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RESEARCH ARTICLE

Introduction of the Pasture Plant Fescue (*Festuca valesiaca*) for the Improvement of Degraded Pastures in the Steppe Zone of Kazakhstan

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Abstract: This study presents the results of a comprehensive evaluation of *Festuca valesiaca*, a dominant perennial grass species widely used in steppe ecosystems for pasture improvement. Previous research has demonstrated the importance of native fescue species in enhancing productivity and resilience of degraded rangelands under arid conditions. However, breeding efforts for this species in Kazakhstan remain insufficiently developed. The research was conducted in 2024-2025 in introduction and competitive nurseries at the Koldy experimental station in Kazakh Research Institute of Livestock and Forage Production (KazRILF LLP). A total of 50 accessions representing two ecotypes were evaluated. The results showed that 14 accessions exceeded the standard variety “Ulan” in forage yield by 5-12% and seed productivity by 10.5-14%. In 2025, accession No. 29 demonstrated significant superiority over the standard variety in key traits, including earlier regrowth, higher plant height, increased foliage, and greater productivity of green mass and seeds. Statistical analysis (ANOVA) confirmed that the observed differences were significant at $p<0.05$. Importantly, this accession maintained high productivity under contrasting agroclimatic conditions, including a dry growing season, indicating its phenotypic stability and adaptability. The obtained results confirm the high breeding potential of *F. valesiaca* and its suitability for the development of climate-resilient varieties for degraded steppe pastures.

Keywords: *Festuca valesiaca,* Pasture Restoration, Drought Tolerance, Ecotype Selection, Forage Productivity, Phenotypic Stability, Steppe Ecosystems

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Introduction

Currently, the steppe zone of Kazakhstan is experiencing intense pasture degradation due to years of overgrazing, changes in moisture regimes, and a decline in the overall agroecological resilience of the territories. These processes lead to

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a decrease in the productivity of natural forage lands, a reduction in biodiversity, and a deterioration in the forage base for livestock. Therefore, the task of restoring degraded pastures by introducing adapted native perennial grass species that are resistant to adverse environmental conditions, capable of self-renewal, and preserving biodiversity is particularly urgent. In this context, fescue (*Festuca valesiaca* Huds.), as one of the dominant species of dry steppes, is of significant interest for breeding and introduction [1].

Among perennial steppe grasses, *F. valesiaca* is distinguished by a combination of valuable adaptive and economic traits. Fescue is characterized by high drought resistance, cold resistance, longevity, and high carbon content, as well as durability and the ability to vegetatively regenerate [2]. Its value as a forage plant is confirmed by data showing its high palatability by animals, especially during the early stages of development. Furthermore, fescue has the ability to strengthen soils and prevent erosion, making it an important component in the biological reclamation of disturbed lands [3, 4].

These adaptive properties are largely determined by the morphological and physiological characteristics of the plant. The fescue root system is powerful and deep, capable of penetrating 1.5-2 meters in search of moisture, making the plant drought-resistant and enabling it to dominate dry, hot steppes [5]. During simulated drought, osmotic regulation (proline, soluble sugars) and antioxidant activation maintain membrane integrity [6]. These traits positively correlate with survival and regeneration after severe dehydration.

The inflorescence is a compressed panicle, spreading during flowering with short branches. Spikelets are 6-8 mm long with a straight awn. The seeds are oblong, 8-12 mm long, straw-yellow in colour; the average weight of 1000 seeds is 0.27 g.

In addition to its biological characteristics, *F. valesiaca* plays an important role in natural pasture ecosystems. It is the dominant species (up to 60% of the grass stand) on old fallow lands of dry steppes with chestnut soils and in mixed-grass steppes on southern chernozems, solonetzic, and deep solonetz soils. It is characterized by high frost and drought resistance. Furrowed fescue is a pasture plant. Under moderate grazing intensity, it persists on natural pastures for many decades.

100 kg of green mass at the earing stage contains 30.3 feed units and 2.9 kg of digestible protein. Sheep, goats, horses, and cattle readily consume green mass on pastures before flowering. Hay harvested before flowering is well consumed by all types of livestock. It is promising for inclusion in mixtures with yellow alfalfa, feather grass, wheatgrass, and awnless brome [7, 8].

Seasonal growth dynamics further determine its forage value and utilization. In spring, it regrows earlier than other grasses; it flowers in May-June, quickly becomes coarse after flowering, and enters dormancy during July-August. Growth resumes with the onset of rainfall. Yields on natural forage lands under grazing conditions reach 5-7 centners of dry matter and 10-12 centners of green matter.

From a floristic and geographical perspective, the genus *Festuca* is well represented in Kazakhstan. In the flora of Kazakhstan, there are also narrowly endemic species: *Festuca shishkinae*, *F. pryamokoloskovaya*, *F. goloskokovae*, *F. saurskaya*, and *F. chuiskaya*, which originate from the mountain systems of the Western Tien Shan. For scientific and practical purposes, two species are of greatest interest:

(1) For the dry steppes of Kazakhstan *F. valesiaca*

(2) For sandy deserts *Festuca bekkeri*

The first species is distributed from the Tarbagatai Range in the east through the steppes of Sary-Arka to the western regions of Kazakhstan, while *F. bekkeri* occupies sandy areas from the Irtysh region to the Caspian lowland [9].

At the same time, significant intraspecific variability is observed within *F. valesiaca*. Fescue is one of the widely distributed species within the *Festuca valesiaca* complex, occurring from semi-desert to mountainous zones [10, 11]. As a result of long-term field studies, distinct ecotypes, including Almaty and Tarbagatai types, have been identified, reflecting adaptation to local environmental conditions [9].

Despite its wide distribution and ecological importance, *F. valesiaca* remains insufficiently studied in breeding programs in Kazakhstan. Most available studies are focused on ecological characteristics, physiological adaptation, and natural distribution of the species, whereas systematic breeding research aimed at improving productivity, stress resistance, and forage quality is limited. In particular, there is a lack of regionally adapted cultivars developed for pasture restoration under

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the extreme continental climate of Kazakhstan [12]. This gap significantly restricts the effective use of this species in pasture improvement programs and highlights the need for targeted breeding studies.

Therefore, the aim of this study is to develop approaches for the breeding of *F. valesiaca* adapted to the conditions of the steppe zone of Kazakhstan. The objectives of the study are:

(1) To evaluate fescue accessions under field conditions

(2) To analyze phenological and biometric traits

(3) To assess productivity and forage value

(4) To identify promising genotypes for further breeding and regional adaptation

The study is based on the following hypotheses:

(1) Natural populations of *F. valesiaca* in Kazakhstan possess significant intraspecific variability that can be utilized in breeding

(2) Selection of genotypes adapted to local agroecological conditions will enable the development of high-yielding and stress-resistant varieties

(3) The use of improved cultivars will contribute to increasing the productivity and sustainability of degraded pastures

Methodology and Conditions of the Research

The main studies were carried out in the foothill desert-steppe zone of the Almaty region, in the Karasai district, at the Koldy experimental station of KazRILF LLP. The research material included 50 accessions of wild populations and two ecotypes of fescue collected during expeditionary surveys in the eastern and south-eastern regions of Kazakhstan. For the primary evaluation, 50 accessions of *F. valesiaca* were used, representing two ecotypes: Almaty (28 accessions) and Tarbagatai (22 accessions).

Field experiments were established using a randomized complete block design with four replicates. The area of each experimental plot was 50 m². Each plot contained 50 plants, with an initial seeding rate of 500 seeds per m² followed by thinning, ensuring a total of no fewer than 120-160 plants per accession for evaluation across replicates. Row spacing ranged from 30 to 45 cm, and the distance between plants within rows was 15-20 cm. The seeding depth varied from 3 to 5 cm.

The experimental site is characterized by ordinary sierozem soils, slightly saline and loamy in texture. The salinity type is chloride (for anions) and sodium-calcium (for cations), and the humus content in the arable horizon ranges from 1.0 to 1.7%. The climate of the region is sharply continental, characterized by significant temperature fluctuations, low precipitation, and frequent drought periods during the growing season, particularly in summer.

The study of introduction material, sowing methods, observations, and comprehensive assessment of morphological characteristics and biological properties of pasture plants were carried out in accordance with the guidelines for the mobilization of plant resources and the introduction of arid forage plants [13], the guidelines for conducting research in seed production of perennial grasses [14], and the methodology of field experiments [15]. The evaluation of samples and ecotypes was conducted based on economically valuable traits, including phenological observations, plant height, foliage, resistance to drought, pests and diseases, yield of pasture forage mass and seeds, and crude protein content.

Phenological observations of *F. valesiaca* samples and ecotypes were carried out according to the method of I.N. [16]. The dates of the beginning (15%) and end (75%) of the following developmental stages were recorded: seedling emergence, tillering (branching), heading, budding, flowering, fruit formation, and seed ripening.

The yield of forage mass (g/m²) was determined under pasture use conditions, with the first cutting conducted at the beginning of the budding stage and the second cutting (aftermath) at the budding stage of regrowth shoots. Seed productivity (g/m²) was determined at the stage of full seed ripening by harvesting inflorescences followed by drying, threshing, and weighing.

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A qualitative assessment of forage nutritional value was carried out in the laboratory for feed evaluation at KazRILF LLP. The determination of crude protein content was performed using standard methods of feed analysis, including the Kjeldahl method for total nitrogen determination with subsequent conversion to protein content. In addition, dry matter content was determined by oven drying to constant weight.

The determination of plant resistance to drought, pests and diseases was carried out according to the generally accepted VIR method [15] using a 5-point scale, where 1 indicates very weak resistance and 5 indicates very strong resistance.

The main parameters evaluated in the nursery experiments included plant height at different developmental stages, foliage before mowing, yield of green and dry biomass, and chemical composition with particular emphasis on crude protein content.

Statistical analysis was performed using analysis of variance (ANOVA), and differences were considered significant at $p<0.05$. A one-factor analysis of variance (ANOVA) was performed with accession as the main factor, using standard statistical procedures. Research results.

To analyze the influence of weather conditions on the growth and development of fescue (*Festuca valesiaca* Schleich. ex Gaudin), average monthly air temperature and precipitation in 2024-2025 were compared with long-term mean values (Table 1). The climatic conditions of the study area are characterized by a sharply continental regime, marked annual temperature fluctuations, and uneven distribution of precipitation during the growing season

According to the long-term data, the average monthly air temperature in the study area ranges from -10.2°C in January to 24.0°C in July, while the annual precipitation averages 470.8 mm. In 2024, the mean annual air temperature reached 10.9 °C, which was 3.0°C higher than the long-term average, whereas annual precipitation amounted to 770.1 mm, exceeding the climatic norm by 299.3 mm. In 2025, weather conditions were also warmer than average: the mean annual temperature was 13.6°C, or 5.7°C above the long-term value, while annual precipitation totaled 520.0 mm, which was 49.2 mm above the long-term norm.

Table 1: Characteristics of meteorological conditions in Almalybak village (2024-2025)

Month	Air temperature, °C (long-term)	2024	2025	Precipitation, mm (long-term)	2024	2025
I	-10.2	1.2	2.6	23.7	38.8	33.6
II	-7.9	4.0	1.5	25.8	43.6	17.1
III	1.4	5.4	6.2	51.9	135.5	76.8
IV	10.5	12.8	15.7	66.1	111.3	57.2
V	15.4	17.6	20.8	66.5	121.2	80.4
VI	21.2	24.5	25.6	54.9	19.7	17.1
VII	24.0	25.0	27.7	36.5	85.2	9.6
VIII	22.3	25.9	24.9	25.0	25.1	17.9
IX	16.6	15.1	19.6	18.6	14.3	31.4
X	8.9	12.0	13.1	33.2	71.8	73.2
XI	0.0	1.5	1.8	35.1	58.1	58.3
XII	-7.0	3.3	3.8	33.6	45.5	47.5
Year	7.9	10.9	13.6	470.8	770.1	520.0

In 2024, especially large positive temperature deviations were observed in January (+11.4°C), February (+11.9°C), March (+4.0°C), June (+3.3°C), August (+3.6°C), October (+3.1°C), November (+1.5°C), and December (+10.3°C). During the main vegetation period, March and April were warmer than average by 4.0 and 2.3 °C, respectively, which likely contributed to earlier regrowth and a more rapid passage of early phenological stages. Precipitation in 2024 was considerably higher than the long-term mean in most months, especially in March (135.5 mm versus 51.9 mm), April (111.3 mm versus 66.1 mm), May (121.2 mm versus 66.5 mm), July (85.2 mm versus 36.5 mm), and October (71.8 mm versus 33.2 mm). At the same time, June precipitation was sharply reduced to 19.7 mm compared with the long-term average of 54.9 mm, and September was also drier than normal (14.3 mm versus 18.6 mm).

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In 2025, the temperature regime was even warmer. From March to August, monthly temperatures exceeded the long-term values by 4.8, 5.2, 5.4, 4.4, 3.7, and 2.6 °C, respectively. Such conditions promoted active vegetative growth in spring but also increased evaporative demand during summer. Precipitation in 2025 was unevenly distributed. Moisture supply was relatively favorable in March (76.8 mm versus 51.9 mm) and May (80.4 mm versus 66.5 mm), but in April precipitation was slightly below normal (57.2 mm versus 66.1 mm). A pronounced moisture deficit developed in summer: in June only 17.1 mm of precipitation was recorded compared with the long-term 54.9 mm, in July 9.6 mm versus 36.5 mm, and in August 17.9 mm versus 25.0 mm. In September, by contrast, precipitation increased to 31.4 mm, exceeding the long-term average of 18.6 mm by 12.8 mm.

Thus, the agroclimatic conditions of the two study years differed markedly. The year 2024 was characterized by increased heat supply combined with abundant spring and overall annual precipitation, which created generally favorable conditions for the growth and development of fescue. In contrast, 2025 was warmer and relatively drier during the summer months, especially in June-August, which indicates the development of drought stress during critical periods of biomass formation.

Therefore, the contrasting hydrothermal conditions of 2024 and 2025 provided a suitable environmental background for evaluating the adaptive potential and productivity of *F. valesiaca* accessions under different levels of moisture availability.

In 2017, an introduction nursery was established at the Koldy inpatient facility of KazRILF LLP for the initial study of wild fescue populations (*F. valesiaca* Schleich. ex Gaudin) from various geographic zones of Kazakhstan. A total of 50 accessions were included, comprising 28 representatives of the Almaty ecotype and 22 accessions of the Tarbagatai ecotype.

Annual comprehensive assessment of the introduction nursery revealed that out of 50 accessions, six samples (No. 22, 28, 29, 30, 40, 42) exceeded the standard in dry matter yield by 1.3-5.0%. Among them, four accessions (No. 22, 28, 29, 30) belonged to the Almaty ecotype, while two (No. 40, 42) represented the Tarbagatai ecotype and showed stable performance over the years.

To further evaluate their stability and productivity, the selected accessions were transferred to a collection nursery. In 2020, seeds of these samples were sown for detailed assessment based on economically valuable traits. At this stage, clear differences between ecotypes were identified. Accessions of the Almaty ecotype were superior in plant height (60-78 cm) compared to the Tarbagatai ecotype (56-65 cm), which contributed to higher seed productivity (24.5 g/m² versus 18.6 g/m²). The best-performing samples reached 23-27 g/m² and 20-21 g/m², respectively. Based on these results, accession No. 29 of the Almaty ecotype was identified as the most promising and transferred to the competitive variety testing nursery.

A competitive nursery was established in 2023 for further evaluation. Phenological observations conducted in 2025 showed that accession No. 29 entered key developmental phases 2-4 days earlier than the standard variety “Ulan”. Booting occurred around April 20, heading on May 6, flowering on May 25, and seed ripening in the first decade of June.

The comparative results of morphological and productivity traits are presented in Figure 1. Accession No. 29 demonstrated clear advantages over the standard variety. Plant height increased by 3.8 cm, foliage by 6%, and green mass productivity by 40 g/m². Seed productivity reached 16.7 g/m², exceeding the standard by 1.4 g/m², indicating high breeding value.

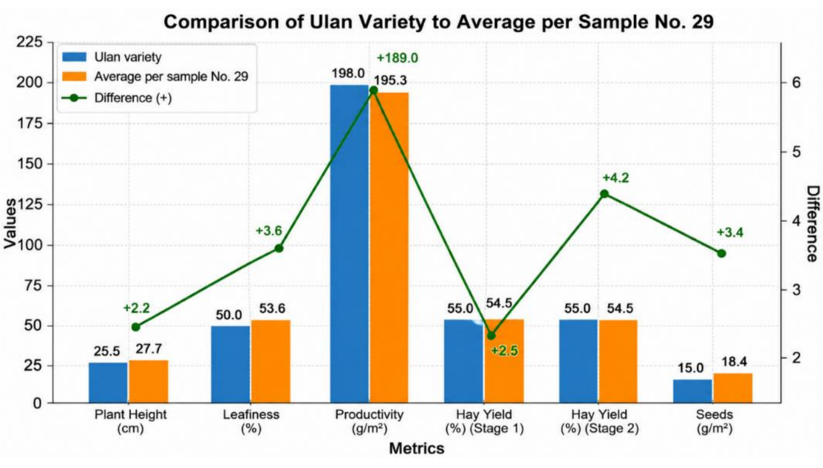

Fig. 1: Comparison of accession No. 29 and the standard variety "Ulan" for major agronomic traits

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To confirm the significance of differences, an analysis of variance (ANOVA) was performed (Table 2). Yield in accession No. 29 (250 g/m²) was significantly higher than in the standard (212.5 g/m²). The difference between treatments (37.5 g/m²) exceeded the $LSD_{0.05}$ value (27.0 g/m²), confirming statistical significance. The F-value exceeded the critical level at $p<0.05$ (df = 1, 6), indicating reliable differences between variants. The coefficient of variation (6.8%) demonstrates high experimental precision.

Accordingly, the differences between accession No. 29 and the standard variety “Ulan” were statistically significant, confirming the reliability of the observed superiority.

Table 2: Average fescue yield values (g/m²)

Options	I	II	III	IV	Average	Group
ST	210	194	216	230	212.5	b
No. 29	230	245	257	268	250.0	a
$LSD_{0.05}$					27.0 g/m²	

Similarly, seed productivity in accession No. 29 (16.7 g/m²) exceeded the standard (15.3 g/m²), with a difference of 1.4 g/m² exceeding the $LSD_{0.05}$ value (1.13 g/m²). The coefficient of variation (4.1%) confirms the reliability of the obtained results.

Moreover, the performance of accession No. 29 was consistent under contrasting agroclimatic conditions observed during the study period. In particular, high productivity was maintained both under relatively favorable moisture conditions and during the dry growing season of 2025, indicating stability of trait expression and a high level of phenotypic adaptability.

In addition to productivity traits, forage quality was evaluated through chemical analysis of pasture biomass at the heading and flowering stages (Table 3). Laboratory analysis included determination of crude protein using the Kjeldahl method, fiber by standard Weende analysis, and carotene content by spectrophotometric methods. Samples were pre-dried at 60-65°C to constant weight before analysis.

Table 3: Qualitative assessment of the nutritional value of pasture forage mass of fescue

Phase	Sample	Protein, %	Fat, %	Fiber, %	BEV, %	Ash, %	Ca, %	R, %	Carotene, mg/kg	OE, MJ/kg; KE, units/kg
Earing	St 1, grade "Ulan" (standard)	14.6	2.4	49.5	24.6	8.9	0.56	0.26	22.1	15.9 / 2.70
Earing	Fescue, accession No. 29	15.8	2.7	48.2	25.3	8.0	0.62	0.29	26.5	16.4 / 2.80
Blooming	St 1, grade "Ulan" (standard)	11.8	2.2	55.4	22.4	8.2	0.45	0.22	16.8	15.1 / 2.55
Blooming	Fescue, accession No. 29	12.2	2.3	56.3	21.0	8.2	0.52	0.26	18.5	15.5 / 2.62

The results of chemical composition analysis (Table 3) showed that forage quality was higher at the heading stage. In accession No. 29, crude protein content reached 15.8%, exceeding the standard by 1.2%, while carotene content (26.5 mg/kg) was higher by 4.4 mg/kg. At the same time, fiber content was slightly lower (48.2% versus 49.5%), indicating improved digestibility. The energy value also exceeded the standard (16.4 MJ/kg versus 15.9 MJ/kg).

During the flowering phase, a decrease in nutritional value was observed. Protein content decreased to 12.2%, fiber content increased to 56.3%, and energy value declined to 15.5 MJ/kg. Such changes are typical for forage crops at later stages of development.

Compared with other perennial steppe forage grasses, the obtained protein (12-16%) and carotene levels correspond to the upper range of typical values, indicating high forage quality of *F. valesiaca* under the studied conditions.

Overall, the obtained results demonstrate the high adaptive potential, productivity, and forage value of accession No. 29, confirming its suitability for further breeding and practical use in pasture improvement.

Discussion. The obtained results confirm that fescue (*F. valesiaca*) has significant breeding potential, allowing for the development of varieties that exceed existing standards in productivity and adaptability. Accession No. 29 of the Almaty ecotype demonstrated consistent superiority in key economically valuable traits, including green mass yield (250 $^{g/m^2}$ versus

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212.5 g/m² for the standard), seed production (16.7 g/m² versus 15.3 g/m²), as well as higher foliage and early regrowth. This indicates that fescue intraspecific variability can be effectively utilized to develop varieties adapted to the arid steppe conditions of Kazakhstan.

Similar trends have been reported in studies demonstrating the importance of native perennial grasses for restoring degraded rangelands and improving ecosystem resilience under arid conditions [1, 17, 18].

Interestingly, the advantage of accession No. 29 is particularly pronounced during the heading phase, when its nutritional value is at its highest: protein content reached 15.8% and carotene content 26.5 mg/kg, exceeding the standard by 1.2% and 4.4 mg/kg, respectively. This makes it possible to recommend accession No. 29 for use in early spring, when the shortage of high-quality feed is particularly acute in livestock production.

Comparable protein concentrations (12–16%) have also been reported for perennial forage grasses in steppe ecosystems, indicating that accession No. 29 falls within the upper range of forage quality under arid conditions.

However, during the flowering phase, the nutritional advantage diminishes, which is consistent with published data on the seasonal dynamics of grass quality, where an increase in fiber content and a decrease in protein and carotene are typically observed at later developmental stages.

A comparison with 2025 meteorological conditions shows that the achieved productivity of accession No. 29 was maintained during an unfavorable dry season, particularly in July and August, when precipitation was significantly below the long-term average. This highlights the high drought tolerance of this ecotype and its potential suitability for cultivation under increasing climatic aridity.

This is particularly important in the context of global climate change, where increasing aridity and temperature extremes are expected to intensify in steppe regions. According to [18], adaptive grassland systems based on drought-tolerant species play a key role in ensuring the sustainability of agricultural production under changing climatic conditions. The ability of accession No. 29 to maintain productivity under moisture deficit highlights its potential as a valuable genetic resource for climate-resilient pasture systems.

It should be noted that fescue, as a dominant species in steppe phytocenoses, performs not only a forage function but also an important ecological role. It contributes to soil stabilization, reduces erosion processes, and supports biodiversity conservation within steppe ecosystems. [19] emphasize the importance of perennial grasses in maintaining ecosystem stability, soil structure, and nutrient cycling, which is particularly relevant for degraded rangelands.

Its ability to reproduce vegetatively and its longevity (up to 30 years or more) make it particularly valuable for long-term pasture restoration programs. In this context, the development of varieties based on local ecotypes is strategically important, as such varieties are better adapted to local environmental conditions and are less susceptible to instability often observed in introduced species.

The superior performance of accession No. 29 observed in the present study is consistent with reports on other perennial Festuca species adapted to arid and semi-arid environments. Studies on Festuca pallescens have demonstrated substantial genetic variability for biomass production, persistence, and adaptation to water-limited conditions, highlighting its breeding potential for dryland ecosystems [3]. Similarly, research on Festuca arundinacea has shown that locally adapted genotypes maintain higher forage quality and productivity under environmental stress than less adapted materials [5]. Comparable responses have also been reported for drought-tolerant perennial forage grasses, where adaptation to local environmental conditions contributes to greater persistence, stable biomass production, and improved resource-use efficiency [7, 18]. Therefore, the results of the present study support the growing international evidence that native Festuca germplasm represents an important genetic resource for breeding climate-resilient forage cultivars and restoring degraded grasslands under increasing climatic aridity.

One limitation of the present study is its relatively short duration, which does not allow a comprehensive assessment of the long-term stability of the selected accession. In addition, the evaluation was conducted within a single agroecological zone, and therefore the ecological plasticity and productivity stability of accession No. 29 under diverse environmental conditions require further verification. Future research should include multi-location trials across different soil and climatic zones of Kazakhstan to confirm the adaptability, ecological plasticity, and productivity stability of accession No. 29 and other promising ecotypes. Long-term studies should also evaluate grass stand longevity, regrowth after grazing, grazing tolerance, and livestock palatability under practical pasture conditions. In addition, integrating molecular genetic approaches with conventional phenotypic evaluation and conducting economic assessments of pasture establishment will further support breeding programs and the practical application of promising ecotypes in sustainable pasture management.

Overall, the present study demonstrates the high potential of fescue breeding as an environmentally and economically effective approach for restoring degraded steppe pastures. The introduction of varieties based on local ecotypes, such as No. 29, will contribute to increasing forage productivity, enhancing drought resilience, and ensuring sustainable development of livestock production systems under arid and semi-arid conditions, while preserving the ecological functions of steppe ecosystems.

Conclusion

The results of this study demonstrate the high potential of *F. valesiaca* as a key species for the restoration of degraded steppe pastures. The selected accession No. 29 showed superior performance in productivity, forage quality, and adaptability compared to the standard variety “Ulan”, confirming its value for breeding programs.

The findings also highlight the importance of utilizing local ecotypes, which exhibit enhanced adaptation to arid and semi-arid conditions. The ability of accession No. 29 to maintain stable productivity under contrasting agroclimatic conditions, including drought, indicates its high phenotypic plasticity and suitability for climate-resilient pasture systems.

However, the study has several limitations. The duration of the experiment was relatively short, which limits the assessment of long-term stability of the selected forms. In addition, the evaluation was conducted within a single agroecological zone, which may not fully reflect the performance of the accessions under diverse environmental conditions.

Therefore, further research should focus on multi-year and multi-location trials across different regions of Kazakhstan to confirm the stability and adaptability of the selected ecotypes. In addition, the application of molecular genetic methods would allow a deeper understanding of the mechanisms underlying stress tolerance and support the development of improved cultivars.

Overall, the introduction of locally adapted fescue varieties can significantly contribute to increasing pasture productivity, improving forage quality, and ensuring the sustainable development of livestock systems in arid environments.

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Author’s Contributions

Meldebekova Nurgul Alikhanovna: Conducted phenological monitoring, collected field data in the introduction and competitive nurseries (2024-2025), and prepared the first draft of the manuscript.
Seitbattalova Ainur Islamovna: Conducted laboratory analysis of plant samples and processed yield structure data.
Ainebekova Bakyt Alpysbaevna: Formulated the research concept, supervised the study.
Abayev Serik Sarbayevich: Developed the experimental design for selection evaluation and coordinated the comparative assessment of ecotypes and promising accessions.
Kenebayev Amankeldi: Performed statistical analysis of experimental data and comparative evaluation with the standard variety “Ulan”.

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Saltanat Toktarbekova: Edited the manuscript, served as the corresponding author, and approved the final version for submission.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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