Sustainable Development
ISSN Print: 3104-4174
ISSN Online: 3104-4182
CD ISSN: 3104-4190
https://doi.org/10.63313/SD.2003

Research Progress and Current Status of High-Speed Precision Maize Seed Metering Devices

Shibin Yan. Fazhan Yang*. Jing Li. Xue Wang. Guangdi Li and Anqi Chen
School of Mechanical and Automotive Engineering, Qingdao University of Technology, Qingdao 266520, China

How to cite this paper: Yan, S. B., Yang, F. Z., Li, J., Wang, X., Li, G. D., & Chen, A. Q. (2025). Research Progress and Current Status of High-Speed Precision Maize Seed Metering Devices. Sustainable Development, 1(1), 51-59. ISSN Print: 3104-4174; ISSN Online: 3104-4182.
https://doi.org/10.63313/SD.2003
Published: 2025-10-17

Abstract

With the advancement of precision agriculture technology, achieving high-accuracy seed metering under high-speed operating conditions has become a core challenge in enhancing maize production efficiency. This paper systematically reviews the research progress and current status of high-speed precision maize seed metering devices, focusing primarily on key technical directions such as mechanical and pneumatic types. It delves into critical issues like effectively improving seed filling performance, optimizing seed cleaning effects, and ensuring seeding accuracy under high-speed conditions. By analyzing and comparing the advantages and disadvantages of key technologies in various maize seed meters, this review summarizes their development status and trends, aiming to provide a reference for the further research, development, and application of high-speed precision maize seed metering devices.

Keywords

Maize; Seed metering device; High-speed; Intelligentization

1. Introduction

Maize is the most widely cultivated grain crop in China. However, its yield per unit area (approximately 6.3 tons/hectare) shows a significant gap compared to developed countries, reaching only about 60% of their levels [1]. This gap directly contributes to a substantial domestic supply-demand shortfall, posing a challenge to food security. A primary reason for this situation is the need for technological improvement in key production stages such as seeding and management. Therefore, developing precision agriculture technologies, represented by high-precision seed metering, is an inevitable choice for narrowing this gap and enhancing production capacity [2].

High-speed precision seeding technology, a key development direction in modern agricultural equipment, refers to achieving single-grain precision seeding at operational speeds exceeding 8 km/h. It effectively ensures uniform plant spacing and orderly seedling emergence, offering multiple advantages such as seed saving, reduced labor for thinning, improved fertilizer utilization, and increased yield and income. As the core actuating component enabling high-speed precision seeding, the performance of the precision seed meter directly determines seeding quality and plays a crucial role in the overall mechanization level and economic benefits of crop production [3]. Among various seed meters, mechanical and pneumatic precision seed meters are the two most widely used types. Mechanical precision seed meters, known for their simple and reliable structure, strong compatibility with existing agricultural machinery, and low manufacturing and maintenance costs, still hold significant importance in field crop seeding in China. Pneumatic seed meters, leveraging their strong adaptability to seed shape, high operational accuracy, and good high-speed performance, are increasingly used in large-scale, efficient seeding operations. The working process of a seed meter typically includes four basic stages: seed filling, seed cleaning, seed guiding, and seed dropping. Under conventional medium to low-speed conditions, both mechanical and pneumatic seed meters can achieve smooth linkage and operation between these stages, resulting in stable and reliable metering that meets general agronomic requirements for precision seeding. However, with the increasing demand for seeding efficiency in modern large-scale agriculture, both types of seed meters face distinct technical challenges under high-speed conditions [4].

2. Types of Seed Meters and Basic Principles

2.1. Mechanical Seed Meters

Mechanical precision seed meters are primarily categorized based on their structure into spoon-wheel, finger-pick, fluted-wheel, disc (horizontal, vertical, and inclined), cell-wheel, and brush types.

Spoon-wheel seed meter: Its core working component is a metering wheel surrounded by several spoon-shaped seed scoops. During operation, the metering wheel rotates within the seed box, and the scoops pass through the seed mass, scooping up single or quantized seeds using their concave structure. Subsequently, the seeds are carried to the seed outlet and dropped by gravity or a seed cleaning device. Its working process can be summarized as "scooping-carrying-dropping". This type is compact and particularly suitable for small to medium-sized seeds.

Finger-pick seed meter: Mainly used for large, flat seeds like maize. Its core component is a metering disc equipped with several spring-loaded fingers. During operation, the fingers open at the bottom of the seed box and use spring force to precisely pick up individual seeds [5]. After picking a seed, the fingers rotate with the disc and are forced open by a fixed rail or opening wheel, releasing the seed into the seed tube, completing the "picking-carrying-releasing" cycle. Its advantage lies in stable picking for specific seed shapes and low seed damage rate.

Fluted-wheel seed meter: A widely used type for drill seeding. Its core is a metering wheel with annular grooves on its surface. During operation, the fluted wheel rotates within the seed-filled box, and seeds fill the grooves (or cells) under gravity [6]. As the wheel turns, excess seeds are scraped off by a seed cleaner, ensuring each cell carries only a quantified amount of seed. When the cell moves past the sealing area to the seed outlet, the seed is discharged by gravity or a seed ejector. Its working process is the typical "filling-cleaning-dropping", enabling continuous drill seeding.

Figure 1. Spoon-wheel seed meter

Disc seed meter: One of the most typical precision seed meters, operating via a specifically shaped metering disc (installed horizontally, vertically, or inclined). The periphery of the disc is precision-machined with cells (indentations) according to seed shape and size. During operation, the disc separates the seed chamber into filling and cleaning zones. In the filling zone, seeds fall into the cells under gravity or with the aid of filling assistance devices. As the disc rotates, the cells reach the cleaning zone where a fixed scraper or brush removes excess seeds outside the cells, ensuring single-seed precision. In the dropping zone, the cell carrying a single seed rotates to the seed outlet, and the seed is forcibly ejected by gravity, a ejector pin, or air flow into the seed furrow. Its working process is "cell filling-mechanical cleaning-forced dropping", offering high precision but requiring high seed size uniformity.

Cell-wheel seed meter: Can be seen as a variant of the disc seed meter. Its core component is a cylindrical cell wheel with numerous regularly distributed cells on its surface. The working principle is similar to the disc type: the cell wheel rotates in the seed box, seeds fill the cells under gravity; subsequently, the wheel passes through the cleaning zone where excess seeds are removed by a cleaning brush or scraper; when the cell rotates to the lower dropping position, the seed drops out of the cell by gravity or a pushing device, completing metering. Its working process is also "filling-cleaning-dropping".

Brush seed meter: Typically used for small, lightweight, or easily damaged seeds. Its core component is a metering wheel with soft bristles on its surface. During operation, the brush wheel rotates in the seed box, and the gaps between bristles can adhere to or carry a small amount of seeds. The elasticity of the bristles allows effective seed pickup while reducing mechanical damage. When the brush wheel rotates to the seed outlet, seeds detach from the bristles due to centrifugal force, gravity, or a scraper. Its working process is "brushing-carrying-detaching", characterized by gentleness and low seed damage rate [7-10].

Figure 2. Cell-wheel seed meter

2.2. Pneumatic Seed Meters

The fundamental difference between pneumatic precision seed meters and mechanical ones is that they primarily utilize aerodynamic principles (negative or positive pressure) to complete seed adsorption, cleaning, and delivery, thereby reducing direct contact and friction between mechanical parts and seeds, offering significant advantages in high-speed operation. Pneumatic precision seed meters are mainly divided into air-suction, air-blow, and air-pressure types.

Air-suction seed meter: Working Principle: Utilizes negative pressure (vacuum) to adsorb seeds. It offers wide adaptability to seed shape and size, extremely low seed damage rate, and ease of achieving single-seed precision. However, its structure is relatively complex, requires a vacuum pump, and has high energy consumption.

Air-blow seed meter: Working Principle: Utilizes positive pressure airflow to blow away excess seeds, completing seed cleaning. It has relatively lower requirements for cell machining precision, provides good cleaning, and is particularly suitable for irregularly shaped seeds like maize. However, it requires a fan to provide high-pressure airflow and generates some noise.

Air-pressure Seed Meter: Comprehensively utilizes negative pressure for adsorption and positive pressure for seed dropping. The positive pressure injection allows the dropping process to be less constrained by gravity, ensuring concentrated and consistent drop points even at high speeds, which is its greatest advantage for high-speed operation [11-12].

Figure 3. Air-suction seed meter

3. Domestic and International Research Status

3.1. International Research Status

Internationally, high-speed precision maize seed metering technology has formed a development system dominated by pneumatic seed meters, with electric drive direct control technology at its core and intelligent monitoring systems as safeguards.

In terms of metering technology, pneumatic seed meters utilize air pressure differentials to complete seed filling, transport, and metering, effectively reducing mechanical damage and laying the foundation for high-speed operation. Among them, European and American companies like Horsch and Monosem have introduced electric drive metering systems. These systems use DC motors to directly drive the seed disc and real-time adjust the disc speed via radar/GNSS speed measurement devices, significantly improving metering accuracy and seed spacing consistency under high-speed operation.

In intelligent control, variable rate fertilization technology based on prescription maps and real-time sensing is widely applied. Simultaneously, seeding quality monitoring systems, such as the WaveVision sensor developed by Precision Planting and the HyRate series photoelectric sensors from Dickey-john, can monitor seed drop status in real time and alert for skips and doubles.

Furthermore, addressing issues like poor filling, difficult seed cleaning, and unstable seed dropping during high-speed operation, research institutions have optimized seed meter structure and airflow parameters using technologies like DEM-CFD coupled simulation. Some institutions have also innovatively proposed centrifugal variable-diameter pneumatic high-speed metering methods to improve filling performance. Currently, advanced international seed meters can achieve a qualified seed spacing index of over 95% at operating speeds ≥ 12 km/h, demonstrating excellent high-speed adaptability [13-14].

Figure 4. Precision planting air-suction seed meter

3.2. Domestic Research Status

Domestic research on high-speed precision maize seed meters has formed a technological system primarily based on mechanical and pneumatic types, with mechatronic integration as the development direction.

Li Yuhuan et al., aiming to solve the problem of poor metering performance in air-suction maize precision seed meters caused by unreasonable design of the seed cleaning device leading to missed cleaning, over-cleaning, etc., proposed a method using a bilateral seed cleaning device and designed such a device, effectively improving the seeding performance of the meter under high-speed operation [15].

He Xiantao et al., to improve seeding quality on sloping land, designed a hillside horizontal disc maize precision seed meter. By analyzing factors affecting the performance of horizontal disc seed meters, they designed inclined cells with different end faces and a shell with annular partitions, and determined its key structural parameters; a bilateral filling was designed on the seed disc to improve seed mass fluidity and filling performance.

Yan Bingxin et al., addressing issues like poor filling effect and easy wear of the air cushion under high-speed operation, designed an air-suction seed meter where the seed disc and negative pressure chamber rotate synchronously. By fixedly connecting the seed disc and negative pressure chamber, they rotate together during operation, eliminating relative motion between the disc and the sealing pad, achieving frictionless operation, low air pressure loss, and high metering accuracy.

Yang Li et al., tackling the severe problem of doubles caused by side-by-side filling of two seeds in centrifugal high-speed maize precision seed meters, proposed a method to reduce the probability of side-by-side seed filling using symmetric protrusions in the cell groove. They designed a T-slot cell, where symmetrically arranged protrusions inside the cell restrict two seeds from filling the cell simultaneously, ensuring single-seed filling, thereby reducing the double index and improving metering quality [16].

Dong Jianxin et al., addressing the inconsistent seed drop points and poor sowing spacing uniformity of posture-controlled guided maize seed meters under high-speed conditions, proposed a method to constrain seed degrees of freedom and guide the dropping direction. They designed a novel guided seed dropping mechanism that reasonably plans the seed guiding trajectory, ensuring constant drop points and initial velocity, which can meet the requirements of high-speed precision seeding for maize wide-narrow row quincunx dense planting patterns.

In summary, domestic research on high-speed precision maize seed meters is evolving from single-structure optimization towards systematic and specialized development. Through multi-link technological innovation and collaborative optimization, the comprehensive performance of seed meters under high-speed and complex conditions is continuously enhanced, providing important support for advancing maize precision seeding technology in China.

4. Recommendations and Outlook

To promote the development of high-speed precision maize seed metering technology to a higher level, future research should focus on breakthroughs in the following three core directions:

Promote the deep integration of mechanics and electronics, and develop electric drive precision metering technology. Current mainstream mechanical and pneumatic seed meters mostly rely on ground wheel drive, suffering from long transmission chains and response lag. Future efforts should vigorously develop electric direct drive technology, using servo motors to directly drive the seed disc, achieving real-time and precise decoupling and matching between seed meter speed and forward speed. This is the foundation for Variable Rate Seeding (VRS), allowing seeding parameters like spacing to be automatically adjusted on-the-go based on prescription maps, and is an inevitable path towards smart seeding.

Deeply integrate intelligent detection technology: Integrate online monitoring systems based on machine vision or high-frequency sensors to perceive metering performance (e.g., qualified index, multiple index, miss index) in real time, and provide alarms and fault location. Develop active correction and adaptive control: Based on monitoring data, build closed-loop control systems for the metering process. When performance degradation is detected, the system can automatically fine-tune parameters like negative pressure, vibration frequency, etc., achieving full-process intelligence of "perception-decision-execution", ensuring stable precision at high speeds.

Breakthroughs in Key Component Design to Enhance High-Speed Operational Limits: Continuously innovate in basic theory and key components. Explore the use of flexible polymer materials or compliant structures (e.g., flexible cleaning brushes, elastic cells) to effectively buffer impact on seeds during high-speed operation, further reducing the mechanical damage rate. Draw on bionic principles to design new cell shapes or seed guiding channels that better conform to the movement patterns of seed populations, fundamentally improving high-speed filling rate and cleaning efficiency.

References

[1] Sun Wensheng, YI Shujuan, QI Hailong, et al. Design and experiment of twin discs intertwined air-pressure high-speed precision seed-metering device for maize delta-row dense plantings[J]. Transactions of the Chinese Society for Agricultural Machinery,2024,55(10):168-179.

[2] Yang Li, Yan Bing Xin, Yu Yi Ming, et al. Global overview of research progress and development of precision maize planters[J]. International Journal of Agricultural and Biological Engineering, 2016, 9(1): 9-26.

[3] Cheng Weidong, Zhang Guohai, Ruan Peiying, et al. Application review on electric-driven seed metering devices of domestic precision seeder for maize or soybean [J]. Journal of Chinese Agricultural Mechanization, 2017, 38(08): 13-16. DOI:10.13733/j.jcam.issn.2095-5553.2017.08.

[4] Zhang Hui, Pan Feng, Ji Chao, et al. Brief Analysis on Research Progress of Electric Drive Precision Seeder in China [J]. Southern Agricultural Machinery, 2022, 53(23): 20-24.

[5] Gui Zhenliang. Design and experiment of electric drive control system for 2BJX-12 wheat planter D]. Henan Agricultural University, 2024. DOI:10.27117/d.cnki.ghenu.2024.000761.

[6] Jiang Zhenhan, Wang Yuxu, Wei Yifei, et al. Design and experiment of control system of electric drive corn high speed operation seeder[J]. Journal of Chinese Agricultural Mechanization, 2024, 45(03): 24-30+57. DOI:10.13733/j.jcam.issn.2095-5553.2024.03.004.

[7] Jiang Chunyan, Geng Duanyang, Meng Pengxiang, et al. Design of Intelligent Plant Spacing Control System for Maize Seeder Based on Motor-driving [J]. Journal of Agricultural Mechanization Research, 2015, 37(09): 100-104. DOI:10.13427/j.cnki.njyi.2015.09.022.

[8] Zhu Ruixiang, Ge Shiqiang, Zhai Changyuan, et al. Design and experiment of automatic reseeding device for miss-seeding of crops with large grain [J]. Transactions of the Chinese Society of Agricultural Engineering, 2014, 30(21): 1-8.

[9] Zhang Meng. Research on multi-objective electric drive intelligent variable precision seeding system[D]. Shandong University of Technology, 2023. DOI:10.27276/d.cnki.gsdgc.2023.000514.

[10] Ding Youqiang, Yang Li, Zhang Dongxing, et al. Control System of Motor-driving Maize Precision Planter Based on GPS Speed Measurement [J]. Transactions of the Chinese Society for Agricultural Machinery, 2018, 49(08): 42-49.

[11] Wang Song, Zhao Bin, Kuang Lihong, et al. Current Situation Analysis and Prospect of Electric Drive Seeding Technology [J]. Journal of Agricultural Mechanization Research, 2022, 44(12): 1-7+21. DOI:10.13427/j.cnki.njyi.2022.12.001.

[12] MONOSEM. ValoTerra Series Electric Precision Planter Technical Datasheet [Z/OL]. 2022[2024-05-20]. https://www.monosem.com/en/products/valoterra-series/valoterra-ultimate.

[13] da Rosa D P, de Oliveira I V, Balestrin J T, et al. Electric drive system for seed metering and its effects on the distribution and development of the corn crop[J]. REVISTA DELOS, 2023, 16(45): 1656-1674.

[14] HE Xiantao, HAO Yongliang, ZHAO Dongyue, et al. Design and test of automatic detector for seed discharge quality of corn precision seeder[J]. Journal of Agricultural Machinery, 2016, 47(10): 19-27.

[15] Li Yuhuan, Yang Li, Zhang Dongxing, et al. Design and Test of Double-side Cleaning Mechanism for Air-suction Maize Seed-metering Device[J]. Transactions of the Chinese Society for Agricultural Machinery, 2021, 52(07): 29-39.

[16] DONG Jianxin, GAO XiaoJun, ZHANG Shilin, et al. Design and Test of Maize Posture Con-

trol andDriving Precision Metering Device for High-speed Seeder[J]. Transactions of the Chinese Society for Agricultural Machinery, 2022,53(11): 108-119.