



Article

Development of an innovative seeder for restoring desert and semi-desert areas in Uzbekistan

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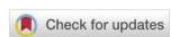
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Abstract: The aim of this study is to provide a scientific basis for an effective approach to the restoration and improvement of natural pastures through the systematic reseeding of native perennial plant species, shrubs, and semi-shrubs adapted to arid environments. The proposed approach is focused on the sustainable recovery of degraded pasture ecosystems by increasing vegetation cover, improving soil protection, and enhancing the ecological and productive potential of natural grazing lands under severe desert conditions. For the restoration of sandy soils and degraded pasture areas, several promising native desert plant species were selected as the primary biological materials, including the shrubs saxaul and cherkez, as well as the semi-shrub izen (prutnyak). These species are naturally adapted to dry and desert climates and are characterized by their ability to survive under limited moisture conditions. Their establishment on degraded sandy lands can contribute to the stabilization of mobile soils, reduction of wind erosion, improvement of vegetation density, and gradual enhancement of the ecological condition and forage capacity of natural pastures. To facilitate the practical application of this restoration approach, a mechanized sowing technology and corresponding seeding equipment were developed. The proposed technical solutions and technological process are protected by patents of the Republic of Uzbekistan, including Patent No. FAP 2670 and Patent No. FAP 3044. These patented developments provide a technical foundation for the mechanized sowing of desert and pasture plant species under difficult soil and climatic conditions. An experimental seeder prototype was developed specifically for the mechanized sowing of saxaul and izen seeds. The machine was designed to provide reliable seed placement and uniform distribution in sandy soils while considering the specific physical and mechanical characteristics of the seed material and the technological requirements associated with desert pasture restoration. The design incorporates technical solutions intended to improve the efficiency and stability of the sowing process under field conditions. The analysis showed that the purity of the prepared seed material was 20–25%, while its germination capacity ranged from 40 to 45%. The results demonstrate the practical potential of combining locally adapted desert plant species with specialized mechanized sowing equipment for the restoration of degraded natural pastures. The proposed technology can serve as a basis for improving vegetation establishment on sandy and arid lands, strengthening soil protection, and supporting the long-term ecological and productive rehabilitation of desert and semi-desert pasture ecosystems.

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Introduction

Arid natural pastures occupy millions of hectares and are predominantly used as grazing lands for livestock. However, significant portions of these ecosystems are currently experiencing various degrees of degradation across almost all regions [1]. Approximately 40% of desert pasturelands are affected by degradation, which has contributed to a reduction of their average productivity by approximately 20–30% [2]. In the Republic of Uzbekistan, about 8.0 million hectares of degraded pasturelands have been identified as requiring improvement and restoration (Table 1).



Globally, arid and semi-arid regions cover approximately 66.7 million km² and support the livelihoods of nearly 2 billion people [3]. According to information provided by the United Nations, drylands occupy approximately 30% of the Earth's terrestrial surface and extend across more than 100 countries, where nearly 2 billion people live [4]. The continuing expansion of desertification and land degradation presents a major environmental and socioeconomic challenge for regions dependent on natural pasture resources. According to projections cited by the United Nations, the continuing development of severe land degradation could result in a substantial increase in the proportion of the global population living in degraded territories [5].

Land degradation has already affected more than 2 billion hectares of productive land worldwide, while approximately 12 million additional hectares are degraded each year [6]. The spatial distribution and structural characteristics of vegetation are closely associated with desertification processes, particularly in areas exposed to intensive livestock grazing [7]. Degradation develops especially rapidly in pasturelands subjected to continuous, year-round grazing, where vegetation has insufficient time to recover naturally [8].

Unregulated livestock grazing and excessive grazing pressure are considered important factors contributing to the deterioration of pasture vegetation and soil resources, as well as to the formation and accumulation of wind-driven sand deposits [9]. The vulnerability of pasture ecosystems increases considerably during dry periods, when both vegetation cover and soil moisture decline substantially [10]. Prolonged and severe drought can further accelerate land degradation and desertification, resulting in decreased vegetation productivity, reduced soil stability, and weakening of the ecological resilience of natural pasture ecosystems [11].

Under these conditions, the restoration and sustainable management of degraded arid and semi-arid pastures require scientifically substantiated technologies and efficient mechanized approaches for establishing native, drought-resistant vegetation [12]. The use of appropriately adapted desert plant species together with specialized sowing technologies may provide an effective basis for improving vegetation cover, stabilizing degraded sandy soils, and restoring the ecological and productive functions of natural pasture ecosystems [9].

Table 1. The level of pasture degradation in the cross section of the Republic of Uzbekistan

Republic of Uzbekistan	The area of degraded grasslands, mil. ha	Degradation size, %
Karakalpakstan	1.50	43.4
Navoi	4.10	43.8
Bukhara	1.2	37.6
Surkhondaryo	0.20	41.2
Samarkand	0.12	23.6
Kashkadarya	0.18	24.5
Jizzakh	0.17	25.4
Total	7.47	40

Currently, considerable areas of degraded natural pastures are distributed throughout almost all regions of the Republic of Uzbekistan, with the total affected area estimated at approximately 8 million hectares [4]. The extent and spatial distribution of degradation differ considerably between regions. Around 40% of the country's desert pastures have experienced degradation to varying degrees, leading to an estimated 20-30% reduction in their average productivity (Table 1). These conditions highlight the need to develop effective technologies and appropriate technical solutions aimed at restoring degraded pasturelands and improving their productive capacity, which is particularly important for the sustainable development of livestock production and pastoral animal husbandry in arid regions [13].

In addition to increasing pasture productivity, preventing further degradation of arid ecosystems represents an equally important objective. Sustainable management of natural pastures therefore requires an integrated approach that combines the rehabilitation of already degraded areas with measures aimed at protecting vegetation and soil resources from continued deterioration. The

application of scientifically substantiated restoration technologies, together with suitable mechanized equipment for establishing native drought-resistant plant species, can play an important role in recovering degraded pasturelands, stabilizing vulnerable sandy soils, limiting the progression of desertification, and strengthening the forage base required for livestock production in arid and semi-arid regions.

Materials and Methods

The present study aimed to develop and experimentally assess a mechanized technology for the rehabilitation of degraded desert and semi-desert areas in the Republic of Uzbekistan through the establishment of native plant species with high drought tolerance. The research methodology incorporated a combination of field observations, laboratory investigations, assessment of seed quality characteristics, and experimental field trials using a newly developed seeder designed for desert vegetation.

The experimental work was carried out on degraded natural pastures and sandy soils representative of the arid and semi-arid zones of Uzbekistan [14]. The selection of plant species was determined by several key characteristics, including their natural occurrence in desert ecosystems, adaptation to severe climatic conditions, drought resistance, and suitability for the restoration of degraded pasturelands.

Three principal native desert and semi-desert plant species were selected as the biological material for the study: saxaul (*haloxylon* spp.), cherkez (*salsola* spp.), and izen (*kochia prostrata*). These species are naturally adapted to arid environments and are considered promising for increasing vegetation cover, improving the stability of sandy soils, and supporting the rehabilitation of degraded natural pasture ecosystems. Their use in combination with mechanized sowing technology provides a basis for establishing drought-resistant vegetation under the challenging soil and climatic conditions characteristic of desert and semi-desert territories.

Second Level Headings

Prior to the sowing experiments, the principal physical and biological characteristics of the seed material were examined. Seed purity and germination capacity were considered particularly important indicators because they have a direct influence on sowing performance, seed placement, and the subsequent establishment of plants under field conditions [15]. The analysis showed that the purity of the prepared seed material varied between 20 and 25%, whereas its germination capacity was within the range of 40–45%.

Third Level Headings

To enable the mechanized sowing of saxaul and izen seeds, an experimental prototype of a specialized desert seeder was designed and manufactured. The construction of the machine was developed with consideration of the distinctive physical and mechanical properties of desert plant seeds, including their relatively poor flowability, as well as the specific technological conditions associated with sowing on sandy soils [16]. The seed-delivery mechanism was intended to maintain a continuous supply of material and provide its uniform distribution and controlled placement in the soil [17]. Particular attention was given to minimizing the occurrence of seed bridging, blockage, and unstable or interrupted seed flow during operation.

Fourth Level Headings

The proposed seeding method and the corresponding machine design were developed using the results of theoretical and experimental investigations. The resulting technical solutions are protected by patents of the Republic of Uzbekistan, namely Patent No. FAP 2670 and Patent No. FAP 3044. Laboratory investigations and field trials were subsequently performed to determine the operational characteristics of the developed seeder and to evaluate the quality and stability of the sowing process under actual soil and climatic conditions.

Fifth Level Headings

Field experiments were conducted to assess several key performance indicators of the developed seeder, including the uniformity of seed distribution, stability of seed delivery, and operational suitability under sandy and degraded pasture conditions. The experimental results were processed and analyzed to evaluate the effectiveness of the proposed mechanized technology for the rehabilitation of degraded desert and semi-desert areas [15]. The findings provided a basis for assessing the practical application of mechanized sowing of native drought-resistant plant species as a means of restoring

pasture vegetation, improving the stability of sandy soils, limiting further degradation, and enhancing the ecological condition and productive capacity of arid pasture ecosystems.

Results

The operating principle of the proposed seeder for sowing the seed heap of desert forage plants, particularly *izen*, is based on the controlled loosening and continuous movement of the seed material within the hopper. Before the machine is put into operation, hopper 7 is filled with the prepared seed mixture. During field operation, the seeder is coupled to a tractor, and its forward movement causes the ground wheels 2 to rotate. The rotational motion generated by the ground wheels is transmitted to the left 4 and right 5 horizontal drive shafts. The rotating horizontal shafts transfer the mechanical motion to the seed-mixture loosening mechanisms installed in the lower part of hopper 7 on bearings 8. Specifically, the left horizontal drive shaft 4 drives the two left shafts 9 of the loosening mechanisms, whereas the right horizontal drive shaft 5 drives the two corresponding right shafts 9 (Fig 1). This arrangement provides synchronized operation of the loosening mechanisms on both sides of the hopper and facilitates the continuous displacement of the seed material toward the metering zone. An important feature of the hopper design is the position of its side walls relative to the seed-mixture loosening mechanisms. The walls of the quadrangular hopper are arranged at an angle of 90° , which helps reduce the contact and friction between the seed mixture and the hopper surfaces. As a result, the seed material can move more freely from the upper section of the hopper toward its lower section. The descending seed mixture is subsequently directed onto the surfaces of the conical fingers 10 installed on the loosening mechanisms (Fig 2). This configuration promotes continuous loosening and movement of the seed heap and helps prevent interruptions in the supply of the seed material during the sowing process.

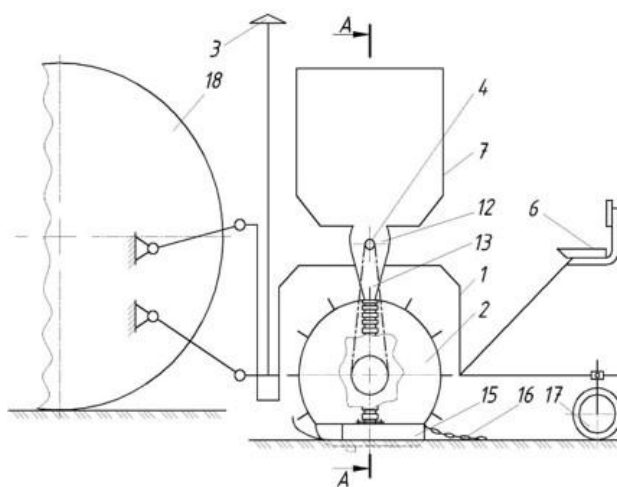


Figure 1. Diagram of the proposed unit for sowing a seed heap of desert forage plants (*izen*).
1-frame, 2-support wheels, 3-marker, 4-5-left and right horizontal shaft, 6-seat, 7-hopper, 8-bearing, 9-seed mixture softeners, 10-cone-shaped fingers, 11-drum distributor, 12-13-seeding apparatus, 14-seed tube, 15-coulter, 16-hedder, 17-compacting roller, 18-tractor chassis.

The seed material initially remains on the surfaces of the conical fingers 10 of the seed-mixture loosening devices 9 until the loosening mechanisms begin to rotate. The conical fingers 10 prevent the seed material from falling directly and abruptly onto the triangular grooves 12 of the distributing drum 11. This controlled movement reduces the possibility of seed accumulation above the grooves and prevents the formation of seed arches that could interrupt the continuous flow of material (Fig 2). As the seed-mixture loosening devices rotate, the conical fingers continuously disturb, separate, and loosen the seed material, thereby maintaining its mobility in the lower section of the hopper. The specific shape and arrangement of the conical fingers ensure a gradual and controlled transfer of the seed mixture toward the triangular grooves of the distributing drum. This process promotes a

more uniform supply of seed material to the grooves and reduces the risk of localized accumulation, bridging, and blockage during operation. Consequently, the continuous movement of the seed mixture toward the metering zone is maintained, contributing to stable and uniform seed distribution during the sowing process.

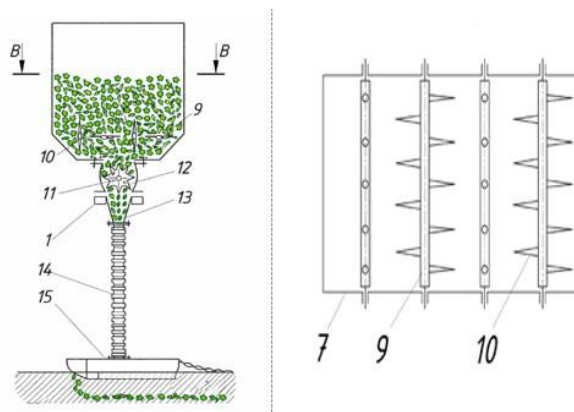


Figure 2. Scheme of the seeding section of the seed harrow for sowing izens.

1- frame, 7-hopper, 9-seed mixture softeners, 10-cone-shaped fingers, 11-drum distributor, 12-triangular chute, 13-seed guide, 14-seed tube, 15-coulter.

The described operating principle enhances the continuity and stability of seed flow and promotes a more uniform distribution of the seed mixture throughout the sowing process. The proposed design enables a stable movement of the non-free-flowing seed material, while reducing the likelihood of bridging, arch formation, and clogging within the hopper. At the same time, it ensures a continuous and reliable supply of the seed mixture to the distributing drum. These features are particularly important for the mechanized sowing of izen seeds, which possess specific physical and mechanical characteristics that can adversely affect their flowability and uniform feeding. Therefore, the use of a specialized seed-mixture loosening and feeding mechanism provides the necessary technological conditions for maintaining stable seed movement and achieving reliable and uniform sowing performance under field conditions.



Figure 3. General view of an innovative seeder for sowing seeds of desert forage plants.

1 – hopper, 2 – shaft (with a conical working section), 3 – drum, 4 – seed feed pipe, 5 – laboratory autotransformer, 6 – distribution panels, 7 – belt conveyor

The main operating parameters of the proposed device were determined under laboratory conditions using a DT-2236B electronic tachometer. The calculated and experimentally obtained

values are presented in (Fig 3). Field trials of the developed seeder were carried out in 2025 at the testing facilities of BMKB-Agromash Joint-Stock Company, located in the Farish District of the Jizzakh Region. Additional field tests were conducted during the same year in the Urtachirchik District of the Tashkent Region. During the field experiments, the seeder was aggregated with wheeled tractors of traction class 0.9–1.4, including the T-40 and MTZ-80/82 models (Fig 4). The selected tractors provided the required traction and operating conditions for evaluating the technological performance of the developed seeder under field conditions.



Figure 4. General view of the experimental machine prototype during experiments.

As illustrated in the figure, an increase in the rotation parameter from 0.01 to 0.075 s results in a consistent increase in the number of sown seeds, from approximately 6 to 17 seeds. The most significant increase occurs within the range of 0.01-0.05 s, during which the number of sown seeds increases from about 6 to 14. With a further increase in the parameter, the number of sown seeds continues to rise, reaching approximately 17 seeds at 0.075 s. In comparison, the number of wingless seeds remains relatively low throughout the investigated range. At parameter values of 0.01-0.02 s, approximately 1 wingless seed is recorded. At 0.03-0.05 s, this value increases to about 2 seeds, while at 0.06-0.075 s it reaches approximately 3 seeds. The observed relationship demonstrates that increasing the operating parameter of the cone-shaped working element intensifies the loosening and displacement of the seed mixture, thereby increasing the quantity of seed material delivered to the distributing mechanism. At the same time, the relatively limited increase in the number of wingless seeds indicates that the working element provides controlled movement and effective separation of the seed mixture. These results confirm that the proposed cone-shaped working element is capable of maintaining a stable and continuous supply of seed material to the distributing mechanism, thereby contributing to improved consistency and reliability of the overall sowing process.

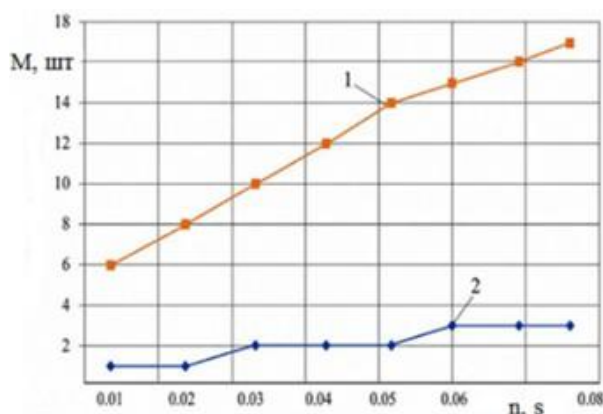


Figure 5. Graph of the dependence of the seed heap quantity on the number of revolutions of the cone-shaped working element. 1 sown seeds, 2 wingless seeds.

In general, the obtained graph demonstrates a clear direct relationship between the operating parameter of the cone-shaped working element and the quantity of seeds supplied to the distributing mechanism. As the number of revolutions of the working element increases, the intensity of loosening and displacement of the seed mixture also increases, resulting in a greater quantity of seed material being delivered to the distributing drum. This relationship confirms that the rotational characteristics of the cone-shaped working element have a significant influence on the continuity and intensity of the seed-feeding process. The analysis of the obtained dependence makes it possible to identify a rational operating range of the proposed device in which the required quantity of seed material is supplied without excessive accumulation or interruption of the seed flow. Within this range, the working element provides sufficiently intensive loosening of the non-free-flowing seed mixture while maintaining controlled movement toward the distributing mechanism. At the same time, the relatively small increase in the number of wingless seeds indicates that an increase in the operating parameter does not result in a substantial deterioration of the quality of seed separation and distribution. Therefore, the experimental results confirm that the appropriate selection of the rotational operating parameter of the cone-shaped working element is an important factor in achieving stable seed feeding and uniform sowing. The identified rational operating range provides a balance between the productivity of the seeding mechanism and the quality of seed distribution, while reducing the risk of bridging, clogging, and unstable seed flow in the hopper. The obtained results can be used as a basis for selecting the optimal operating parameters of the proposed device for the mechanized sowing of izen seed material under field conditions.

Discussion:

The experimental results indicate that the developed planter provides a more stable, continuous, and uniform sowing process within the established agrotechnical requirements compared with conventional manual sowing methods [15]. The obtained results demonstrate that the mechanization of seed metering and distribution has a direct effect on the stability of seed placement along the sowing row [17]. In particular, the controlled separation of the seed material at a predetermined rate and its subsequent delivery into the furrow formed in the prepared sandy soil resulted in a more consistent longitudinal distribution of seeds. Such uniformity is an important technological requirement for the establishment of an evenly distributed plant stand, especially under the difficult environmental conditions characteristic of desert and semi-desert ecosystems. The observed effect is particularly significant for the sowing of izen (*Kochia prostrata*), which is characterized by relatively small seeds and specific physical and mechanical properties. Unlike conventional free-flowing agricultural seeds, the seed material used for desert forage plants may have limited flowability and a tendency to form localized accumulations, bridging, or interruptions in the seed flow. These characteristics complicate the use of conventional metering systems and can lead to irregular seed discharge. Therefore, the technological stability of the seed-feeding mechanism is an important factor determining the overall

quality of sowing. The developed planter addresses this problem through continuous loosening and controlled movement of the seed mixture toward the metering and distributing components

The operating principle of the developed planter contributes to maintaining the mobility of the seed material within the lower part of the hopper. The seed-mixture loosening devices continuously disturb and separate the material, preventing the formation of stable arches and localized accumulations above the distributing drum. The conical working elements provide a gradual transfer of the seed mixture toward the distributing grooves, which promotes a continuous supply of seed material to the metering zone. As a result, the probability of bridging, clogging, and intermittent seed discharge is reduced. This technological feature is particularly important when working with non-free-flowing seed mixtures, for which conventional gravity-based feeding may not provide sufficient stability. The improvement in sowing uniformity can also be associated with the controlled interaction between the seed mixture and the distributing mechanism. The continuous movement of the seed material ensures that seeds are supplied to the metering zone under relatively stable operating conditions. Consequently, the amount of seed delivered to the furrow is less susceptible to sudden fluctuations. Stable seed delivery is especially important for desert forage crops because excessive local concentration of seeds may lead to competition between emerging plants, whereas insufficient seed density may result in gaps in vegetation cover. Both situations can reduce the effectiveness of pasture restoration and negatively affect the formation of a uniform vegetation layer.

The practical significance of the results extends beyond the improvement of individual sowing operations. By facilitating the mechanized establishment of native drought-resistant vegetation, the proposed planter can support the implementation of restoration measures on degraded desert and semi-desert lands. Uniform sowing, stable seed delivery, and reduced labour requirements create favourable technological conditions for increasing the scale of pasture rehabilitation. Consequently, the proposed mechanized approach can serve as a basis for further field studies aimed at evaluating plant emergence, survival, vegetation density, and forage productivity under different soil and climatic conditions. Further investigations should also focus on optimizing the interaction between seed quality, operating speed, working-element rotation, sowing rate, and soil conditions in order to determine the most effective technological parameters for large-scale restoration of degraded arid pastures.

Conclusions

The experimental results demonstrate the effectiveness of the developed planter for mechanized sowing of desert forage plant seeds under sandy-soil conditions. Compared with manual sowing, the planter provides more stable seed delivery, more uniform longitudinal seed distribution, and higher operational productivity while reducing operator-dependent variability. Its key feature is a cone-shaped working element in the lower part of the hopper, which continuously loosens and displaces the non-free-flowing seed mixture. This mechanism reduces seed bridging, accumulation, and blockage, helping maintain continuous seed flow and the required sowing rate.

The developed planter offers a promising technical solution for establishing desert forage vegetation on sandy and degraded lands. More uniform seed placement may improve seed utilization and support vegetation establishment, although these benefits require further field validation. Future studies should evaluate performance under different soil moisture levels, operating speeds, and sowing rates, alongside seedling emergence, survival, fuel consumption, labor requirements, and economic feasibility. The proposed design provides a basis for further development of specialized seeders for desert and semi-desert pasture rehabilitation.

Authors' contribution

Conceptualization and methodology, E.T.Farmonov.; software, validation; formal analysis, research, resources, data collection, writing preparation of the original draft, Sh.X.Mirzaeva.; writing review and editing, visualization, Sh.X.Mirzaeva.; supervision, E.T.Farmonov, M.D.Kholmurodova. All authors have read and approved the published version of the manuscript.

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Ethics approval

This study did not involve human participants or animals; therefore, specific ethical approval was not required. The research was conducted in accordance with generally accepted principles of scientific ethics..

Consent for publication.

"Informed consent was obtained from all study participants."

Data Availability Statement

We encourage all authors of articles published in the journal to share their research data. In this section, please specify where the data supporting the reported results can be found, including links to publicly archived datasets analyzed or generated during the study. If no new data were created or if data is unavailable due to privacy or ethical restrictions, a statement is still required.

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Conflict of interest

The authors declare no conflicts of interest.

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