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A TECHNICAL ANALYSIS OF THE FUNCTIONAL PRINCIPLES OF PNEUMATIC SEEDING MECHANISMS IN MODERN AGRICULTURAL SEEDERS

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Abstract:
This article provides a comprehensive analysis of the operational principles of seed metering mechanisms in pneumatic seed drills, which are widely used in modern agricultural engineering. Pneumatic sowing systems utilize vacuum-generated airflow to ensure precise and uniform seed placement, contributing to higher crop yields and efficient energy usage in farming operations. The study explores the structural components and functionality of key units within the seeding mechanism, such as the vacuum fan system, seed distribution chambers, drive wheels, and energy transmission components.
Special attention is given to the design configurations developed by the GSKB (State Special Design Bureau) and their integration into the EDX 9000 series seeders. These machines are evaluated in terms of seeding accuracy, operational efficiency, and adaptability to various field conditions. The research highlights the role of mechatronic systems in optimizing seeding performance and reducing material losses during operation.
Moreover, the application of pneumatic drills in precision agriculture is discussed, along with their significance in enhancing planting quality in large-scale crop production. The findings suggest that innovations in vacuum-based seed delivery systems can lead to improved planting uniformity and resource efficiency, making pneumatic seeders an essential element in the modernization of mechanized sowing technologies.

Keywords: Pneumatic seed drill, sowing mechanism, vacuum fan system, wheels, energy efficiency, GSKB design, sowing machine, EDX 9000.

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Introduction

In recent years, under the leadership and initiatives of the President of the Republic of Uzbekistan, Shavkat Mirziyoyev Miromonovich, significant attention has been directed towards the development of the agricultural sector. In particular, the application of modern sowing machinery in the cultivation of field crops such as cottonseed, maize, sunflower, soybeans, and others has played a crucial role in achieving substantial improvements in agricultural productivity [1].

The widespread use of pneumatic seed drills for precision sowing has steadily increased due to their efficiency in individual seed placement. For example, in the 2023 sowing season, cotton planting began 18–20 days earlier than the previous year and was successfully completed within 10–15 days. Over 2,484 high-efficiency pneumatic seeders were utilized across 500,000 hectares of farmland, resulting in the conservation of approximately 15,000 tons of seed cotton and 5,000 tons of diesel fuel. To enhance productivity, 113,000 hectares were sown using a double-row sowing scheme—14,000 hectares more than the previous year—and 228,000 hectares were sown using a 76 cm spacing suitable for machine harvesting, marking an increase of 111,000 hectares [2-5].

Sowing is one of the most critical processes in crop production technology. The primary agro-technical requirements of this stage include timely sowing within optimal periods, adherence to the designated seed rate, minimal mechanical damage during seed metering, and precise placement of seeds into the soil. In row-crop cultivation, precision is considered not only in the uniformity of sowing depth but also in the even distribution of seeds across the field surface [6,7].

The intra-row spacing (seed interval) and inter-row spacing (row spacing) are determined based on the nutritional area required for the optimal development of a single plant. This nutritional area is a decisive factor in yield formation, crop quality, and the plant's ability to suppress weed growth. The optimal nutritional area depends largely on the biological characteristics of the crop, including the duration of the vegetation period, the extent of vegetative mass, the robustness of the root system, as well as soil fertility, moisture availability, and other environmental conditions [8-11].

Early-maturing crops with compact root systems generally require less nutritional

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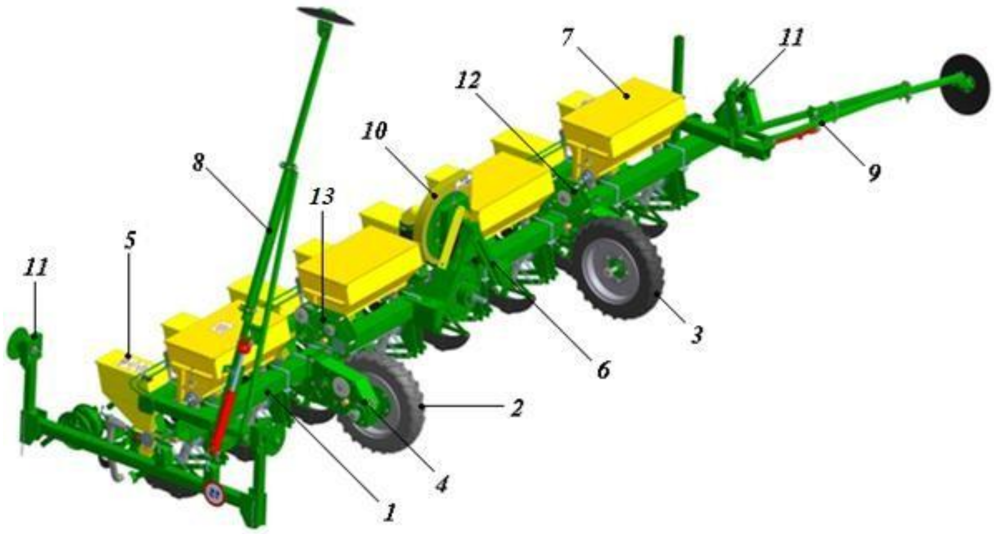
area compared to long-season crops with extensive vegetative mass. For example, melon crops, which possess strong vegetative growth and creeping root systems, are usually sown using point or hill-drop methods with inter-row spacing of 140–210 cm and intra-row spacing of 70–140 cm. Accordingly, the nutritional area for such crops ranges from 9,800 to 29,400 cm².



1 – Frame; 2, 3 – Wheels; 4, 12, 13 – Clamping mechanisms; 5 – Working unit; 6 – Mounted device; 7 – Additional fertilizer system; 8, 9 – Row markers; 10 – Vacuum-generating fan system; 11 – Transport units.

Figure 1. Pneumatic seed drill

Pneumatic seed drills can be classified according to a variety of characteristics, including: functional purpose, structure of working components, type of metering system, traction method, assembly configuration, tractor traction class compatibility, method of seed delivery to the furrow, row configuration, type and number of frame sections, and the applicable sowing technique.

From the perspective of purpose, pneumatic seeders are generally divided into two major categories: universal seeders and crop-specific (specialized) seeders. Universal seeders—commonly referred to as grain drills (see Figure 1)—are capable of sowing seeds of various crops with differing technological requirements. These machines are typically designed for row spacing between 60

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and 90 cm (most commonly 70 cm) and are equipped with universal coulters, allowing for both individual and sectional sowing of crops such as maize, sunflower, cucurbits, and other row crops.

Specialized seeders, on the other hand, are adapted for the precise sowing of a single crop species or a narrow group of crops with similar growth and agronomic conditions. Among the key subtypes of specialized pneumatic seeders are those designed for sugar beet, vegetables, melons, cotton, and forestry crops.

Pneumatic seed drills (Figure 2) designed for row crops with 45 cm inter-row spacing typically consist of no fewer than 12 sowing units. The internal layout and structure of these sowing units differ from conventional grain seeders due to the specific arrangement and integration of component modules.

Figure 2. Planting equipment

Melon and gourd crops typically require large inter-row spacings ranging from 140 to 210 cm, and they are commonly sown using hill-drop or point sowing methods. The sowing pattern accommodates the expansive vegetative growth and creeping root systems of such crops, which demand larger nutritional areas per plant.

With the increasing versatility of maize seeders, the sowing of melon-type crops is now frequently being carried out using modified or adjustable maize planting units. These developments have enabled multipurpose planters to be adapted for a broader range of crop types. Nevertheless, despite such technological advancements, the specific agronomic and mechanical requirements of cucurbit crops—especially in terms of seed spacing, soil contact, and planting depth—

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continue to necessitate dedicated sowing solutions in certain cultivation contexts.

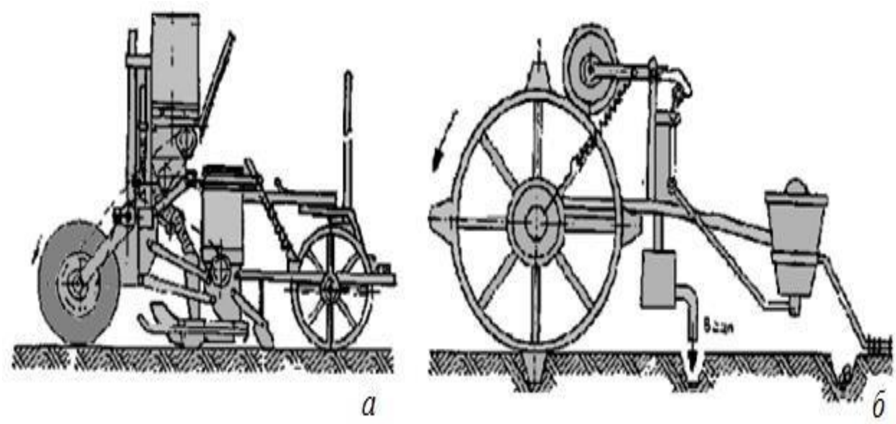

Figure 3. Melon planting machine (design, 1974)

At the same time, planting devices up to 6 m wide are usually made with purpose-built frames (Figure 4).

Figure 4. Pneumatic seeder and precision seeding device

Most modern row-crop planting machines are designed as integrated systems, which enable simultaneous seed placement and fertilizer application. These machines are typically equipped with lifting and dosing mechanisms that enhance operational efficiency by reducing labor input and ensuring uniform nutrient distribution alongside sowing.

In conclusion, the analysis of pneumatic seed drills—both in terms of their

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structural design and field performance—demonstrates their vital importance in modern agriculture. Their effective use contributes to improved sowing accuracy, resource optimization, and ultimately, higher crop productivity. Continued research and technological advancement in this area remain essential for addressing the evolving needs of sustainable and precision farming.

Conclusion

The analysis of the structural and functional principles of pneumatic seed drills reveals their essential role in enhancing the efficiency and precision of sowing operations in modern agriculture. The widespread implementation of pneumatic drills in Uzbekistan, particularly in cotton and maize cultivation, has demonstrated significant improvements in resource savings, timely sowing, and yield outcomes. Empirical data from recent planting campaigns, including the utilization of over 2,400 high-performance pneumatic seeders across 500,000 hectares, affirm the practical effectiveness of these machines in large-scale agricultural practices.

Pneumatic seeders offer precise seed metering, uniform depth placement, and accurate row spacing due to their advanced vacuum fan systems and modular planting units. This contributes not only to optimal plant nutrition through correct spacing but also enhances plant resistance to weeds and improves crop quality. Moreover, the adaptability of these machines—ranging from universal models to specialized planters for melons, vegetables, and forest crops—ensures their suitability for diverse agronomic requirements.

In addition, the integration of seeders with fertilizer application systems represents a key advancement in reducing manual labor and improving agronomic efficiency. The ongoing modernization and design improvements, including those made by institutions such as GSKB, support the further refinement of these technologies for local and regional agricultural conditions.

In conclusion, the continued research, development, and deployment of pneumatic seed drills are crucial for the sustainable intensification of crop production. Their role in precision farming technologies will remain central in addressing food security and optimizing the use of agro-resources in Uzbekistan and beyond.

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