In 2009, Xinjiang Machinery Research Institute developed a self-propelled unpaired pepper harvester concerning foreign harvesters, and this model adopts a tube-snapping finger-type picking device [25]. In 2021, the new 4JZ-3600B self-propelled pepper harvester from Muzhen adopts a 3.6 m cutting deck, which is not limited by the crop spacing during operation. The cutting platform is equipped with flexible picking drums, which can adapt to the flexible picking of pepper varieties in different regions, with a low breakage rate of pepper, low loss rate, and high picking efficiency. In 2012, ShiheziGuangda Agricultural Machinery Co., Ltd. developed a self-propelled pre-picked pepper harvester with a belt comb [26], with the picking head using an inverted trapezoidal grooved plate and picking comb teeth located on the inverted trapezoidal grooved plate, which makes the picking head durable and does not In 2019, ShiheziGuangda Agricultural Machinery Co., Ltd. developed a 4JZ series self-propelled pepper harvester with widths of 1.6m, 2.6m, and 3.6m, as shown in Figure 3, which is a 4JZ-3.6 self-propelled pepper harvester produced by Guangda. The machine is a roller-picking device with a star-wheel sorting device and a fan to sort out light and small impurities. It greatly saves labor and material resources, and the picking effect is relatively good with a relatively low impurity rate [27-29].

Fig. 3.4JZ-3.6 self-propelled pepper harvester

Ltd. has developed a 4AZ-2200 type self-propelled pepper harvester, which adopts the spiral spring-tooth type picking and cutting platform with strong adaptability, high picking rate, and low breakage rate, and is suitable for different varieties of pepper harvesting. The harvesting platform adopts hydraulic control to lift and lower, which can adjust the rotating speed and height of the platform according to the variety and yield of pepper, effectively ensuring the picking quality of pepper. The multiple scavenging device provides cleaner harvesting and more labor-saving. XueShimin [30], Zhang Junsan [31] et al. used a 4JZ-3600 self-propelled pepper harvester produced by Xinjiang Muzhen Machinery Co. Ltd. to conduct experiments and obtained the line graphs of the effects of changes in picking drum speed and operating driving speed on pepper fruit breakage rate and pepper fruit loss by testing and analyzing and processing the experimental data. The results show that the picking drum speed of the pepper harvesting table greatly influences the breakage rate and loss rate in the pepper harvesting process. The~~has a great influence on the breakage rate and loss rate in the pepper harvesting process, and the~~ picking operation speed and the drum picking speed should be reasonably adapted to obtain a lower breakage rate and loss rate.

Due to the high rigidity and small contact surface of ordinary steel wire popping teeth, it is easy to break the skin of fruits, which causes fruit deterioration and rotting at the later stage, and it is difficult to meet the harvesting requirements of plate pepper. To enhance the applicability and versatility of the popping tooth harvesting table and reduce the damage rate to pepper fruits during harvesting, Zou Daozhong et al. designed a nylon popping tooth-based pepper picking table that can imitate manual picking and can adjust its picking angle through the ambrosia roller according to the plant height, which is suitable for harvesting different varieties of peppers [32].

Lei Mingju [33] analyzed and studied the picking device of a 4LS-1.6 type pepper harvester for the problems of excessive weight, insufficient reasonable device structure and motion parameters, and large guided vibration and noise. Using the method of static and dynamic sensitivity analysis, the frame parameters were optimized, and after optimization, the frame weight was reduced, the vibration was reduced, and a better combination of motion parameters for the picking device was obtained, which provided a theoretical basis for the development of the pepper picking device. To reduce the mechanical damage to pepper during picking, Duan Yilei et al [34] used a spring-tooth roller-type pepper picking device for picking damage experiments on pepper with plate pepper as the object and studied the characteristics and mechanism of damage caused by the spring-tooth roller device in the process of picking pepper. The results showed that the breakage rate of pepper in the process of picking was 10%, and the damage was mainly caused by the shearing, impact, and friction of the spring teeth on pepper during picking, which provides reference and guidance for the improvement and design of special picking devices for low-damage pepper as well as a good operation process.

Overall, with the continuous promotion of agricultural production to land intensification, large-scale production, and intelligent agriculture, China's self-propelled pepper harvester technology level has made great progress, but there

are still problems of weak independent innovation, long-term dependence on imports of high-end harvesting machinery and its core components, and low level of intelligence. At present, the market is mainly put into the production of domestic brands of pepper harvesters on the whole product cost performance and reliability to be improved, limited reliability, high failure rate, basically not equipped with intelligent aspects, resulting in high costs of use, affecting agricultural production.

2.4 Domestic and foreign intelligent variable operation equipment technology research status

Foreign combine harvesters are developing in the direction of large-scale, functional modularity and product intelligence. Foreign combine harvester intelligent technology is mainly reflected in crop yield detection technology, intelligent automatic control technology, and intelligent communication system. Wheat harvesting intelligent technologies such as wheat harvesting driverless and automatic navigation obtain parameters such as walking speed, feeding volume, seed moisture content, yield, loss rate, and machine working condition through advanced agricultural sensors; meanwhile, multi-sensor information fusion technology is used to achieve adaptive adjustment of operating parameters of working parts such as cutting table, feeding, decorating, and cleaning, to realize the precise operation of wheat harvesting [35].

Intelligent variable operation agricultural equipment, as the development direction of China's agricultural machinery industry at this stage, plays an important role in improving operational efficiency and reducing farmers' labor intensity, and the development of intelligent agricultural equipment in China is still in the primary stage in general, and there are still many challenges that need to be overcome [36-37]. Intelligent variable operation control technology mainly includes variable seeding, fertilizer application, spraying, weeding and variable operation harvesting technology, especially variable fertilizer application technology is most widely used.

Since variable fertilizer application technology is still in the development stage in China, most of the variable fertilizer machines currently used are modified based on the original fertilizer application machinery, and most of the research only stays in the field trial stage [52].

Wang Linsheng [38] et al. proposed a new soybean combine travel speed control system for propeller travel difficulties and the problem of cold resistance of the pouring cylinder, introduced a four-wheel independent drive wheel motor into the tire drive system of the combine, and used PID controller and fuzzy algorithm to realize the intelligent control of the wheel motor of the soybean combine, and the research of the soybean combine provided a technical reference.

In summary, in China's crop harvesting on large-scale, functional modularity, intelligence, and other aspects of slow development, and ~~in~~ Europe and the United States, and other developed countries there is a certain gap, especially in the intelligent variable harvesting operations, still in the initial stage, in the height adjustment of the cutting table, picking device speed, harvesting equipment forward speed and other aspects of variable operating parameters of self-adaptation is still in the research and testing stage, not in the actual agricultural production It has not been applied in actual agricultural production.

3. THE DEVELOPMENT TREND OF INTELLIGENT PEPPER HARVESTING

The development trend of intelligent mechanized pepper harvesting is mainly reflected in the following aspects:

1. intelligent yield measurement system of harvesting machinery self-propelled pepper harvester pepper yield measurement system consists of flow sensor, moisture sensor, rotational speed sensor, walking speed sensor, GPS

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receiver and onboard computer and other components. The yield measurement device calculates the grain flow through the pull sensor data of the yield flow meter, carries out filtering, moisture compensation, rotational speed compensation, and travel speed compensation respectively, and gets the real-time yield flow data, thus drawing the yield change curve with time to measure the grain yield, and draws the grain yield distribution map with the GPS positioning system.

2. Variable operation parameter adaptive control adopts multi-sensor information fusion technology to realize the adaptive adjustment of operating parameters of the cutting table, picking drum, feeding, cleaning, and other working parts, to realize the precise operation of crop harvesting.

3. Automatic driving and navigation technology agricultural machinery automatic navigation is an important part of intelligent agricultural equipment, the use of automatic navigation technology will enable staff to better control the quality of operations, improve the efficiency of agricultural machinery operations in the field, reduce fatigue, to ensure the efficiency of field operations and operational effectiveness. Automatic driving of agricultural machinery is based on satellite navigation, sensors, artificial intelligence (machine vision), and computer technology to accurately position agricultural machinery trajectory and monitor~~achieve accurate positioning of agricultural machinery trajectory and implement monitoring of~~ agricultural machinery operation information and operation status through intelligent terminals.

4. High reliability. Mainly reflected in the product manufacturing process and supply chain system, it is also necessary to strengthen the research on new materials and advanced manufacturing processes to continuously improve product quality and reliability and enhance competitiveness in the international market.

Comment [A10]: Conclusions are expected with saving in operational cost and future need in papper mechanization. Which operation is least mechanized and which one is most? Also, indicate the required efforts to implement smart machinery/ climate smart machinery and AI based applications demands in present aspects of mechanization

Comment [A9]: Cite examples

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