Pneumatic Feed Mechanism for Precise Seeding of Peanut Seeds

Feruza Alimova[1][a], Boikov Vladimir Petrovich[2][b], Jdanovich Cheslav Iosifovich[2][c]
[1]*Tashkent State Technical University, Mechanical Engineering Department, 100057 Tashkent, Uzbekistan*
[2]*Belarusian National Technical University, Minsk, Republic of Belarus*

Keywords: Pneumatic Mechanism, Peanut Seeding, Precision Sowing.

Abstract: The article presents the results of research work on the development of sowing machines that ensure high-quality implementation of the technological operation of sowing peanut seeds. The results of research on the development of a pneumatic feed mechanism with optimal parameters for precise sowing of peanut seeds in a dotted method, taking into account the peculiarities of the soil and climatic conditions of Uzbekistan, are presented. An improved design of a feed mechanism, including a sowing disc that combines the functions of turning the mass of seeds in the seed chamber, clearly capturing seeds by dosing elements, removing seeds from the seed chamber and transporting them to the unloading zone has been proposed. This design solution helps to minimize the process of seed damage, improve the process of capturing and holding seeds in the cells of the sowing disk, which improves the accuracy of their dotted sowing into the cluster and sustainable accurate sowing of peanut seeds according to the given seed consumption. The rational parameters of the sowing disk of a pneumatic feed mechanism, ensuring sowing of peanuts with uniform distribution of seeds-18% and seed consumption - 60 kg/ha are presented.

1 INTRODUCTION

At the present stage of development of agricultural production, one of the main tasks of the agricultural policy of the Republic of Uzbekistan is the need to produce various oilseeds, including peanuts, which are valuable raw materials for the confectionery, medical and technical industries. In Uzbekistan, peanut crops occupy about 7 thousand hectares. The soil and climatic conditions of Uzbekistan make it possible to grow peanuts in almost all areas with a yield of 27...30 c/ha (Program for researching scientific priorities of agriculture, global, regional and territorial scheduled for 2022-2026, 2021).

The sowing scheme should provide a nutritional area in rainfed conditions - 70x(25-30), in irrigated conditions - 70x(10-15) cm. In continuous plantings, the distance between bunch-type plants can be 30 x 60 cm or 15 x 75 cm; for shoot types, more space is allowed (Yang et al., 2022), (Feruza et al., 2024). Peanuts are often sown together with other species.

The most common sowing method is wide-row with row spacing of 70 cm. For this, corn or cotton seeders are used. Peanuts can be cultivated using the checkrowing method according to a 70x70 cm pattern with 6-8 plants in one hill. This method has the advantage of increasing productivity and reducing labor costs for caring for crops by 1.5-2.0 times.

One of the most important conditions for obtaining high peanut yields is high-quality sowing of seeds and the technology for its implementation, carried out in a short agrotechnical time frame. Currently, in world practice, the creation of seeding aggregates with high productivity and adapted to specific soil and climatic conditions is carried out in the main directions: increasing the level of versatility of seeders and the use of improved pneumatic precision seeding devices (Alimova et al., 2023), (Maojian et al., 2022). So, for example, in seeders that operate at high speeds, a pneumatic seed dispenser is widely used, which provides dotted single-grain seeding of uncalibrated seeds and is highly resistant to vibrations (Wan et al., 2020), (Xiao et al., 2014). To improve the movement of seeds, activate the

[a] https://orcid.org/0000-0003-1463-6969
[b] https://orcid.org/0000-0003-2561-0270
[c] https://orcid.org/0000-0002-3165-7625

Alimova, F., Petrovich, B. V. and Iosifovich, J. C.
Pneumatic Feed Mechanism for Precise Seeding of Peanut Seeds.
DOI: 10.5220/0014262400004738

In *Proceedings of the 4th International Conference on Research of Agricultural and Food Technologies (I-CRAFT 2024)*, pages 281-286
ISBN: 978-989-758-773-3; ISSN: 3051-7710

supply of seeds to the collection zones and transport them to the dumping site, use a brush-type seed supply device, flexible belt type seed feeder, compartment type section feeder (Yudao et al., 2020), (Yang 2016). When filling the intake chamber of the device with seeds, to speed up the suction process and prevent clogging of the sampling holes, the "suck before and blow after" model is used, which mainly consists of a combination seed dispenser with air suction, three-position switch, seed waste collection device, vacuum fan, and so on (Liao et al., 2004). The inexpediency of widespread use of expensive foreign-made seeders is associated with the specifics of the republic's fields for peanut crops, which have small areas. The use of wide-cut sowing aggregates in such conditions is impossible.

However, the existing models of domestic seeders today do not fully meet the agrotechnical requirements for uniform sowing of seeds and at the same time lead to high costs. In this regard, it is very important to develop a sowing apparatus that is highly accurately adapted to the specific soil and climatic conditions of Uzbekistan. Due to the fact that in the republic the seed material is a mixture of seeds of different varieties and calibers, the possibility of precise sowing with mechanical devices is practically excluded. In pneumatic devices, when installing disks with medium-sized holes and the presence of large seeds, sowing stops, when installing disks with large holes for large seeds, the holes are quickly clogged with medium seeds, and small ones pass through the holes and are thrown out by the exhauster onto the field surface.

Analysis of the results of preliminary studies of the operation of these seeders for sowing peanut seeds showed increased crushing and damage to seeds, clogging of sowing elements with seed material, uneven sowing, which leads to additional labor costs: replanting, thinning and excessive consumption of seed material.

The analysis showed that in most cases, the physical and mechanical properties of seeds of complex shapes (peanuts, sunflower) significantly limit the range of types of sowing devices capable of ensuring the stability of the process of dosing and distribution of seed material, which indicates the need to create new types of working bodies to ensure high-quality single selection and seed distribution. Based on the analysis, the design of a universal sowing apparatus has been developed, intended for single selection of peanut seeds having a complex shape (Yu et al., 2014). Purpose of the study - increasing the uniformity and stability of seed distribution in a row based on improving the technological process of dotted sowing of peanut seeds with minimal crushing through the development and improvement of the design of the sowing apparatus, as well as the justification of its parameters and operating modes (Liu et al., 2016).

2 MATERIALS AND METHODS

Based on an analysis of the results of research and development work on the mechanization of sowing various seeds of agricultural crops, the type and design of the apparatus for sowing peanut seeds was selected, and the direction of theoretical and experimental research was determined. The general methodology included conducting exploratory experiments, developing theoretical premises, experimental studies in laboratory and field conditions, and economic evaluation of research results. The studies were carried out in the Central Asian region under the conditions of the sharply continental climate of the Republic of Uzbekistan on typical gray soils. The sowing rate of husked seeds is 50-80 kg/ha. The optimal plant density is 100-120 thousand/ha. The sowing depth is 6-8 cm and depends on the moisture content and granulometric composition of the soil.

In accordance with the purpose of the work, the task of the research was to study the physical and mechanical properties of peanut seeds of zoned varieties. The Uzbek Crop Research Institute (UzNIIR) is studying peanut samples from the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). As a result of the study, two varieties of peanuts were zoned: "Salomat" and "Mumtoz". The Mumtoz variety is zoned for main sowing, and the Salomat variety is zoned for both main and re-sowing in the south of Uzbekistan (Kashkadarya and Surkhandarya regions). In addition, the Tashkent-112 variety, belonging to the Valencia group and the Kibray-4 peanut variety, belonging to the Virginia group, are currently cultivated in Uzbekistan.

When determining the physical and mechanical characteristics of peanut seeds, a developed methodology was used to determine the damageability and shear stress of seeds, and instruments were also used to measure pressure and air flow speed. In the process of experimental research, a universal laboratory bench, experimental samples of the apparatus, and a field installation were used.

In the process of research, the basic laws of higher mathematics, theoretical mechanics, laws and rules of mathematical statistics, methods of mathematical planning of experiments and strain gauges, as well as methods given in existing regulatory documents (GOST 20915-11, GOST 31345-2017, UzDst 319:2017, RD Uz 63.03-98, GOST R 53056-2008).

Structure and Working Principle of Pneumatic Feed Mechanism. The pneumatic sowing apparatus has a housing combined with the shell of the vacuum chamber and a sowing disk tightly adjacent to it, a seed hopper located above the intake chamber as shown in Figure 1. A cutter for excess seeds is installed in the upper part of the intake chamber. Inside the intake chamber there is a dispenser with a dosing window. The intake chamber fits tightly to the housing of the sowing device, combined with the shell of the vacuum chamber and the sowing disk. The sowing disc is secured to the shaft using a clamping washer and a bolt. In order to create the minimum required column of seeds in the seed capture zone, a groove is made on the dispenser, which allows the dispenser to be installed at a different angle to the sowing disk using a lock. A tight fit of the sowing disk to the housing of the apparatus, combined with the shell of the vacuum chamber, is achieved using a spring, thereby ensuring tight contact between the sowing disk and the shell of the vacuum chamber. According to the design, in order to minimize the contact of easily damaged seeds with the sharp edges of the rotating disk, in the proposed sowing device, between the housing of the device, combined with the shell of the vacuum chamber and the intake chamber, a locking plate is installed, equal in thickness to the sowing disk.

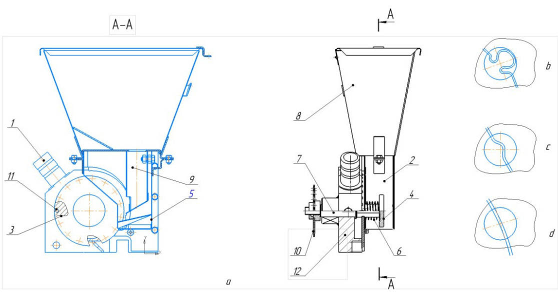

Figure 1: a-General view of pneumatic feed mechanism: *1*-suker; *2*-intake chamber; 3-sowing disk; 4-washer; 5-locking plate; 6-spring; 7- shaft; 8- seed hopper; 9-dispenser; 10-sprokit; 11- hole; b- hole with Ω-shaped jumper, c- hole with S-shaped jumper, d- hole with straight-shaped jumper.

Due to the fact that peanut seeds have a complex shape and vary in weight and size, the disk cells must ensure precise suction with a minimum of damage, excluding slaughter in the cells and gaps during sowing. For this purpose, the disk cells are made in the form of holes of increased diameter with jumpers.

3 RESULTS AND DISCUSSION

An analysis of existing technologies and the technical means used in their implementation is made. Data are presented on the possibility of sowing peanut seeds in a dotted manner using existing pneumatic sowing devices. The technical characteristics of dotted pneumatic seeders used today in the fields of our Republic are considered. To find the type of sowing device for sowing peanut seeds, tests were carried out on the pneumatic devices of the SPP-8FS (Russia), SMH-4-04-01 (Uzbekistan), TC-M 4150 (Russia), SUPN-6(8)M (Russia) seeders. The tests were carried out on a laboratory bench, the specified operating mode corresponded to a seeder speed of 6 km/h. Disks for sowing corn with cells with a diameter of 5.0 mm were used. The results are shown in Table 1.

Table 1: Results of laboratory tests of pneumatic sowing devices for sowing peanut seeds of the Tashkent-112

Indicators	SUPN-6(8)M	SPP-8FS	SMH-4-04-01	TC-M 4150
Weight of sown seeds, g	412.3	407.8	203.9	404.7
Weight of whole seeds, g/%	390.0/ 94.6	377.1/ 92.5	186.2/ 91.3	389,3/ 96.2
Mass of crushed seeds, g/%	10.3/ 2.5	12.35 /3.0	6.93/ 3.4	7.7/1.9
Mass of seeds with damaged shell, g/%	12.0/ 2.9	18.3/ 4.5	10.81/ 5.3	7.7/1.9
Total damage, %	5.4	7.5	8.7	3.8
Seed sowing rate, M_{cp}, pcs/m	6.7	8.7	6.6	7.3

Based on the test results, it can be concluded that the operation of the above devices does not meet the initial requirements for sowing peanuts: seeding rate

- 9...12 pieces / m (140...170 thousand pieces / ha), crushing - no more than 2%.

Key-Parameter Selection and Seeding Process Analysis. Selection of key parameters and determination of the optimal diameter of the sampling holes on the seeding disc

The required vacuum ΔP in the chamber is determined by the formula

$$\Delta P \geq \frac{m_{cp} \times V_{pr}^2 + 2 \times Q_{cp} + d_{otv}}{k_p \times \varphi \times S \times d_{otv}},$$

where d_{otv} is the diameter of the hole; Q_{cp} - seed weight; φ - coefficient of friction of the seed in the cell; m_{cp} - average seed weight; k_p - rarefaction coefficient.

Suction force F_{pr} acting on the seed taking into account Newton's classical formula:

$$F_{pr} = k_a \times f \times \gamma \times \frac{(V_B - V_C)}{g},$$

where k_a is the aerodynamic coefficient; γ - specific gravity of air; f is the cross-sectional area of the seed; V_B, V_C - air and seed movement speeds; g is the acceleration of free fall.

$$k_a = \frac{F_{pr}}{\Delta P \times S}$$

The suction force is expressed through the area of the hole S and the vacuum ΔP.

$$P = k \times \Delta P \times S,$$

where k is a proportionality coefficient that takes into account the total effects of various factors.

Analysis of the above formulas shows that the suction force depends on the speed of movement of the seeds, the magnitude of the vacuum, the size of the seeds and the cross-sectional area of the hole. The excess of this force over the force of weight and centrifugal force contributes to the reliable capture of seeds by the holes on the disk, holding them in the hole until the hole with the seed arrives in the position of dropping into the groove formed by the opener. Focusing on sowing large peanut seeds as a first approximation, the diameter of the hole on the disk should be at least 7.5 mm.

Force Analysis of Seed Fixation on the Disk Hole. To ensure accurate sowing of peanut seeds that vary in size and weight, a jumper must be installed in the disc holes, which at the same time increases resistance and reduces air flow speed. The seed, fixed to the hole of the disk in the seed chamber, must be accurately transported to the discharge point (between the cheeks of the opener) and must not leave it during movement. One of the decisive factors when choosing speed modes of operation of the device is the permissible angular speed of the disk at which the seed does not leave the hole. The theoretical analysis carried out made it possible to select the range of permissible angular velocities of the disk when working with seeds with the highest and lowest weight force, depending on the vacuum force in the hole R_v as shown in Figure 2. The dependence is parabolic in nature and for a vacuum force P_v = 0.055 N, the permissible angular velocity should not exceed 24 rad/s

Selection of the Cell of the Seeding Disk. To reliably capture very large and heavy peanut seeds by the cell of the sowing disk, it is necessary to have a large diameter, into which, however, small seeds will freely pass and medium-sized seeds will jam. Therefore, in the experimental apparatus, the sowing disk cells are made in the form of holes of increased diameter with jumpers. For experimental testing and selection of the jumper shape, disks were made with holes of different diameters and different jumper shapes (straight, S-shaped and Ω-shaped). According to the research results as shown in Figure 3, the most stable interval between seeds was obtained with holes with diameters of 7.5...9.5 mm with an Ω-shaped jumper. The analysis of the study of the influence of jumpers on the crushing of peanut seeds when working with experimental disks is no more than 0.6%, which satisfies the initial requirements.

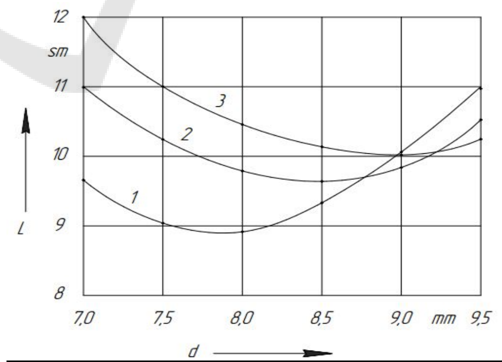

Figure 2: Permissible angular speed of the disk ω depending on the force of pressing the seed to the cell: 1 - for seeds weighing 0.0037 N; 2 - for seeds weighing 0.0058 N

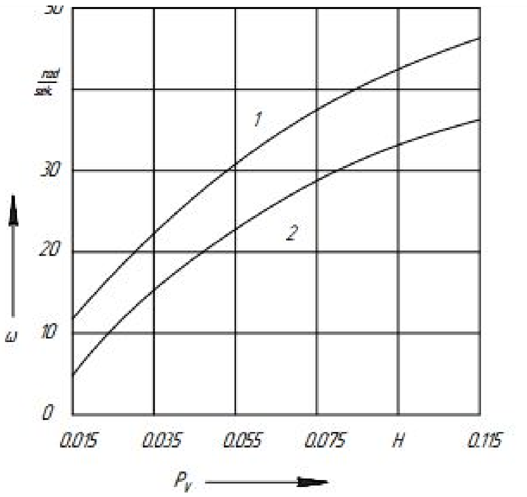

Figure 3: Changing the interval between seeds in a row (L) depending on the diameter of the hole (d): 1- with Ω-shaped jumper; 2-with S-shaped jumper; 3-with a straight jumper

The influence of the rotation frequency of a disk with different cells on the interval between seeds in a row during operation of the apparatus under study was studied. According to the experimental results as shown in Figure 4, as the disk rotation speed increases, the seeding uniformity decreases. Thus, cells were accepted for further work - holes with a diameter of 7.5...9.5 mm with Ω-shaped and S-shaped jumpers.

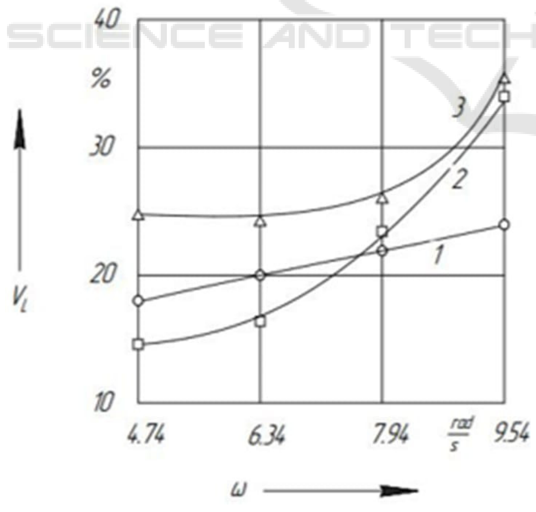

Figure 4: Change in the coefficient of variation of the interval between seeds in a row (V_L) depending on the rotation speed of the sowing disk (ω) with cells: 1 - with an Ω-shaped jumper; 2-with S-shaped jumper; 3 -with straight shaped jumper

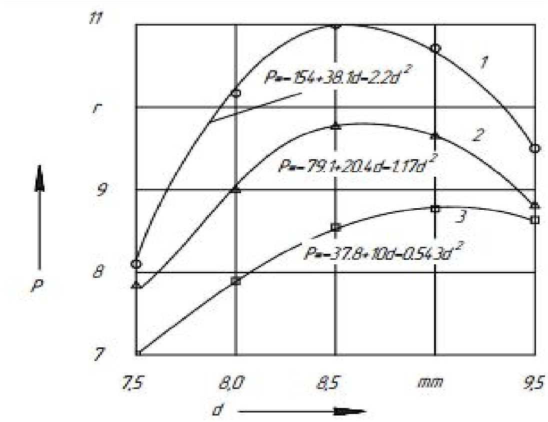

Figure 5: Change in the force of pressing a peanut seed P to flat disk cells of various diameters when the seed is positioned: 1 - with a spheroidal end; 2 - sharp end; 3 - flat

4 CONCLUSIONS

1. A promising direction has been identified for increasing the efficiency of the process of precise sowing of seeds of complex shapes. In accordance with the chosen direction, the technological and design parameters of the dotted seeding apparatus have been developed and justified. Patterns of changes in the quality indicators of the precision seeding process were obtained depending on the parameters of the sowing disk cells and the kinematic operating modes of the apparatus.
2. Based on the research, a sowing apparatus has been developed that provides dotted sowing of peanut seeds. The obtained analytical dependencies and theoretical conclusions can be used by design organizations and research institutions when creating new designs of seeding devices for precision seeders.
3 The most suitable for precise sowing of peanut seeds is a vacuum pneumatic device with a sowing disk having cells in the form of holes with a transverse Ω-shaped jumper, which ensures trouble-free operation of the device with uniformity of seed distribution V = 18% and seed consumption of 60 kg/ha. Seeding disk parameters: angular speed - 4.8….5.2 rad/s; thickness - 4 mm; number of cells - 16 pcs; cell diameter - 8.5 mm.

REFERENCES

BIO Web of Conferences , 01026 (2024) I-CRAFT-2023 85 https://doi.org/10.1051/bioconf/202485 01026

F A Alimova, M T Saidova and B Sh Primkulov (2023) Pneumatic feed mechanism for accurate sowing of bare cotton seeds AEGIS-III-2023 IOP Conf. Series: Earth and Environmental Science 1231 (2023) 012012 IOP Publishing doi:10.1088/1755-1315/1231/1/012012 https://scholar.google.com/scholar?oi=bibs&hl=ru&cites=4322034996561925007&as_sdt=5

Feruza Alimova, Mukhayyokhon Saidova, Bekzod Primqulov, and Tunahan Erdem (2024) Optimization of the parameters of the pneumatic feed mechanism for precise clustered sowing

https://scholar.google.com/scholar?oi=bibs&cluster=13166930500057174961&btnI=1&hl=ru

Liao, Q.; Deng, Z.; Huang, H.(2004) Application of the high speed photography checking the precision metering performances. Trans. J. Huazhong Agric. Univ. 2004, 22, 570–573.

Liu, H.; Xu, X.; Liu, J.; Wang, C. Working characteristics of vertical shallow-basin type seed-metering device based on high-speed photography and virtual simulation. Trans. CSAE 2016, 32, 13–19.

Maojian Wei, Peisong Diao, Wenjun Wang (2022) Design and experiment of the seed delivery device with a rotating brush wheel for precision seeder. Scientific Paper • Eng. agríc. 42 https://doi.org/10.1590/1809-4430-Eng.Agric.v42n6e20220089/2022 https://www.researchgate.net/publication/365809234

"Program for researching scientific priorities of agriculture, global, regional and territorial scheduled for 2022-2026" approved by the Cabinet of Ministers on April 24. 2021 -1 in conditions of typical irrigated gray soils of the Tashkent region pp 16

Wan, S.; Zhang, J.; Zhang, Z.(2020) A major change in peanut planting technology: Single seed precision sowing. Trans. Chin. J. Oil Crops 2020, 42, 927–933.

Xiao Lian Lü, Zhi Chao Hu, Hui Juan Zhang, Wei Wang (2014) https://doi.org/10.4028/www.scientific.net/AMR.945-949.330 Design and Research of the Air-Suction Peanut Precision Dibbler, Advances in Manufacturing Science and Engineering V. Advanced Materials Research (Volumes 945-949). June 2014 330-334p

Yang Xiang, Jianming Kang, Chunyan Zhang, Qiangji Peng, Ningning Zhang and Xiaoyu Wang (2022) Analysis and Optimization Test of the Peanut Seeding Process with an Air-Suction Roller Dibbler. Agriculture 2022, 12(11), 1942; https://doi .org/10.3390/agriculture12111942 Submission received: 25 October 2022 / Revised: 15 November 2022 / Accepted: 16 November 2022 / Published: 17 November 2022

Yang, L.; Yan, B.; Zhang, D.; Zhang, T.; Wang, Y.; Cui, T.(2016) Research Progress on Precision Planting Technology of Maize. Trans. Chin. Soc. Agric. Mach. 2016, 47, 38–48.

Yu, J.; Ding, Y.; Liao, Y.; Cong, J.; Liao, Q.(2014) High-speed photography analysis of dropping trajectory on pneumatic metering device for rapeseed. Trans. J. Huazhong Agric. Univ. 2014, 33, 103–108.

Yudao Li, Zhanhua Song, Fade Li, Yinfa Yan and others. Design and Test of Combined Air Suction Cotton Breed Seeder.Journal of Engineering. 2020(29):1-11DOI:10.1155/2020/7598164