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# The results of experimental research of a rotor seed-metering unit for sowing non-free-flowing seeds

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## Abstract

The production and cultivation of new high-quality seed varieties are linked to the sowing of various crops with diverse physical and mechanical seed properties. Efficient seed-metering unit operation is critical during the technological process of fodder crop cultivation, predominantly when sowing non-free-flowing seeds. The quality of seed sowing and crop yield significantly rely on the design precision of seed-metering devices, technical maintenance and appropriate calibration. A rotary seed metering device was incorporated to ensure that non-friable seeds are uniformly sown, thus maintaining consistent seed supply and consumption at all stages of circulation. The study of the proposed device's productivity dependence on its operating parameters is justified because these variables affect crucial indicators such as the capacity to achieve and sustain the desired seeding rate over the entire operational duration. The study presents findings from an experimental investigation on sowing non-free-flowing (non-flowing) and finely dispersed seeds using a rotor seed-metering unit. The tests aimed to ascertain the precision and evenness of sowing such crops. It was observed that the speed of rotation of the seed-metering unit's vane disk is a key factor in the uniformity and supply of sown seeds. The limits of variation in rotor rotation speed and rotor seed-metering unit productivity per second were established to guarantee the desired seeding rate for various crops, including alfalfa, *Agropyron*, and *Bromus inermis*.

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## Introduction

The advancement of livestock farming and an increase in its output are linked with crop production, specifically the growth of fodder. Among crops used for this purpose, perennial grasses are highly significant. This is due to the fact that they can yield various inexpensive types of fodder while requiring minimal spending on cultivation. The majority of farming land in the Republic of Kazakhstan is devoted to the growth of these grasses (Filipova *et al.*, 2015). The analysis of sown crops indicates a wide range of physical and mechanical property variations. Some crops are covered in villi, many are small-seeded and tend to group together, while others are poorly separated and embedded in the soil. A particular group of fodder crops consists of those with low flowability. For example, *Bromus inermis* (a variety of fescue), *Agropyron*, *etc*. In addition, there are grass non-free-flowing and small-seeded grass seeds, differentiating in size and flow properties. Seeds of leguminous plants and other grasses possessing a smooth surface, characterized by a low coefficient of friction, are commonly referred to as 'flowing'. In contrast, non-flowing or non-free-flowing seeds encompass cereal grasses bearing rough and oblong surfaces such as *B. inermis* and *Agropyron*. These seeds exhibit uneven outer scales along with osteoid points measuring 3-4 mm in length.

Currently, there are no bespoke seeders exclusively designed for sowing non-free-flowing and finely dispersed seeds. Available commercial seeders often fall short of fulfilling the demands of agricultural technology due to a varied range of physical and mechanical properties of seeds, diverse methods of seed supply, laboriousness of sowing and varying agrotechnical requirements. Such challenges have led to the necessity and improvements in the design of sowing machines. (Filipova *et al.,* 2015).

Scientific researches have identified rotor-working devices as a potential solution for dealing with small-seeded crops (Sarimsakov *et al.,* 2021). With further testing, it is expected that rotor-working devices will become widely used for crops such as cotton, triticale and others (Sirakov *et al*., 2019), making them a universal tool. However, future research is necessary to enable rotor working devices to accurately function as metering devices for seeders. Universal sowing machines have the capability to sow various crops, including small seeds. The distance between plants

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can be altered as per agrotechnical needs (Swapnil *et al.,* 2017).

The regression analysis of the mechanical sowing machine operation shows that the research in this direction is relevant (Li *et al.,* 2021). Although investigations were performed on dry rice seeds, the simulated apparatus demonstrated high seeding accuracy. The research conducted theoretical investigations on rotor seed-metering units that operate with non-free-flowing small seeds (Farmonov *et al.,* 2021). The fundamental mathematical relationships among the structural and kinematic parameters of the apparatus and properties of the seeds have been established. These investigations must be experimentally verified. Moreover, the research by Choi *et al*. (2018) on panicum and sorghum seeds affirms the need to develop and define the parameters for unique seed-metering units that differ from the standard reel ones. Seeds possessing distinct physical, mechanical, and geometric features necessitate a unique approach to the design of seed-metering mechanisms.

The optimal choices for planting selective grass seeds are mechanical or electromechanical seed-metering units (Yaropud and Datsiuk, 2021). These units can achieve up to 99% accuracy in seed dispersal, but design enhancements are required to attain such results. The mechanical seed-metering units exhibit greater promise in this regard as they can be more easily adapted to suit small and non-free-flowing seeds owing to their extensive flexibility for improvements (Ovchinnikov, 2017).

The study by Kryuchin *et al.* (2021) examined the rotor seed-metering units used for grass seed sowing in mini seeders. The findings highlighted the suitability of these continuous seeding machines for sowing diverse non-free-flowing seeds with a high degree of universality. The study suggested that the proposed seed-metering unit has the capacity to function consistently at propeller shaft speeds of up to 30 rpm. However, this limitation may hinder the provision of all required seeding rates.

Due to their straightforward nature, mechanical seed-metering units for selectively sowing grasses can be produced via 3D printing, which reduces their production cost and enhances their technological advancement (Nemtinov *et al.,* 2019). Moreover, such seed-metering units display an operational instability of no more than 3.5% within the operating parameters.

With reference to the above, the purpose of this article is to investigate the kinematic properties of rotor seed-metering units to guarantee uniformity and continuousness when sowing non-free-flowing and finely distributed seeds at a wide range of sowing rates, in accordance with agrotechnical demands.

## Materials and Methods

### Seed properties

Various types of forage seeds were carefully selected from Figure 1 and Table 1, along with their corresponding technological indicators listed in Table 2, to assess the functionality of the proposed seed metering system and the experimental seeder (Meshetich *et al.,* 2015).

If the seeds of alfalfa are large and bud-shaped, and its plants are flowering with good flowability, then the grains of *Agropyron* and *B. inermis* have flattened, grooved and elongated shapes of a greyish-yellow color with scaly coatings of varying degrees of fluidity. Additionally, they have powerful root systems that can reach up to 1.5 meters in length, as shown in Figure 1.

The laboratory data obtained (Table 1) indicate that the closer the ratio of the coefficient of kinetic friction to the coefficient of static friction is to 1, the lower the compaction coefficient and the higher the seed outflow coefficient become. This trend determines the factors of non-free flowability of the seed. Additionally, a reduction in the coefficient of static friction results in an increase in the coefficient of internal friction. Hence, to increase the coefficient of


**Figure 1**. Features of the geometric parameters of seeds and plants of feed crops: **a**) *Bromus inermis*; **b**) *Alfalfa*: **c**) *Agropyron*.

**Table 1.** Physical and mechanical properties of non-free-flowing seeds.

| Seed name | Coefficient of internal friction, $f$ | The ratio of the coefficient of kinetic friction to the coefficient of static friction | Compaction coefficient, $K_V$ | Seed outflow coeffi-cient, $\lambda$ | Repose angle, $\alpha^0$ |
|---|---|---|---|---|---|
| Alfalfa (*Medicago sativa*) | 0.97 | 0.68/0.71= 0.96 | 1.24 | 0.56 | 0.42 |
| *Agropyron (Agropyron et Schult)* | 1.35 | 0.62/0.72= 0.87 | 1.12 | 0.48 | 0.53 |
| *Bromus inermis (Lyess)* | 1.52 | 0.6/0.79 = 0.76 | 0.86 | 0.46 | 0.58 |

outflow of non-free-flowing seeds with a high coefficient of internal friction, it is crucial to construct a seed-metering device that has the capability of actively selecting seed material from the hopper for subsequent transport. Table 2 presents the criteria for regular, continuous sowing of seeds with a row spacing of 30-45 cm and the related seed drills, which are chosen based on the usage of different fertilizers. The reasons for choosing fodder crops with low flowability, namely Lucerne (Sinehybridnaya variety), Zhitnyak (Dalalyk variety) and Awnless Rump (Akmolinsky 91 variety) are: i) prevalence of crops in most of the sown areas of the Republic of Kazakhstan; ii) a wide range of physical and mechanical properties that characterize the difficult flowability of seeds (Table 2); iii) an established state system for the production of seeds adapted to the specific soil and climatic conditions of the republic; iv) obtaining stable and sustainable yields of fodder crops.

## Laboratory setup

The functioning of the seed-metering unit is significantly affected by the physical and mechanical properties of seeds. Determining properties include dimensional and mass features (width, length, thickness and grain density), strength (resistance to mechanical damage), frictional (coefficients of rest and movement) and aerodynamic (windage coefficient). For non-free-flowing and finely dispersed seeds, these properties may exhibit a wide range of variation. Considering the physical and mechanical seed properties, we designed and developed the rotor seed-metering unit and detailed parameters, ensuring a consistent supply and consumption of seed material, resulting in a uniform flow during seeding (Laryushin *et al.,* 2021; Kehayov *et al.,* 2022).

Algazin *et al*. (2017) and Isaev *et al*. (2011) conducted theoretical investigations that analyzed the influence of the pitch, radius, and rotational speed of the rotor on the productivity of the rotor seed-metering unit. They also investigated the feasibility of adjusting the seeding rate by altering the rotor's speed. Subsequently, experiments were conducted on a model and laboratory installation to validate these findings and determine the relationship between the rotor's performance and rotational speed (Figure 2). The seed-metering unit (Figure 2a) functions as follows: the sowing cylinder

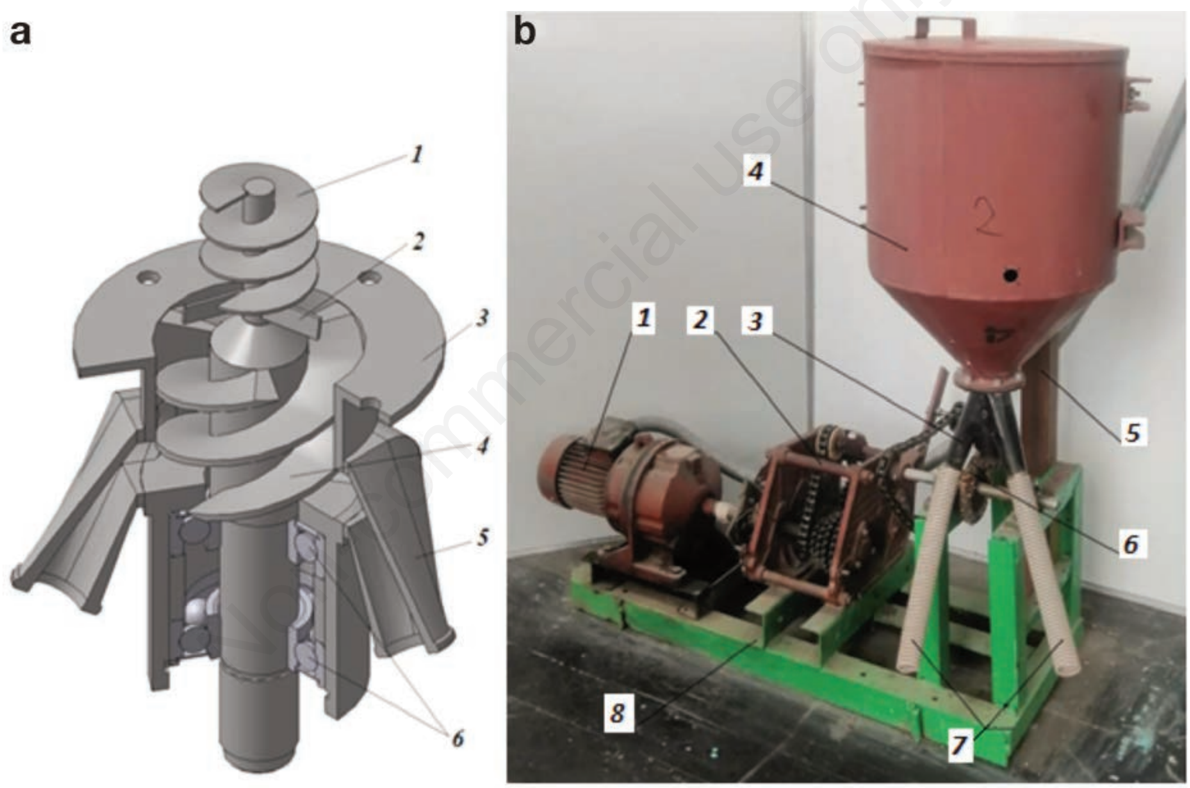


**Figure 2**. Model (**a**) and laboratory installation (**b**) of the seed-metering unit. Numbers?

**Table 2.** Technological indicators of fodder crops.

| Seed | Alfalfa | *Agropyron* | *Bromus inermis* |
|---|---|---|---|
| Variety | *Medicago sativa* | Et Schult | Lyess |
| Sowing norm, kg/ha | 8-12 | 100-12 | 14-18 |
| Depth closures, cm | 2-3 | 1-4 | 3-4 |
| Productivity, t/ha | 12-20 | 6-20 | 14-18 |
| Regionalization areas | Almatinskaya Pavlodarsakya (2011) | Pavlodarskaya (2011) | Akmolinskaya Pavlodarskaya (1998) |

3, with spiral 4 and supercharger (screw) 1, rotates via the drive of the seed-metering unit, supported by installed bearings 6. The screw's spirals capture the seeds and transport them to blade 2, which intercepts and moves them toward the helical spirals of the seed-metering unit. The helical spiral evenly distributes the seed flow across its surface and conveys them to the periphery in the direction of two hoses 5.

The proposed seed-metering unit offers a key advantage of consistent supply and consumption of seed material at each stage. This includes the movement of seeds from the seed hopper through the seeding window with the assistance of a blower, their journey inside a cylindrical pipe to the distribution cone under the guidance of blades, their cone-shaped distribution around the casing's periphery, capture via coils of a helical spiral, movement up to the distribution head, separation into individual flows in the distribution head, and direction towards the seed ducts. This consistency will ensure precision in all aspects and avoid variations in the quality of seed distribution.

The laboratory installation (Figure 2b) consists of an electric motor 1, a gearbox 2, a sowing machine 3, a hopper 4, a rack 5, a bevel gear 6, a seed tube 7 and a frame 8. An electric motor 1, a gearbox 2, a bevel gear 6 and a rack 5 are installed on the frame 8 The sowing machine 3 is fixed to the rack, and the seed ducts 7 are fixed on the sleeves of the sowing machine.

The equipment functions in the following manner: prior to commencing operations, fill hopper 4 with seeds and select the required gear ratio on gearbox 2. Next, activate electric motor 1, which transfers torque to the gearbox 2. Subsequently, the rotational motion is transferred at a 90° angle through the chain drive to the bevel gear 6, which then initiates the sowing unit 3. The sowing unit 3 doses seeds from hopper 4 and enables them to flow through the sleeves to the seed tube via gravity In a screw seed drill, the cylindrical part of the hopper functions as a supply conduit wherein the quantity of bulk material entering the machine is reliant on various parameters. The blower shaft (screw) is secured to the top of the sowing screw through a threaded connection. Additionally, a supply pipe that conforms to rational parameters is interconnected to the bunker. An optimally parameterized supercharger is installed in the bunker of the pilot plant. The supercharger has the following specifications: diameter $D$=45 mm; shaft length l=90 mm; shaft diameter $d$=12 mm; pitch $S$=24 mm; thickness $a$=2 mm; length $L_н$=48 mm (Aduov *et al.,* 2019). The rotational speeds of the gearbox and the sowing shaft were measured in laboratory experiments using the UT371 tachometer. The seeds were weighed with an accuracy of 0.005 grams on a CAS MW-II-300 BR scale and timed with a stopwatch.

## Field test setup

To evaluate the performance of the metering unit during operation, an experimental seeder was designed and developed. This seeder includes multiple components such as a frame, seed box, a gear mechanism, seed-metering unit, double-disc coulters and experimental sowing sections from leashes and furrow-forming rollers installed on them, rods 3, springs 4, cylindrical nozzles 5, trays 6, adjustment mechanism 8 and press wheel 7, support wheel 9, sowing unit 10 and seed hopper 10 (Figure 3).

The manufactured grass seeder consists of a frame 1, a hopper 2, a sowing machine 3, a seed pipe 4, coulters with rollers 5, a bevel gear 6, a drive shaft 7, a gearbox 8. In total, 6 hoppers, 6 sowing machines, 6 bevel gears, 12 coulters, 2 gearboxes with sup-


**Figure 3**. Experimental seeder for sowing non-free-flowing seeds.

port wheels and 2 drive shafts.

Seed sowing is achieved through the following process: the seeds are transferred from the hopper through sowing devices to the double-disk coulters, and then planted into the soil. The cylindrical nozzles in section 5 then move the seeds through the seed ducts to trays 6, which evenly distribute the seeds across the entire width of the furrow created by the furrow-forming rollers. The seeds are then hit and covered with soil to a specified depth by the chain trains.

During field tests, sowing was carried out at a depth of 2 and 4 centimeters, with a row spacing of 30 cm and a working speed of 7 km/h, the seeding rate for awnless brome was 13.4 and 17 kg/ha, and for wheatgrass 8.4 and 12 kg/ha. To adjust the experimental seed drill to the seed rate *Q* (kg/ha), the ratio of the seed rate (*N*) to the area sown (*S*) was used:

$$Q = \frac{N}{S}, \tag{1}$$

If the seeding rate *Q* is expressed through the radius of the support-drive wheel ($Q_k$) or the speed of the unit ($Q_V$), then we have:

$$Q_k = \frac{i \cdot z \cdot m}{2 \cdot \pi \cdot b_M \cdot R_W(1-\varepsilon)} \tag{2}$$

or

$$Q_V = \frac{n \cdot i \cdot z \cdot m}{b_M \cdot V_a}, \tag{3}$$

where:
$i = \omega_d/\omega_w$– gear ratio of the angular speed of rotation of the disk $(\omega_d)$ to the angular speed of rotation of the support-drive wheel $(\omega_w)$, $c^{-1}$;
$z$ = number of sowing devices;
$R_w$ = radius of the support-drive wheel, m;
$\varepsilon$ = wheel slip coefficient on the soil;
$n$ = rotation of the support-drive wheel, rev/s;
$m$ = weight of seeds, kg;
$V_a$ = speed of movement of the unit, m/s;
$b_M$ = seeder coverage width, m.
Knowing the calculated seed mass $M_S$, which the seed drill should sow at a given rate for *n* revolutions of the support wheel, makes it possible to determine the corresponding sowing rate $Q_S$:

$$M_s = \frac{\pi \cdot D \cdot n \cdot B_P \cdot Q_S}{10^4\,(1-\varepsilon)}, \tag{4}$$

or

$$Q_s = \frac{M_S \cdot 10^4(1-\varepsilon)}{\pi \cdot D \cdot n \cdot B_P}, \tag{5}$$

where:
$D$ – diameter of the support-drive wheel;
$B_P = k \times b_M$ – seeder coverage width, m;
$k$ – number of rows to be sown.

The operation of the rotor seed-metering unit on an experimental seeder was evaluated through laboratory and field tests. These tests were conducted using the fundamental principles of classical mechanics, such as rotation dynamics, solid media mechanics, and laminar flow motion, as well as agricultural mechanics, including loose media mechanics and sowing seed mechanics. To ensure accurate testing, statistical planning was employed for both laboratory and field trials, specifically employing multivariate variance analysis. The method for testing and the accompanying methodology are founded on the agrotechnical evaluation of equipment for sowing and spreading solid mineral fertilisers.

Laboratory tests were carried out in the following order. The laboratory conducted tests in a specific sequence: Firstly, non-flowing grass seeds were introduced into the bunker.

Initially, non-flowing grass seeds were deposited in the bunker. Containers were positioned beneath the hoses of the sowing machine, which dispensed the seeds. The gearbox was adjusted to a specific, predetermined speed of the sowing shaft. The laboratory conducted experiments sequentially. Upon switching on the electric motor, the timekeeper commenced simultaneously. Gravity-fed the bulk material from the bunker into a designated container. The time and data acquired for the expiration of the bulk material were meticulously documented in a tabular format. The experiments were replicated five times, both for grain crops and seed materials. The hopper was filled with the succeeding bulk material, and the expiration time was measured. After performing the tests on seed materials with a fixed rotary speed in the gearbox, the speed was then varied and the process was repeated. All experimental data were recorded in the observation log. It was found that non-flowing grass seeds have an expiration time of 100-120 seconds. The consumption of bulk material was determined by dividing the mass of the poured material $M_S$ (g) by the expiration time $t$ (c): $Q = \frac{M_s}{t}$, g/s.

Thus, the processed results of the tests were recorded in a table.

Mathematical and statistical methods were utilised to process and evaluate the dependability of experimental test results. These methods included assessing the homogeneity of flow variances, calculating the variance of experiment reproducibility for full-factor experiments, evaluating the value and significance of regression coefficients using Student's criteria, and checking the model's adequacy according to Fisher's criterion. The experimental data were processed using the MS Excel software, which included the data analysis: Descriptive Statistics feature and the MathCad system. The research findings were analyZed in the laboratory using traditional methods and a system-structural approach. The experiments involved manipulation of two or three independent variables. Using the experimental design, initial parameters such as sowing uniformity were established, and corresponding criteria were assessed to determine their significance and accuracy. The following criteria were employed. To establish the regression equation ($M_s$, $q_1$, $q_2$) and evaluate their reliability $R^2$ on the graphs, the method of adding Trendlines to point data in Microsoft Excel was applied, with further formatting.

## Results and Discussion

During the course of the field experiments, three crops were selected for examination, each exhibiting properties that varied substantially. Throughout the study, all necessary agrotechnical indicators were determined and assessed, including seed germination. The experiment was extensive, and certain results, such as indicators for alfalfa, were featured in our publications (Isaev *et al.,* 2011, Nemtinov *et al.,* 2019, Ovchinnikov, 2017).

The data presented in Tables 3 and 4 were obtained based on the results of the laboratory tests.

During field tests, taking into account the relief of the field and the agrotechnical requirements for sowing grass seeds in this region, the optimal speed of 7 km/h was chosen. The sowing rate

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depends on the speed of movement since the drive of the sowing units is taken from the supporting wheels.

The dynamics of the process were assessed in this case, specifically the rate of seed flow measured in grams per second (g/s) from the sleeves. The average values of Sleeves 1 and 2 were obtained through five experimental repetitions, which were then averaged to obtain the experimental points necessary to establish the regression equation.

Graphs showing the relationship between the productivity of the rotor seed-metering unit and its rotational speed, measured by mass indicators and seeding rate, are displayed in Figures 4 and 5.

Based on Eq. (4), the alteration in seed mass ($M_s$) resulting from rotor seed-metering unit rotational speed (n) displays linear dependency, as described by the regression equation $M_s = A_n + B$. The coefficients $A$ and $B$ serve as approximations. Furthermore, the corresponding $R^2$ approximation coefficients are depicted in the graphs.

Figure 4 depicts that the recommended sowing rate for *Agropyron* seeds between 7 to 16 kg/ha can be achieved by adjusting the speed of the rotor seed-metering unit, ranging from 25 to 35 $min^{-1}$ or 2.62 to 3.66 $rad^{-1}$. It is crucial to maintain these parameters to ensure proper seed sowing. To attain the desired seeding rate, the mass of seeds per second needs to fluctuate from 0.17 to 0.265 g/s. Similar relationships between seed-sowing productivity and rotary speed have been identified while sowing *B. inermis* seeds, as demonstrated in Figure 5. The seed-metering unit shaft rotates at a speed 18 to 20 kg/ha, corresponding to 2.82 to 3.24 $rad^{-1}$, at the required seeding rate of 27 to 31 $min^{-1}$. These figures guarantee a sowing machine productivity range of 0.44 to 0.48 g/s.

Comparable findings from the study of Kehayov *et al.* (2022) reveal that seeding tools can maintain minimal seed harm at seeding rates up to 0.5 g/s, thereby averting any negative impacts on germination. The research findings demonstrate that for optimal seeding rates in accordance with agrotechnological requirements, the seed-metering unit developed requires a rotational speed between 25 and 35 rpm. The designed drive and seed-metering unit permit speed alterations up to 87 rpm, ensuring the achievement of seeding rate demands for all, if not most small-sized crops. The range of rotational speeds employed not only avoids any potential mechanical damage to seeds caused by the seed-metering unit, but also ensures consistent seed flow for uniform sowing rates throughout the entire speed range. As indicated by research data (Choi *et al.*, 2018; Ovchinnikov, 2017), screw seeding devices compared to reel ones are able to provide even greater productivity, while not damaging small seeds. Depending on the diameter of the sowing screw, its maximum angular speed can reach 10 $s^{-1}$.

The *Agropyron* and *B. inermis* seeds were tested comprehensively across the seeding rates ranging from 0.17 to 0.48 g/s, with both seed hoses receiving an even and uninterrupted supply. However, when sowing *Agropyron*, there is a difference in seed supply to the first and second hoses (the type of seed tubes is the same), although the uniformity and uninterrupted operation in both hoses are preserved. This difference is attributable to the unique geometric, physical, and mechanical attributes of these seeds.

Swapnil *et al.* (2017) noted that the characteristics of small-seeded crops' seeds can result in their uneven transportation from the sowing apparatus to the coulters. The type of inner surface, length and slope of the seminal ducts play an important role here. Therefore, it is advisable to use short, smooth and vertical seminal ducts to ensure optimal transportation.

Seed uniformity properties are determined in the seed preparation laboratory, research and production center of grain in preparation for sale in accordance with the relevant requirements of the State standard of the Republic of Kazakhstan.

The approved methodology by the State Commission for Variety Testing of Agricultural Crops in the Republic of Kazakhstan for testing the distinctness, uniformity and stability of crops has been utilized for comparing seed characteristics. The criteria for the field trials involve the provision of the necessary material, specifically an original sample of seeds weighing 1.5 kg, which comply with the requirements for sowing quality and varietal purity not lower than the category of elite seeds, and should not have been treated with pesticides. The tests are conducted on a field where the plants develop naturally, and each trial should comprise at least 60 individual plants split into two replicates, with a plant density of approximately 200 per meter.

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**Table 3.** The results of laboratory tests to determine the weight and seeding rate of Agropyron seeds (variety Agropyron et Schult).

| Test No. | *n, rpm* | Seeds weight, *gr/sec* | | Average seeds weight *Ms, g/sec* | Seeding rate *QS, kg/ha* |
|---|---|---|---|---|---|
| | | *Hose 1, q1* | *Hose 2, q2* | | |
| 1 | 24.92 | 0.203 | 0.13 | 0.167 | 8.33 |
| 2 | 27.42 | 0.263 | 0.147 | 0.205 | 10.26 |
| 3 | 31.78 | 0.29 | 0.154 | 0.222 | 11.11 |
| 4 | 35.12 | 0.335 | 0.2 | 0.267 | 13.37 |
| 5 | 40.25 | 0.382 | 0.229 | 0.306 | 15.29 |

**Table 4.** Results of laboratory experiments to determine the weight and seeding rate of *Bromus inermis* seeds [variety *B. inermis* (Leyss)].

| Test No. | *n, rpm* | Seeds weight, *gr/sec* | | Average seeds weight *Ms, g/sec* | Seeding rate *QS, kg/ha* |
|---|---|---|---|---|---|
| | | *Hose 1, q1* | *Hose 2, q2* | | |
| 1 | 24.92 | 12.18 | 7.798 | 9.99 | 8.325 |
| 2 | 31.78 | 17.41 | 9.252 | 13.33 | 11.11 |
| 3 | 40.25 | 22.94 | 13.77 | 18.35 | 15.29 |
| 4 | 77.15 | 36.73 | 36.66 | 36.69 | 30.58 |
| 5 | 87.21 | 37.80 | 43.09 | 40.45 | 33.7 |

The proposed seeding apparatus is intended for sowing non-friable and fine seeds that exhibit a diverse range of physical and mechanical traits. The rotor-seed unit, which has been developed with a spiral blower, ensures consistent seed feeding and sowing, thereby guaranteeing optimum seed feeding regularity. Further research is needed to identify patterns in the observed irregularity, which is not present when the seed dosing unit is operating with *B. inermis*.

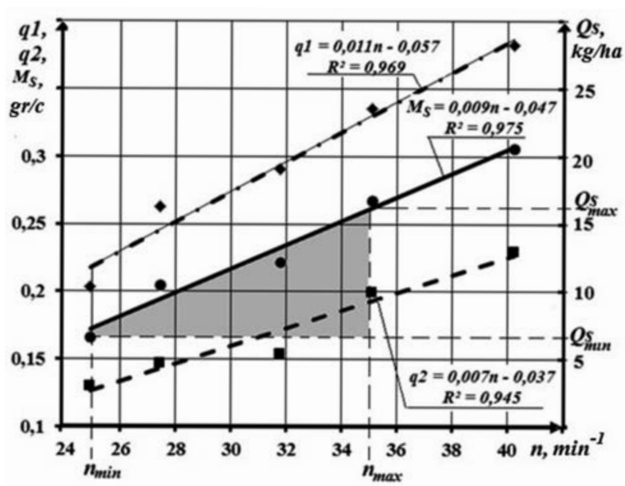


**Figure 4**. Productivity dependence of the rotor seed-metering unit on the rotational speed when sowing *Agropyron* seeds (variety *Agropyron et Schult*). Notes: *q1* and *q2* - linear regression equations for seed weight passing through sleeves No. 1 and No. 2, respectively.

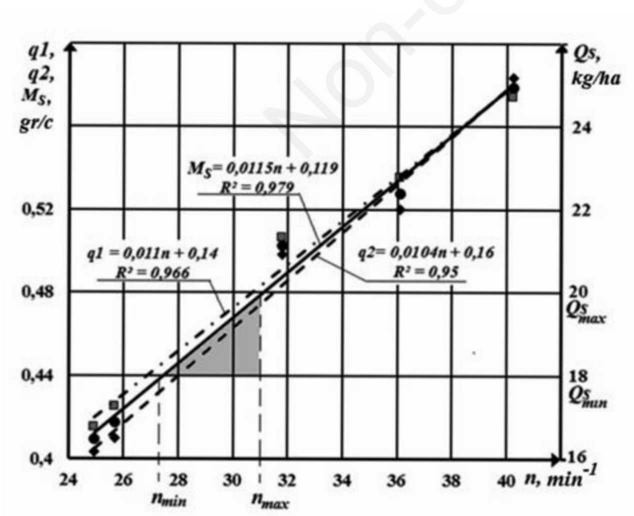


**Figure 5**. Productivity dependence of the rotor seed-metering unit on the rotational speed when sowing *Bromus inermis* seeds [variety *B. inermis* (Leyss)]. Notes: *q1* and *q2* - linear regression equations for seed weight passing through sleeves No. 1 and No. 2, respectively

## Conclusions

To summarize, it can be concluded that the experimental seed drill proposal, employing the seed metering unit for sowing grass seed, satisfies the agro-technical requirements.

Research shows that the drill can mitigate physical and mechanical property effects and boost the efflux coefficient of non-free-flowing seeds. Therefore, it is necessary to use a seed-metering unit with an active selection of seed material from the hopper for its transportation. The rotor seed-metering unit's design for sowing non-free-flowing seeds has been proposed and experimentally verified. It guarantees a steady supply and consumption of seed material throughout all stages of its movement.

The conducted laboratory research proves that the required seeding rate for the selected design parameters should be set by changing the rotary speed, *i.e.*, by changing the gear ratio of the seed-metering unit shaft drive. The seeding rates specified by the requirements were evenly sown over the entire range: i) for *Agropyron et Schult* in the range from 7 to 16 kg/ha with a change in the rotational speed of the rotor the seed-metering unit in the range from 25 to 35 min$^{-1}$, which corresponds to an angular velocity from 2.62 to 3.66 rad$^{-1}$; ii) for seeds of *Bromus inermis* (Leyss) in the range from 18 to 20 kg/ha by changing the rotational speed of the seed-metering unit in the range from 27 to 31 min$^{-1}$, which corresponds to an angular velocity from 2.82 to 3.24 rad$^{-1}$.

Over the entire speed range of the rotor seed metering unit, no seed damage was observed.

## References

Aduov M., Nukusheva S., Tulegenov T. 2019. Seeder for sowing difficult-to-flow grass seeds. Materials of XV Inter. Sci.-Pract. Conf. within the Framework of XXI Inter. Agro-Industrial Exhibition "Agrouniversal-2019", Stavropol, Russian Federation. pp. 15-9.

Algazin D., Vorobyov D., Zabudskiy A., Falkovich L., Danniker A. 2017. Teoreticheskie issledovaniya katushechnogo vintovogo vyisevayuschego apparata [Theoretical research of the screw sowing device]. Res. Sci. Electron. J. Omsk. SAU. 1:1-8. Link?

Choi I.S., Kang N.R., Kim Y.K., Jun H.J., Choi Y., Kang T.G., Hyun C.S., Lee S.H., Kim J.G., Yu S.H., Chung S.O. 2018. The study on the design factors of the groove-roller seed metering device for seeder of foxtail millet & sorghum. J. Biosyst. Eng. 43:303-8.

Farmonov E., Khudayarov B., Abdillaev T., Farmonova F. 2021. Substantiation of the selector drum parameters of the universal seeding device of the innovative seeder. E3S Web Conf. 264:05020.

Filipova N.I., Parsaev E.I., Zadorozhnaya L.V., Kobernitsky V.I. 2015. Sorta kormovyih kultur selektsii Nauchno-proizvodstvennogo tsentra zernovogo hozyaystva imeni A.I. Baraeva: Katalog [Varieties of fodder crops selected by the Research and Production Center for Grain Farming named after A.I. Baraeva: Catalog]. Astana. Available from https://baraev.kz/recomendaciya/katalog_sortov/102-sorta-kormovyh-kultur-selekcii-zernovogo-hozyaystva-imeni-npc-a-i-baraeva.html (accessed on 11 October, 2022)

Isaev Yu., Semashkin N., Nazarova N. 2011. Obosnovanie protsessa peremescheniya semyan spiralno-vintovyim rabochim organom [Justification of the process of moving seeds with a

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spiral-screw working body]. Bull. Ulyanovsk State Agric. Acad. 1:97-4. https://cyberleninka.ru/article/n/obosnovanie-protsessa-peremescheniya-semyan-spiralnovintovym-rabochim-organom

Kehayov D., Atanasov A., Bozhkov I., Zahariev I. 2022. Influence of seed density and gear ratio on quantity of sowed seeds. 21st International Scientific Conference Engineering for Rural Development, Jelgava, Latvia. pp. 194-8.

Kryuchin N., Kotov D., Andreev A., Artamonova O. 2021. Development and research of seeding devices for selected self-propelled pneumatic seeder. BIO Web Conf. 37:00092.

Laryushin N.P., Shukov A.V., Kiryukhina T.A., Yashin A.V. 2021. Innovative seed planter implements for resource-saving sowing technologies. IOP Conf. Ser.: Earth Environ. Sci. 953:012012.

Li H., Zeng S., Luo X., Fang L., Liang Z., Yang W. 2021. Design, DEM simulation, and field experiments of a novel precision seeder for dry direct-seeded rice with film mulching. Agric. 11:378.

Meshetich V., Shurmanbaev N., Kaliaskarova A., Nokusheva Z. 2015. Kormoproizvodstvo na severe Kazahstana [Feed production in the north of Kazakhstan]. Petropavlovsk. Link?

Nemtinov V., Kryuchin N., Kryuchin A., Nemtinova Yu. 2019. Design and study of seeding devices for small selection seeding machines. E3S Web Conf. 126:00008.

Ovchinnikov V. 2017. Results of the study of damage to small seeds from the disk sowing apparatus. Mordovia Univ. Bull. 27:190-8.

Sarimsakov O.Sh., Turg`unov D.U., Babaeva M.N.Q. 2021. Current state and analysis of equipment for cleaning and selection of seeds. Intern. J. Prog. Sci. Technol. 29:337-6.

Sirakov K., Stoilova A., Palov I., Muhova A. 2019. Study on the effect of presowing electromagnetic treatment on the number and lengths of roots and lengths of sprouts of triticale seeds the cultivar colorit. Interl. J. Innov. Approaches Agric. Res. 3:466-4.

Swapnil T.V., Kasturi M.L., Girish P.V., Rajkumar P. 2017. Design and fabrication of seed sowing machine. Int. Res. J. Eng. Technol. 04:704-4.

Yaropud V., Datsiuk D. 2021. By improving breeding seeder sowing device small seeded crops. Vib. Eng. Technol. 1:152-11.

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