Test Results of a Pneumatic Precision Seeder for Bare Cotton Seeds Under Climatic Conditions of Water-Eroded Soils

Mukhayyokhon Saidova[1], Feruza Alimova1 Surayyokhon Khasanova[1]

[1]Tashkent State Technical University, 100095 Tashkent, Uzbekistan;
m.saidova87@mail.ru , feruza.alimova.1961@mail.ru, hasanovasurayyo93@gmail.com

Abstract

This article presents the design and laboratory test results of a pneumatic precision seeder intended for sowing cotton seeds under soil and climatic conditions affected by water erosion. The seeding disk features suction holes with rounded triangular tips and Y-shaped barriers between them. The use of a vertical disk-type pneumatic seeder ensures the optimal grouping of seeds within the holes, enabling reliable suction of various types of agricultural crop seeds regardless of their mass and shape. It also ensures precise grouping in the feeding chamber and their accurate transfer to the furrow zone, resulting in the formation of maximally dense and accurate seed placements in the row. Such a device enhances the functionality of pneumatic seeders and enables high-precision seed placement.

Key Words: *Pneumatic seeder, seed spacing, disc, cotton.*

Introduction

The world is leading in the development of energy-resource technologies and modern technical means for growing cotton. The volume of cotton fiber cultivation on a global scale is 23477 thousand tons, including in India - 6205, China - 5987, USA - 4555, Brazil - 1895, Pakistan - 1785, Australia - 1045, Turkey - 871, Uzbekistan - 838 and Turkmenistan - 296 thousand tons [1-3]. Seeder one of the important tasks is considered to be the improvement and development of new scientifically based energy-resource-saving ones that ensure high quality of work and efficiency. In this regard, certain successes have been achieved in developed foreign countries, including the USA, Turkey, India, China and other countries, with great attention being paid to the development and application of pneumatic sieves that accurately sow seeds [4-6].

Targeted scientific research is being conducted worldwide to develop resource-saving technologies for precision sowing of cotton seeds, to create new models of technical equipment for implementing these technologies, and to improve existing machines in order to enhance their resource efficiency during operation. Within this scope, it is necessary to carry out scientific studies focused on designing a pneumatic seeder capable of sowing three seeds per nest with high precision under various soil and climatic conditions, and to justify its parameters to ensure compliance with agrotechnical requirements.

The seeding rate is determined based on the soil and climatic conditions of the region, sowing time, sowing methods, and other related factors.

In single-seed sowing, one seed is placed in each spot, whereas in nest sowing (group sowing), two or more seeds are dropped into each spot (in fact, even a single-seed spot is referred to as a "cluster").

Cluster sowing is a method where seeds are grouped and sown at fixed distances from one another along the row. This method remains widely used today. The reason is that seeds grouped in clusters emerge more easily through the soil layer compared to singly sown seeds, and the seedlings sprout earlier and more uniformly.

In cluster sowing of cotton seeds, it is required that the number of seeds in each cluster be as uniform as possible. The distance between clusters within a row (typically 15–30 cm) is selected according to cotton cultivation agrotechnics.

The advantage of cluster sowing is that, if rain falls after sowing and a soil crust forms, the grouped seeds in the cluster are more likely to break through the crust. The main drawback of cluster sowing is the higher seed consumption.

Materials and Methods

In addition to general requirements, region-specific sowing requirements adapted to local soil and climatic conditions have also been developed. For instance, in soil-climatic conditions where soil erosion is present, the spring sowing season is often followed by rainfall, which frequently leads to the formation of a crust on the soil surface. In such conditions, single seeds sown individually may not be able to break through the crust and risk remaining underneath it. Therefore, it is advisable to place 2–3 seeds in each nest during sowing [7].

Schemes for nest sowing of cotton seeds are presented in Table 1.1.
Nest Sowing Schemes for Cotton Seeds
Table 1.1

Plant Type	Field Type	Number of Plants (thousand/ha)	Row Spacing (cm)	Sowing Pattern (cm)	Number of Seeds per nest
Cotton	Irrigated land	70-80	60	60x60	3
		90-100	60	60x50	3
		110-130	60	60x45	3
		70-80	60	60x40	2
		110-130	60	60x30	2
		110-130	60	60x25	2
		70-80	90	90x30	2
		90-100	90	90x25	2
		110-130	90	90x20	2

Size Groups of Different Cotton Seed Varieties
Table 2.1

Seed Size Category	Sizes of Graded (Selected) Cotton Seeds, mm		
	Thickness (mm)	Width (mm)	Length (mm)
Average	3,75-5,5	4,5-5,5	8,0-10,5
Short & Large	4,0-6,0	5,0-6,0	7,0-9,5
Small	3,75-5,5	4,5-5,5	7,0-9,5
Long & Large	4,0-6,0	5,0-6,0	8,0-10,5

In cotton-growing regions, the mechanical composition of soils is classified as follows: heavy loam soils make up 71.9%, medium loam soils 20.7%, and light loam soils 7.4%. In autumn, cotton fields are plowed to a depth of 35–40 cm. Deep autumn plowing increases soil permeability and improves leaching of salts when irrigation water is applied during winter. Soil clods naturally break down and soften during winter due to alternating freezing and thawing. As a result, in spring, the upper soil layer retains moisture well and has improved aeration. Before sowing, fields are loosened both in early spring and immediately before planting. Weedy fields are chiseled across the surface to a depth of 10–12 cm. Due to these agrotechnical measures, the 5–10 cm topsoil layer where seeds are sown becomes soft, uniformly textured, and crumbly. The soil layer below 10 cm is slightly compacted but still easily loosened [8].
The set of agrotechnical methods for preparing soil for sowing must be differentiated depending on whether the field was plowed in autumn or early spring. However, in all cases, the 0–10 cm top layer must be sufficiently loose for effective seed placement and healthy plant development. It must also retain moisture accumulated over the fall and winter and be free of weeds.
After heavy rains, a soil crust may form on the surface. Nearly all soils in irrigated farming zones of Central Asia are prone to crusting.

Figure 1. Field area with crust formation on the soil surface.
The main reason for this is the extremely low granularity of these soils and the weak water resistance of soil aggregates. After rainfall or irrigation, the topsoil swells and becomes muddy, and when it dries, it hardens into a crust and cracks. This crust negatively affects soil properties and crop development by reducing water permeability and air exchange. It also accelerates moisture evaporation from the soil (by up to 20–30%). In fields where a thick

crust has formed, seedling emergence may be delayed by 3–5 days, and plant density may be significantly reduced [9-11].

Results and Discussion

The objective of the study is to expand the functionality of the pneumatic feed mechanism for the exact sowing of a predetermined number of bare cotton seeds by a clustered method. The problem is solved by the fact that in the proposed pneumatic feed mechanism (figure2) is a sowing disc with suction cells, which are made in the form of a triangle with rounded tops and with a bridge inside. In this case, the bridge has a Y - shaped form, abuts with its ends against the sides of the triangle.

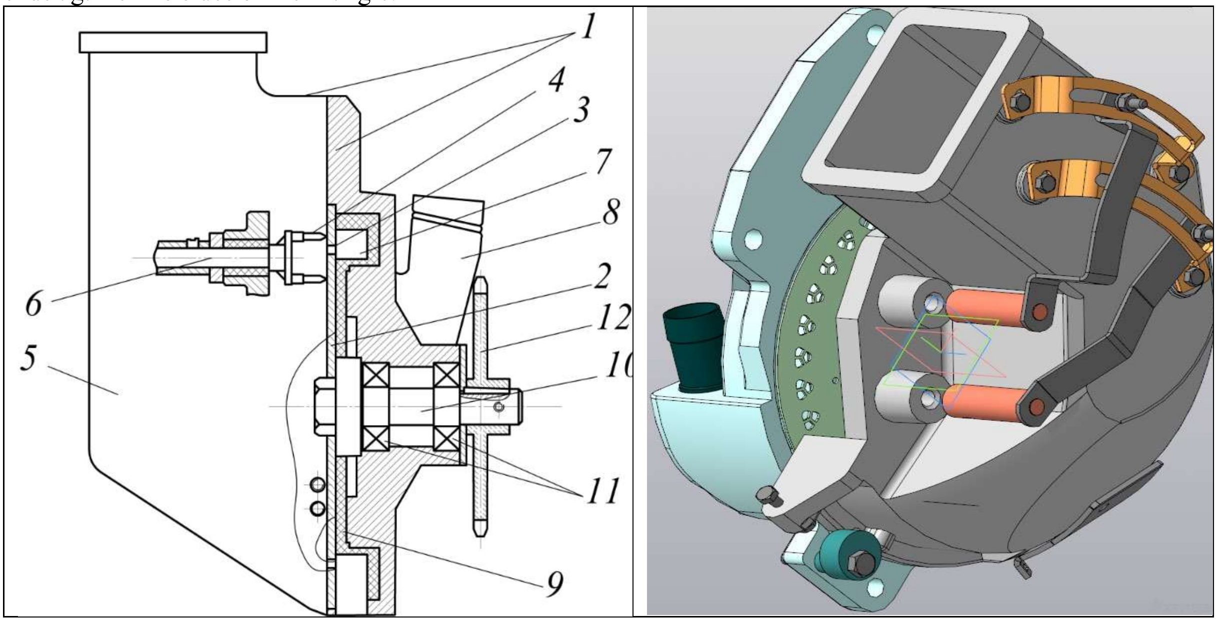
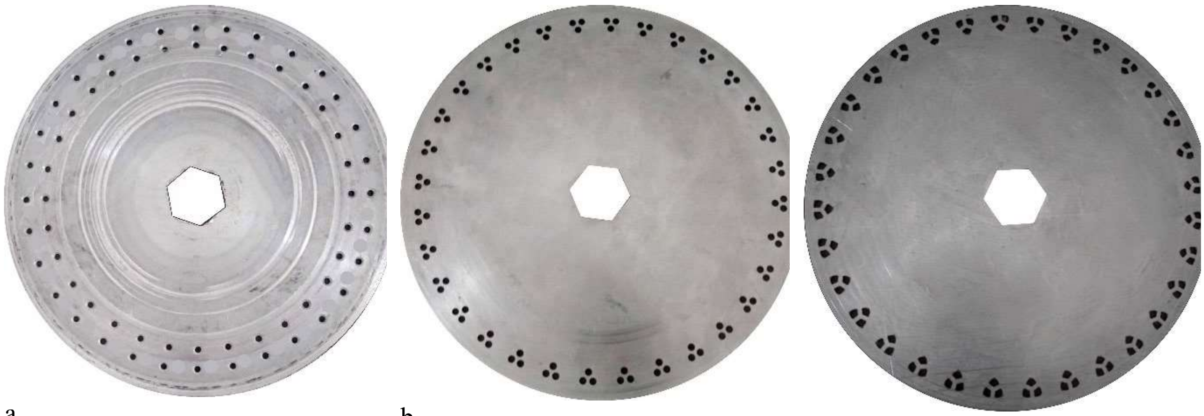


Figure 2. Scheme and 3D model of pneumatic sowing feed mechanism

The proposed pneumatic feed mechanism operates as follows. When creating a vacuum in the rarefaction chamber 7 air passes through the branch pipe 8 to the fan of the planter from the feed chamber 5, cells 3 of the sowing disc 2 and the rarefaction chamber 7; in order to avoid loss of vacuum power, the sowing disc is tightly pressed against the rarefaction chamber with a circular gasket 9. When the sowing disk 2 rotates, mounted on a hexagonal shank of the shaft 10, which rotates on plain bearings 11 when the drive mechanism 12 acts on it, the seeds are carried away by the air flow and in groups (3 pcs. each) stick to the cells 3 with bridges 4 on the sowing disk 2, regardless of their masses and shapes, closing the path for the passage of air and thereby maintaining a constant vacuum in the chamber 7. Due to this rarefaction, a group of seeds lingers in the cells. The shape of the cells is due to the rational form of the group arrangement of 3 seeds, namely the triangle. The tops of the triangle have a rounded shape in order to more reliably suction a group of seeds due to the complete locking of the cells, which eliminates the loss of air flow force and improves the suction capacity of the cells. The presence of a Y - shaped bridge 4 ensures reliable fastening of a seeds group in the cell, eliminates damage to the seeds and clogging of the rarefaction chamber 7. The centers of the cells 3 of the sowing disc are located on the same circle. The rotating disc 2 carries the groups of seeds beyond the vacuum. In the lower part of housing 1, by removing the vacuum, groups of seeds move away from the cells and, under the action of gravity, exactly 3 pieces fall into a narrow groove formed by the coulter.

Based on the above, experiments were conducted on the existing and improved planting discs of the PS-4 pneumatic seeder. Figure 3 shows pictures of planting discs.



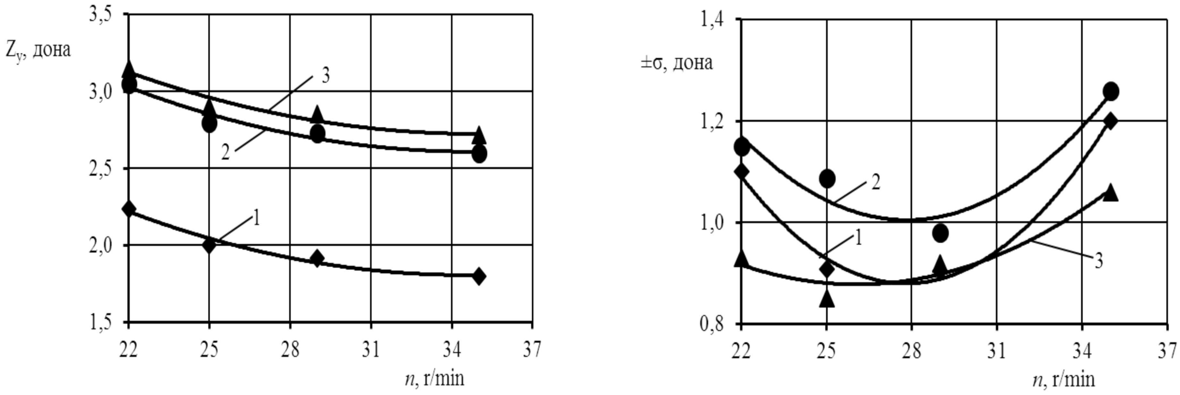
a b c

Figure 3. Seeding discs with different hole configurations

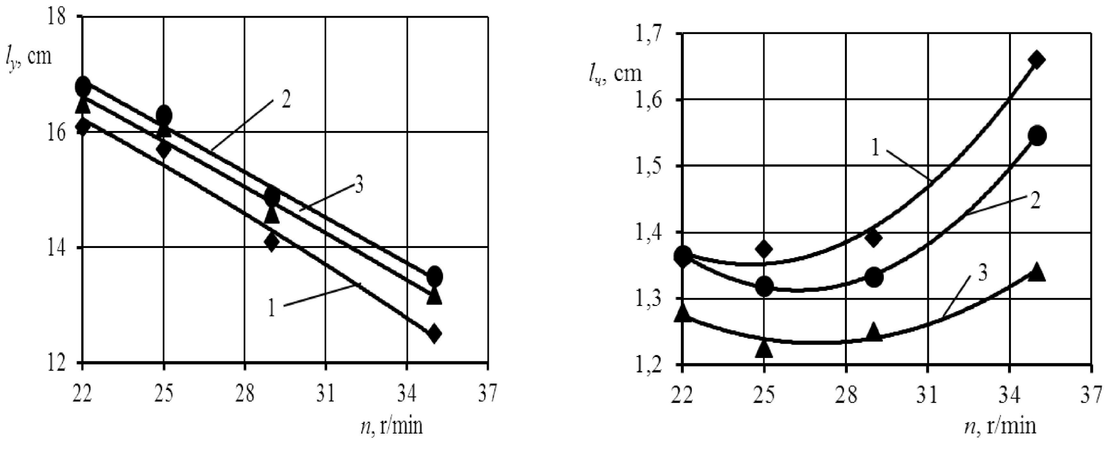
1.Variant 1: a seeding disc with two circular holes (Figure 3a),
2.Variant 2: a seeding disc with three circular holes (Figure 3b),
3.Variant 3: a seeding disc with triangular suction holes having rounded tips and a Y-shaped barrier between them (Figure 3c).

The experiments were conducted at the seeding disk rotation speeds of 22, 25, 29 and 35 r/min. The results of the experiments are shown in Fig. 4. Fig. 4, a shows that when the seeding disk rotation speed changed from 22 r/min to 35 r/min, the number of seeds falling into the cell decreased from 2.24 to 1.80 seeds in the disk of variant 1, from 3.05 to 2.06 seeds in the disk of variant 2, and from 3.15 to 2.71 seeds in the disk of variant 3. The reason for this is that the seeds are not sufficiently absorbed into the cells. This is a consequence of the lack of time necessary for reliable absorption of the seeds into the cells (Fig. 4, a). Analyses show that the number of seeds falling into the cells is inversely proportional to the number of rotations of the sowing disc. The reason for this is that when the number of turns increases, the seed does not stick tightly to the hole and falls out of the nest when other seeds touch it. This leads to the fact that the nest remains empty. As a result, the number of seeds sucked into the sucking holes decreases. In this case, the standard deviation of the number of seeds falling into the nest changes according to the law of a parabola depending on the number of turns (Fig. 4, b). The distance between seeds in the cells decreased as the rotation speed of the planting discs increased. This is because an increase in the number of rotations reduces the suction capacity of the holes in the disc. Therefore, it is necessary to select the rotation speed of the disc and the number of cells in the disc in such a way that the required planting quality is ensured at a certain speed of the seeder's movement.

In the experiments conducted, planting accuracy decreased along a curve as the planting speed increased. The reliability of cottonseed suction into the hole is negatively affected by the short duration of the process within the "hole-vacuum-seed" system and the interaction forces between cottonseeds in the seed chamber. The unique characteristics of the suction holes in the Variant 3 disc help ensure reliable grouping and holding of cottonseeds in the cell and their delivery to the separation zone under vacuum.



а) *б*)



c) d)

1 – Seeding disc with two circular holes 2 – seeding disc with three circular holes 3 – seeding disc with triangular suction holes having rounded tips and a Y-shaped barrier between them

Figure 4: The effect of the planting disc's rotation speed on: (a) the number of seeds in the cells, (b) its mean square deviation, (c) the distance between cells, and (d) the elongation of the cells.

From the graphs, it's clear that the number of cottonseeds falling into the holes met agrotechnical requirements when the rotation speed of all discs varied between 22-30 r/min. The width and elongation (i.e., clustering) of the cottonseed cells were higher in Variant 3.

Conclusions

1.Utilizing a vertical disc pneumatic planting apparatus designed with suction cells on the planting disc that are triangular with rounded ends and feature a Y-shaped barrier between them ensures: Rational arrangement of groups in the cells. Reliable suction of various agricultural crop seeds in groups into the cells, regardless of their mass and shape. Precise grouping of seeds in the feeding chamber and their transfer to the furrow opener zone. Stable formation of maximally clustered, accurate cells in the planted furrow. Such apparatuses serve to expand the functionality of pneumatic seeders and enable high-precision cluster planting of seeds.

2.To ensure the required suction of seeds into the cells of a planting disc designed for cluster planting and their removal from the general mass, the following parameters are recommended for the triangular cell ends: Radius of rounding: 1.64 mm Width: 6.58 mm Height: 6.13 mm Pitch of suction cells: 18.72 mm Circumferential speed of the planting disc (at the center of suction cells): 0.27 m/s Diameter of the planting disc (at the center of suction holes): 195 mm Full diameter: 231 mm Rotation speed of the planting disc: 0.44 rev/s (26.4 rev/min) Angular velocity: 2.81 rad/s Number of suction cells on the planting disc: 32 units

3.To form clustered cells at the bottom of the planting furrow at a given movement speed, the installation height of the planting apparatus from the furrow bottom and the seed drop angle should be as small as possible.

4.When the rotation speed of the planting disc was between 22-30 r/min, the quality indicators for cottonseed planting met agrotechnical requirements.

5.With the planting disc featuring triangular suction cells with rounded corners and an internal Y-shaped barrier (Variant 3), planting accuracy was within the normal range when the seeder's movement speed was from 1.95 m/s to 2.76 m/s.

6.The force required to separate cottonseeds from the disc holes was higher in the planting apparatus with triangular suction cells (rounded corners, Y-shaped internal barrier) compared to other variants.

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