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SOYBEAN EARLY-MATURING EXOTIC LINES ASSESSMENT UNDER ENVIRONMENTAL CONDITIONS OF THE TASHKENT REGION, UZBEKISTAN

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SUMMARY

A comparative analysis of economically valuable traits of the early-maturing soybean (*Glycine max* L.) exotic cultivars (K-126, K-127, and K-183) with the local standard cultivar Orzu was the aim of this study. The analysis centered on assessing the soybean genotypes' adaptability to the soil and climatic conditions of the Tashkent Region, Uzbekistan. The examined key indicators included grain yield, 1000-seed weight, and protein, oil, and cellulose contents. Analysis of variance revealed significant differences among the soybean cultivars, identifying promising directions for breeding. The standard cultivar Orzu demonstrated the highest yield and protein content. The exotic cultivar K-126 stood out for its high oil content, suggesting its potential for vegetable oil production. The exotic cultivar K-183 showed the maximum cellulose content, beneficial for use in the biomaterial and bioenergy production. The results identified the promising soybean genotypes for targeted breeding focused on food, oil production, and industrial bioresource applications.

Keywords: Soybean (*G. max* L.), early-maturing exotic cultivars, economically valuable traits, grain yield, 1000-seed weight, protein, oil, cellulose content

Key findings: The early-maturing soybean (*G. max* L.) exotic cultivars revealed significant differences for grain yield, protein, oil, and cellulose content, indicating the highest genotypic variability and adaptability to the Tashkent Region's conditions. The standard cultivar Orzu showed the highest grain yield and protein content, while the exotic cultivars K-126 and K-183 demonstrated superior oil and cellulose contents, respectively.

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INTRODUCTION

Global agriculture-related production needs to be doubled by 2050 to meet the rapidly growing population and diet shifts, with a need for increasing crop production by 2.4% per year (Godfray *et al*., 2010; Tilman *et al*., 2011; Ray *et al*., 2013). The soybean (*Glycine max* L.) is a primary and multiuse crop that produces 56% of the edible oil and more than 25% of the protein used in human food and animal feed globally (Wilson*,* 2008). The cultivated soybean (*Glycine max* L. *Merrill*) attained domestication from the wild soybean (*Glycine soja* Sieb. & Zucc.) in China over 5000 years ago (Caldwell and Howell*,* 1973). Soybean has become one of the most important legumes for seed oil and protein production, used for humans and livestock (Lima *et al.,* 2015).

Soybean is the most widely cultivated crop among the legumes and oilseed crops in global agriculture. The United States, Brazil, Argentina, China, and India account for 90% of the world's soybean cultivation areas, revealing considerable attention to this crop. In previous years, countries like Canada, Italy, France, Bolivia, and Russia have also prioritized soybean cultivation. Over the past 20 years, global soybean production has increased 2.16 times (130 million tons annually), cultivation area has expanded by 1.6 times, and yield has improved 1.35 times (Baranov *et al.,* 2005). Soybean grains entail direct usage to produce over 1000 byproducts, and they are one of the primary crops for the production of protein feed, oil, soybean meal, and compound feed (Changrong *et al.,* 2007).

Soybean, often referred to as the 'golden bean,' is also well-known as the meat that grows on plants. As a climate-sensitive crop, soybean adaptation to diverse climatic conditions remains a continuous challenge. Key factors influencing its adaptation include temperature, photoperiod, and water availability. The optimal combination of these climatic factors allows for favorable germination and growth conditions, avoiding adverse impact and maximizing the yields. The selected promising cultivars can serve as potential parental lines for advancing breeding programs and should undergo further evaluation for their adaptive potential under various environmental conditions (Nasir *et al.,* 2023).

Soybean, being a member of the legume family, is an excellent precursor for various crops. In turn, autumn cereals, cotton, potatoes, maize, and rice are well-suited as precursors for soybean cultivation (Lavrinenko *et al.,* 1978). The root nodules help soybeans maintain nitrogen balance and enhance soil fertility by increasing the biological nitrogen available for subsequent crops (Turchin*,* 1959). Integrating soybeans into crop rotation also enhances soil fertility, boosts the yield of subsequent crops, and elevates agricultural practices. The All-Russian Soybean Research Institute has developed various crop rotation schemes tailored for farms in the Far East. These schemes consider factors such as soil and climatic conditions, and soybeans occupy 29%–33%, cereal crops 29%–44%, and forage crops 22%–29% of the rotation area (Lavrinenko *et al.,* 1978). Similar crop rotation systems have successful development for the Krasnodar Krai, Rostov, and Volgograd regions; the Volga region; and Tatarstan in the Russian Federation. Fields cultivated with soybeans experience reduced soil erosion, improved nitrogen balance and soil structure, and enhanced soil fertility (Baranov*,* 2005).

According to the current average annual growth rate of the productivity, 55% of the required increase in soybean production will be achieved by 2050. Therefore, the development and cultivation of high-yielding soybean cultivars is an urgent need (Ray *et al.,* 2013). Achieving the high crop yields requires cultivating genotypes specifically adapted to certain soil and climatic conditions. Depending on the crop cultivars and the growing environments, soybean plants can be short or tall. Soybeans are predominantly an upright-growing plant; however, they also come in prostrate and climbing forms. The selection of superior soybean genotypes is a complex process because the agronomic traits of economic importance are of a quantitative nature, some being correlated with each other, and because of their low heritability (Nogueira *et al.,* 2012).

This study aimed to assess early-maturing exotic soybean cultivars for their adaptability to the soil and climatic conditions of the Tashkent Region. The hypothesis was that certain exotic soybean cultivars will demonstrate better adaptability and yield potential under these conditions, making them suitable for use in various breeding programs. The primary objective of the presented study was to conduct a comparative analysis of early-maturing exotic soybean cultivars based on agronomic traits. Likewise, it sought to identify potential candidate genotypes for future breeding programs under the soil and climatic conditions of the Tashkent Region, Uzbekistan.

MATERIALS AND METHODS

Experimental location and procedure

The experimental soil at the Research Institute of Plant Genetic Resources, Tashkent, Uzbekistan, was typically an irrigated, carbonate-alkaline gray soil with a humus layer of 0.6–1.0 meter thick. The carbonate layer has a depth of 50–60 cm. In terms of mechanical composition, the soils were moderately heavy, with groundwater depth of 7–8 meters, and non-saline. The soil of the experimental field contains humus (0.935%) with medium supply, nitrogen content (27.5 mg/kg) categorized as low, phosphorus content (37.0 mg/kg) classified as medium, potassium content (373.2 mg/kg) that was high, and the soil has a slightly alkaline pH of 7.84.

The Tashkent Region's climate is distinct with abundant sunlight, rapid temperature fluctuation throughout the day and crop seasons, hot and dry summers, and irregular winters. The annual duration of sunny days was 2800–2900 hours (360–400 hours in summer and 90–100 hours in winter). The average annual air temperature was +13 °C to +14 °C. The average temperature in January ranges from -0.4 °C to +1.5 °C, while in July, it ranges from +27 °C to +29 °C. The absolute minimum temperature was -28 °C to -35 °C, and the absolute maximum temperature was +43 °C to +44 °C. Annual precipitation ranges between 250 and 500 millimeters, with most occurring during winter and spring. The snow cover typically lasts for 25–70 days. Warm days extend over 220 days per year, with temperatures exceeding +15 °C (from April 14 to October 5) and totaling 173 days. The accumulated effective temperature was above +15 °C (1310 °C) (Uzhydromet, 2024). The local soybean cultivar Orzu occupies the largest cultivation area in the Tashkent Region, Uzbekistan, with the said genotype selected as the standard cultivar for comparison with exotic soybean cultivars.

Description of the cultivar Orzu

The cultivar Orzu, as the soybean standard, succeeded its development through an individual selection at the Uzbekistan Rice Research Institute, with a botanical type of *Glycine max* L. It has the following description: vegetation period (95–100 days); plant height (90–100 cm); lowest pod position (10–12 cm); number of branches (3–5); pods per plant (90–100); seeds per pod (2–4); 1000-seed weight (150–155 g); and seed composition (protein 40%–42% and oil 20%–22%). The soybean cultivar Orzu is also resistant to lodging, shattering, and diseases and suitable for mechanized harvesting. Under favorable conditions, it can yield 2.0–2.5 tons per hectare.

The comparison of the soybean (*G. max* L.) standard cultivar used three exotic cultivars: K-126, K-127, and K-183. These exotic cultivars were part of the soybean collection preserved at the Research Institute of Plant Genetic Resources, Tashkent, Uzbekistan. Their countries of origin were the USA, Moldova, and China, respectively. The soybean experiment began at the experimental fields of the Research Institute of Plant Genetic Resources, Tashkent, Uzbekistan. The research employed the following methodologies, i.e., 'Methodology of Field Experiments' and 'Methodology for State Cultivar Testing of Agricultural Crops,' Moscow (Dospekhov, 1985).

The seed composition of soybean cultivars, such as protein, oil, and fiber content, entailed measuring using an InfraLUM FT-12 analyzer at the Plant Physiology and Immunity Laboratory, Research Institute of Plant Genetic Resources, Tashkent, Uzbekistan. The performed measurements used a quartz cuvette with a 20 mm optical path length, suitable for accurate analysis in the UV-visible spectrum. All the recorded data for various parameters underwent the one-way analysis of variance (ANOVA), with the Pearson correlation analysis employing the statistical software package SPSS 21 (Melnik, 1983; Liubischev, 1986; Bühl and Zöfel, 2005; Nasledov, 2011).

RESULTS

In breeding soybeans (*G. max* L.), one of the most challenging issues is the introduction and development of new, intensive, and early-maturing cultivars, which are high-yielding, resistant to drastic environmental variations, diseases, and pests, and adaptable to saline and water-deficient conditions. These cultivars must also possess high protein and oil content, resistance to pod shattering, suitability for mechanized harvesting, and compliance with global standards. This challenge arises because various economically valuable quantitative traits in soybeans can exhibit inverse variations under varied environmental conditions, making the development of such cultivars a critical task in current agricultural science.

Promising genotypes should simultaneously unite some desirable attributes, aiming at the highest yields to meet the demand of the productive sector (Cruz, 2013). Throughout the selection process in breeding programs, the primary objective was to improve the main character and enhance and maintain the expression of the yield-related traits consistently (Nogueira *et al.,* 2012). However, the direct selection for quantitative traits' inheritance incurs influences from the environment and interrelations, which can cause a series of unfavorable variations in other valuable traits (Vasconcelos *et al.,* 2010). The selection based on one or a few traits has appeared to be inefficient because it develops a less favorable performance with the other traits not considered in the selection (Bárbaro *et al.,* 2007).

The knowledge of associative behavior among the traits of interest allows the identification of variables that can be beneficial in indirect selection, especially when the heritability of the main character is low (Nogueira *et al.,* 2012). Wild soybeans generally occur with smaller seeds and contain higher levels of protein. Cultivated soybeans produce larger seeds with higher oil content. Thus, no reports existed that a single gene can simultaneously alter seed size and oil and protein content, although some quantitative trait loci (QTLs) govern seed size, with the oil and protein content in soybeans identified through previous genetic analyses (Soy-Base, 2024).

At the initial stage of the study, preliminary analysis of the raw data proceeded, resulting in descriptive statistics for all the economically valuable traits derived from the experimental field data (Table 1). The descriptive analysis includes means formulation, the lower and upper bounds of the 95% confidence interval for the means, medians, variances, standard deviations, minimum and maximum values, ranges, skewness, kurtosis, and graphical representations of all the economically valuable traits. Additionally, the data distribution sustained testing for normality using the Kolmogorov-Smirnov test.

In soybean breeding, valuable agronomic traits, such as grain yield, 1000-seed weight, protein and oil content, and fiber content, are highly significant. The average grain yield of the soybean cultivar Orzu (3.677 t/ha) was higher than all other genotypes (Table 1). This can be due to the homogeneity of the cultivar Orzu. For the standard cultivar Orzu, the grain yield showed a standard deviation (2.7) and standard error (0.49). In the soybean's exotic cultivars, K-183, K-126, and K-127, the determined grain yields were 3.317, 3.63, and 3.08 t/ha, respectively. Among these genotypes, the highest standard deviation was evident in the cultivar K-183

Table 1. Preliminary descriptive statistics for economically important traits in the early-maturing standard and exotic cultivars of soybean.

Traits and cultivars		N	Means	Std. Deviation	Std. Error	95% Confidence Interval for mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Grain yield	Orzu	30	36.7280	2.70280	0.49346	35.7188	37.7372	32.11	42.00
	K - 183	30	33.1767	7.45595	1.36126	30.3926	35.9608	22.87	46.09
	K - 126	30	36.3043	6.33978	1.15748	33.9370	38.6716	27.07	44.22
	K - 127	30	30.8033	3.25889	0.59499	29.5864	32.0202	23.56	35.39
	Total	120	34.2531	5.79724	0.52921	33.2052	35.3010	22.87	46.09
1000-seed weight	Orzu	30	146.4577	3.66796	0.66968	145.0880	147.8273	140.20	151.32
	K - 183	30	155.1030	1.77513	0.32409	154.4402	155.7658	151.98	158.20
	K - 126	30	159.6387	1.09140	0.19926	159.2311	160.0462	157.60	162.00
	K - 127	30	124.7343	1.75079	0.31965	124.0806	125.3881	121.35	128.10
	Total	120	146.4834	13.66355	1.24731	144.0136	148.9532	121.35	162.00
Protein content	Orzu	30	42.9320	1.42290	0.25978	42.4007	43.4633	40.29	44.98
	K - 183	30	39.2600	0.45796	0.08361	39.0890	39.4310	38.25	39.87
	K - 126	30	37.0233	1.40727	0.25693	36.4979	37.5488	34.21	38.69
	K - 127	30	38.2993	0.97565	0.17813	37.9350	38.6636	35.80	39.85
	Total	120	39.3787	2.47749	0.22616	38.9308	39.8265	34.21	44.98
Oil content	Orzu	30	20.1690	0.86217	0.15741	19.8471	20.4909	17.62	21.36
	K - 183	30	21.3333	1.18762	0.21683	20.8899	21.7768	18.69	24.00
	K - 126	30	23.4797	1.17472	0.21447	23.0410	23.9183	21.36	25.65
	K - 127	30	22.8390	1.48209	0.27059	22.2856	23.3924	20.50	25.68
	Total	120	21.9553	1.75530	0.16024	21.6380	22.2725	17.62	25.68
Fiber content	Orzu	30	14.8657	0.29289	0.05347	14.7563	14.9750	14.25	15.21
	K - 183	30	12.2973	0.68101	0.12434	12.0430	12.5516	11.02	13.68
	K - 126	30	13.7913	1.42026	0.25930	13.2610	14.3217	11.25	17.47
	K - 127	30	14.4833	1.14274	0.20863	14.0566	14.9100	11.25	15.87
	Total	120	13.8594	1.38328	0.12628	13.6094	14.1095	11.02	17.47

(7.46). For exotic cultivars K-126 and K-127, the standard deviation values were 6.34 and 3.25, respectively. The standard errors for these three cultivars, K-183, K-126, and K-127, were 1.36, 1.16, and 0.59, respectively.

The soybean seed size, indicated by the 1000-seed weight, determines the seeding rate for a cultivar. The results further showed the average 1000-seed weight of the soybean standard cultivar Orzu was 146.5 g, and for exotic cultivars K-183, K-126, and K-127, the values were 155.1 g, 159.64 g, and 124.73 g, respectively. The standard deviation for the standard cultivar Orzu was 3.67, while for exotic cultivars K-183, K-126, and K-127, the values were 1.78, 1.09, and 1.75, respectively. The standard error for the standard and exotic cultivars was the same and less than 0.67.

Soybeans are unique due to their high-protein content and essential amino acids. The protein content in the standard and exotic cultivars was, for Orzu, 42.93%; K-183, 39.26%; K-126, 37.0%; and K-127, 38.3%. The standard deviation ranged from 0.45 to 1.42, and the standard error was between 0.08 and 0.26 for all the soybean genotypes. Soybean oil is notable for its quality and palatability. Laboratory analysis revealed the highest oil content emerged in the soybean exotic cultivar K-126 (23.48%), exceeding the standard cultivar Orzu by 3.31%. The two other exotic cultivars, K-183 and K-127, had oil contents of 21.3% and 22.84%, respectively. For seed oil, the standard deviation ranged from 0.86 to 1.48, with a standard error of 0.16 to 0.27 for all the soybean genotypes.

Soybeans are also rich in carbohydrates, including fiber. The biochemical analysis using the InfraLUM FT-12 analyzer showed the highest fiber content appeared in the standard cultivar Orzu (14.87%) as compared with the lower values recorded in the soybean exotic cultivars, i.e., K-183 (12.3%), K-126 (13.8%), and K-127 (14.48%). The standard deviation ranged from 0.29 to 1.42, and the standard error was between 0.053 and 0.259 for fiber content among all the soybean genotypes.

The summarized results of the one-way analysis of variance are available in Table 2. The second column of Table 2 displays the between-group, within-group, and total sums of squares, reflecting the traits variation around their means. The third column lists the degrees of freedom, which are essential for calculating the variances of between-group and within-group shown in the fourth column. These variances were the data used to compute the Fisher's F-statistic (F) and its corresponding significance level (p-value), presented in the last two columns. If the F-statistic equals 1, it suggests nonsignificant differences between the group means. Otherwise, if the p-value is lower than the chosen significance level (0.05), then it indicates significant differences between the groups. This analysis provides insight into the variability of economically important traits and helps determine whether the differences between the studied soybean cultivars are significant.

Analysis of variance

The soybean cultivars' data, comprising various traits of grain yield, 1000-seed weight, protein content, oil content, and fiber content, underwent the analysis of variance. For each indicator, the sum of squares, mean squares, F-statistic, and significance level incurred calculations to evaluate the differences between and within groups (Table 2).

Grain yield: The analysis revealed the highest F value (F = 8229, $P < 0.001$), indicating significant differences among the groups for grain yield (Table 2). The between-group sum of squares was 3,959.444, with a mean square of 1,319.815. The within-group mean square was 2.842.

1000-seed weight: The assessment indicated notable differences for 1000-seed weight across the groups (F = 138, $P < 0.001$). The between-group sum of squares was 2,216.415, with a mean square of 720.538. The within-group mean square was 5.215, further confirming significant variations.

Table 2. Analysis of variance for economically valuable traits in the early-maturing standard and exotic cultivars of soybean.

Traits		Sum of squares	Degrees of freedom (d.f.)	Mean squares	F-Statistic (F)	Significance (p-value)
Grain yield	Between groups	701.769	3	233.923	8.229	0.000
	Within groups	3297.576	116	28.427		
	Total	3999.344	119			
1000-seed weight	Between groups	21611.433	3	7203.811	1381.268	0.000
	Within groups	604.982	116	5.215		
	Total	22216.415	119			
Protein content	Between groups	580.584	3	193.528	149.828	0.000
	Within groups	149.833	116	1.292		
	Total	730.418	119			
Oil content	Between groups	200.470	3	66.823	46.645	0.000
	Within groups	166.180	116	1.433		
	Total	366.650	119			
Fiber content	Between groups	115.397	3	38.466	39.731	0.000
	Within groups	112.304	116	0.968		
	Total	227.701	119			

Table 3. Bonferroni multiple comparison test for key agronomic traits in the early-maturing standard and exotic cultivars of soybean.

Dependent variable			Mean difference	Std. Error	Significance	95% Confidence interval	
						Lower bound	Upper bound
Grain yield	Orzu	K - 127	5.92467*	1.37665	0.000	2.2294	9.6199
	K - 126	K - 127	5.50100*	1.37665	0.001	1.8057	9.1963
1000-seed weight	Orzu	K - 183	-8.64533*	0.58965	0.000	-10.2281	-7.0626
		K - 126	-13.18100*	0.58965	0.000	-14.7638	-11.5982
		K - 127	21.72333*	0.58965	0.000	20.1406	23.3061
	K-183	K - 126	-4.53567*	0.58965	0.000	-6.1184	-2.9529
		K - 127	30.36867*	0.58965	0.000	28.7859	31.9514
	K-126	K - 127	34.90433*	0.58965	0.000	33.3216	36.4871
Protein content	Orzu	K - 183	3.67200*	0.29345	0.000	2.8843	4.4597
		K - 126	5.90867*	0.29345	0.000	5.1210	6.6964
		K - 127	4.63267*	0.29345	0.000	3.8450	5.4204
	K-183	K - 126	2.23667*	0.29345	0.000	1.4490	3.0244
		K - 127	0.96067*	0.29345	0.008	0.1730	1.7484
	K-126	K - 127	-1.27600*	0.29345	0.000	-2.0637	-0.4883
Oil content	Orzu	K - 183	-1.16433*	0.30904	0.002	-1.9939	-0.3348
		K - 126	-3.31067*	0.30904	0.000	-4.1402	-2.4811
		K - 127	-2.67000*	0.30904	0.000	-3.4995	-1.8405
	K-183	K - 126	-2.14633*	0.30904	0.000	-2.9759	-1.3168
		K - 127	-1.50567*	0.30904	0.000	-2.3352	-0.6761
Fiber content	Orzu	K - 183	2.56833*	0.25405	0.000	1.8864	3.2503
		K - 126	1.07433*	0.25405	0.000	0.3924	1.7563
	K-183	K - 126	-1.49400*	0.25405	0.000	-2.1759	-0.8121
		K - 127	-2.18600*	0.25405	0.000	-2.8679	-1.5041
	K-126	K - 127	-0.69200*	0.25405	0.045	-1.3739	-0.0101

*Significant at the $P \leq 0.05$.

Protein content: Substantial differences were also evident among the groups for protein content (F = 119, $P < 0.001$). The between-group sum of squares was 580.584, while the within-group sum of squares was 604.982. This confirms that protein content remarkably differs across the groups.

Oil content: Analysis of variance for oil content showed significant differences between groups (F = 119, $P < 0.001$). The between-group sum of squares was 366.550, with a mean square of 200.470. The within-group mean square was 1.433 with a degree of freedom of 116.

Fiber content: Considerable differences were also distinct among the groups for fiber content (F = 39.731, $P < 0.001$). The between-group sum of squares was 115.397, which was higher than the within-group sum of squares (112.304). The mean square values were 38.466 and 968, respectively, confirming significant differences between the groups.

The significant differences identified through the analysis of variance only indicate the presence of differences between group means. However, it cannot specify which cultivars differed from each other. In addressing this, multiple post-hoc comparisons continued using Bonferroni's test (Table 3). Among the various criteria available in the SPSS package, Bonferroni's correction is one of the simplest and most commonly used methods for controlling Type-I error. This method also adjusts the significance level by dividing the initial alpha (Type-I error rate) by the number of comparisons, ensuring the error rate remains within 5%.

Multiple comparisons among the soybean cultivars

The multiple comparison results comprising key agronomic traits, such as grain yield, 1000-seed weight, and protein, oil, and fiber contents among the soybean cultivars Orzu, K-183, K-126, and K-127, relied on Bonferroni's test (Table 3). The soybean standard and exotic cultivars surfaced with significant differences for grain yield and seed oil quality traits.

Grain yield**:** In the soybean standard cultivar Orzu, the grain yield was significantly higher than all the exotic cultivars (Table 3). The grain yield of the exotic cultivar K-127 was 5.92467 units lower than the standard cultivar Orzu, and the said difference was significant ($P < 0.001$). Comparisons between other pairs of soybean cultivars also revealed relevant differences.

1000-seed weight**:** The soybean exotic cultivar K-127 demonstrated a considerably lower 1000-seed weight than all other cultivars. The 1000-seed weight was 21.7233 units lighter than the standard cultivar Orzu and was significantly ($P < 0.001$) recorded as the most pronounced difference. Notable differences were apparent across all the paired comparisons.

Protein content**:** The soybean standard cultivar Orzu had a remarkably higher protein content than all other examined cultivars. Compared with the exotic cultivar K-126, it significantly ($P < 0.001$) contained 5.90867 units more protein. Meaningful differences appeared across all cultivars for protein content.

Oil content**:** The soybean exotic cultivar K-126 exhibited a distinct advantage in oil content and had 3.31067 units, which was significantly ($P < 0.001$) higher than the standard cultivar Orzu. Other soybean cultivars also showed substantial differences for oil content.

Fiber content**:** For fiber content, the largest difference was visible between the soybean exotic (K-183) and standard cultivar (Orzu). The cultivar K-183 was significantly ($P < 0.05$) higher, containing 2.56833 units more fiber content. Meanwhile, the notable differences occurred among all other soybean cultivars for fiber content.

DISCUSSION

In Uzbekistan, the main requirements for soybean cultivation are high yield and rich biochemical composition. Combining valuable quantitative agronomic traits, such as high yield, protein content, and oil content, in a single cultivar remains one of the most important tasks for plant breeders. Over the years, scientists have conducted numerous investigations, resulting in the development of cultivars with various desirable traits. However, due to drastic climate changes and other challenges, plant breeding continues to require the constant introduction of new cultivars every year. High-yielding cultivars are essential for every crop species. In the studies conducted by Xudoyberdieva *et al.* (2025), the same soybean samples analyzed in this article, K-126, K-127, and K-183, were also the specimens. According to the research findings, these exotic cultivars stood out for their early maturity, attaining recommendations as promising early-maturing genetic materials for breeding programs. In the presented study, these early-maturing cultivars entailed further analysis for their key quantitative economic traits, including yield, 1000-seed weight, and protein, oil, and fiber contents. Shavkiev *et al.* (2024) conducted a study on both local and exotic soybean cultivars grown in Uzbekistan and concluded that the local cultivars "Tomaris-60" and "Ustoz-60" were more productive than the exotic cultivars. However, our results revealed significant differences among the studied soybean cultivars for grain yield (Figure 1). The local cultivars Orzu and K-126 demonstrated the highest grain yields, while the two exotic cultivars K-183 and K-127

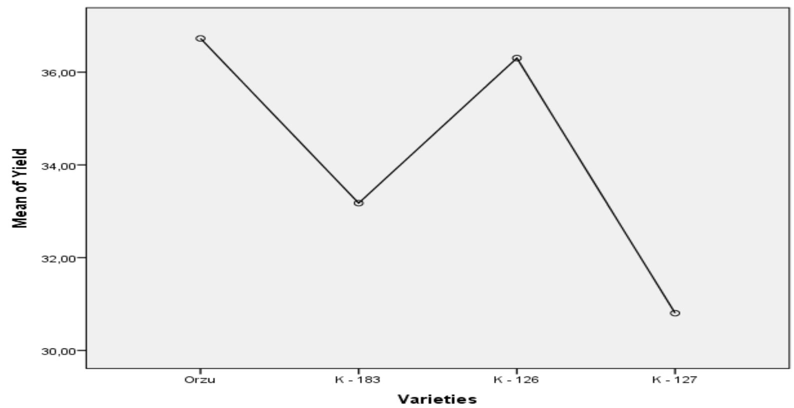

Figure 1. Grain yield of the early-maturing standard and exotic cultivars of soybean.

performed significantly lower than the genotypes Orzu and K-126. This variability can likely be because of the specific agrotechnical care, soil conditions, and the varied climatic adaptability of each cultivar. The distinct responses of these soybean cultivars to environmental and management factors underline the importance of selecting the right cultivar for particular environmental conditions. The exceptional grain yield of the exotic cultivar K-126 suggests its potential as an initial material for further breeding programs, showing its adaptability and robust performance under experimental conditions. Additionally, in the study conducted by Kurbanbaev *et al.* (2023), several soybean cultivars from the botanical collection—Bk-9, Bk-18, Bk-24, Bk-80, Bk-90, Bk-96, K-90.20, K-2600, NC-17480, and Ya-04565—demonstrated superior performance in debated discussions for morphological and yield-related traits, thus being selected to enrich the genetic collection. Among them, K-2600 showed the highest grain yield per plant (48.3 ± 1.30 g) and the most grains per plant (346.4 ± 6.48 pcs), while Bk-105 had the heaviest 1000-grain weight (215.9 ± 0.15 g). These findings indicate the exotic early-maturing cultivars studied in our research have lower yields than the medium- and late-maturing soybean cultivars grown in the country.

Another important agronomic trait studied in the research is the weight of 1000 seeds, which determines the sowing rate of each cultivar—that is, how many kilograms of seeds are planted per hectare. Rakhimov *et al*. (2021), and Kholikova *et al.* (2020) have conducted scientific studies on the 1000-seed weight of soybeans in Uzbekistan. According to their findings, the 1000-seed weight of soybean plants varies between an average of 90 grams and 180 grams, depending on the characteristics of the cultivar. This study's results illustrated the exotic cultivar K-126 exhibited the highest 1000-seed weight, reflecting superior seed quality and potential for seed weight characteristics (Figure 2). The 1000-seed weight underscores its value for specific agricultural practices that prioritize seed size and weight. Conversely, the exotic cultivar K-127 had the lowest 1000-seed weight, suggesting factors influencing seed weight during its growth and development require further investigation for confirmation. Understanding these factors could provide insights for improving the performance of the cultivar and optimizing its use in future breeding and production systems.

The soybean plant stands out from other crops due to the composition of its seeds. In our country, research on the biochemical composition of soybean seeds by Kurbanbaev *et al.* (2023) reported that for biochemical traits, Gen-15, Gen-13, and Gen-11 had the highest oil content, whereas Gen-19, Ehtiyozh, Gen-9, and Gen-26 exhibited the maximum protein content. The cultivar Sochilmas showed the greatest ability to fix nodule bacteria (96.65 ± 0.11), contributing to soil improvement by releasing bacteria after maturity. Furthermore, an inverse relationship between K_2O and humus was noteworthy, with

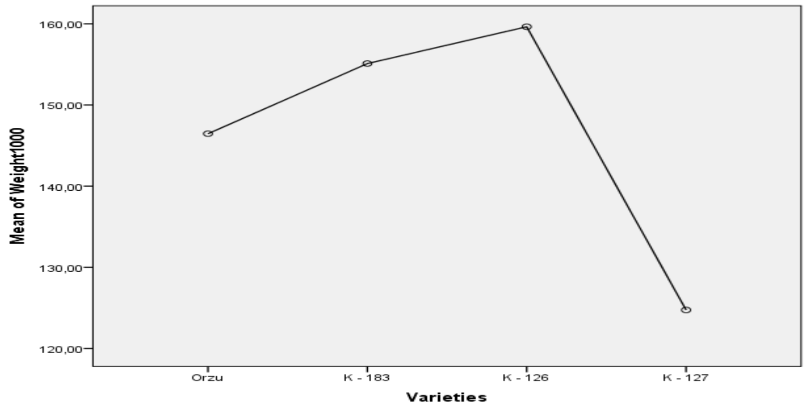

Figure 2. Thousand seeds weight of the early-maturing standard and exotic cultivars of soybean.

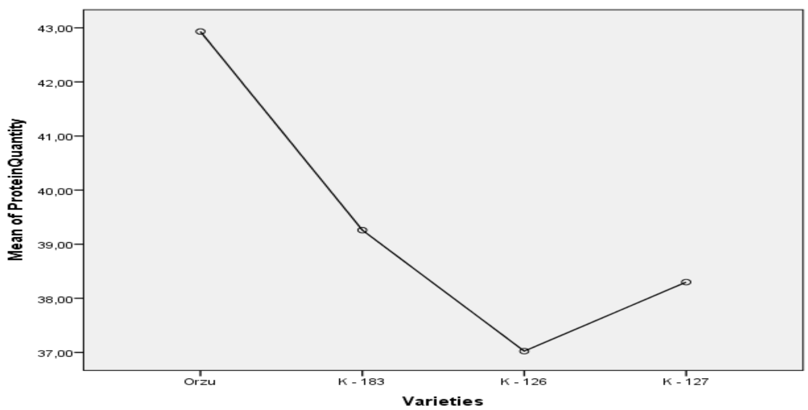

Figure 3. Protein content of the early-maturing standard and exotic cultivars of soybean.

decreased K_2O and increased humus in certain plots after harvest (Kurbanbaev *et al.,* 2023). In a previous study (Khudoyberdieva and Rakhmankulov*,* 2023), when the same samples underwent evaluation in the soybean collection nursery, the protein content was notably 36.6% in the K-126 cultivar, 34.5% in K-127, and 38.2% in K-183. However, our 2024 results (Figure 3) showed that Orzu had the highest protein content (42.9%), while the exotic cultivar K-126 had the lowest value (37.0%). This variability among the soybean cultivars for protein content reflects the nutritional value and future breeding significance of the seeds. The standard cultivar Orzu, with its high-protein content, holds considerable value for food and feed applications, becoming identified as an excellent choice for use in industries requiring high-quality protein sources. In soybean cultivars, the protein content further enhances its importance in agricultural and commercial sectors.

Soybean is a leading crop in the global market due to its high oil content. Compared with a previous work (Khudoyberdieva and Rakhmankulov*,* 2023), in 2022, the oil content in the soybean cultivars K-126, K-127, and K-183 was 23.6%, 22.2%, and 19.6%, respectively. However, our 2024 results (Figure 4) illustrated the exotic cultivar K-126 demonstrated the topmost oil content (23.48%), while the standard Orzu had the lowest (20.4%). This inverse relationship between protein and oil content observed in the cultivars Orzu and K-126 exemplifies the phenomenon of negative association between these two traits. Such findings highlight the

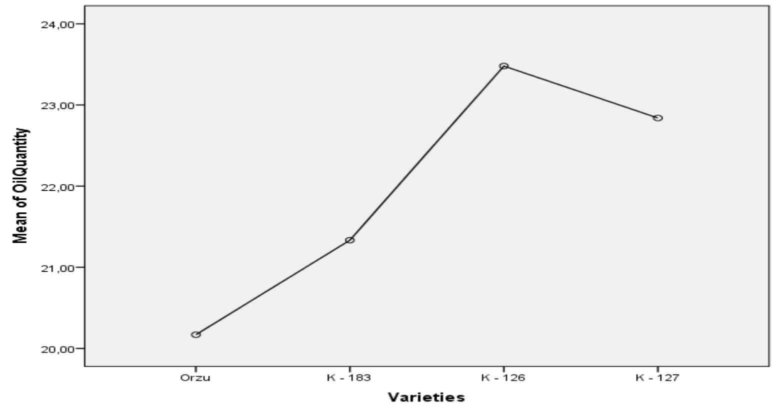

Figure 4. Oil content of the early-maturing standard and exotic cultivars of soybean.

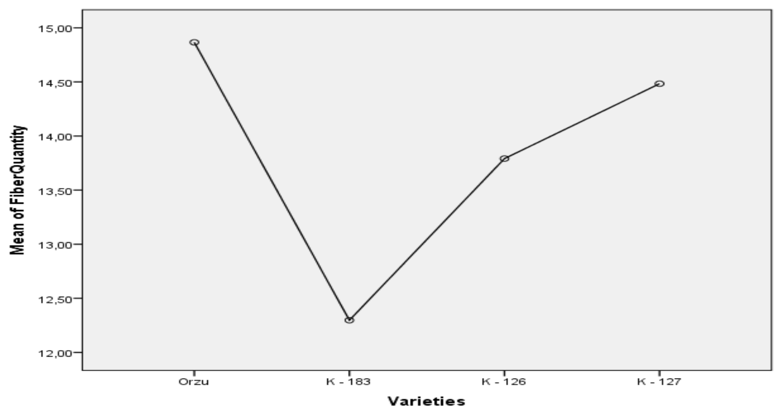

Figure 5. Fiber content of the early-maturing standard and exotic cultivars of soybean.

trade-off between these two traits, which is an important consideration in breeding programs aiming to optimize the balance of protein and oil content depending on the intended agricultural and industrial use of the soybean cultivars.

Scientific research on fiber content has not yet progressed in Uzbekistan, which highlights the novelty of this study. However, in exotic countries, numerous studies are progressing on the biochemical composition of soybean seeds. For the fiber content, the studied soybean cultivars depicted significant differences (Figure 5). The standard cultivar Orzu showed the highest fiber content, while the exotic cultivar K-183 exhibited the lowest value for the said trait. These results highlight the standard cultivar Orzu's potential as a source of fiber, which could be particularly valuable for applications in bioenergy, biomaterials, and feed production. Conversely, the lower fiber content in the exotic cultivar K-183 may indicate suitability for applications where reduced fiber levels are advantageous, warranting further investigation into its specific uses

CONCLUSIONS

This study showed early-maturing soybean (*G. max* L.) cultivars perform differently under the environmental conditions of the Tashkent Region, Uzbekistan, revealing significant variations in grain yield, 1000-seed weight, and protein, oil, and cellulose contents. The standard cultivar Orzu and exotic cultivars K-126 and K-183 stood out for their high productivity and seed quality traits, identifying them as promising candidate genotypes for different uses, including food, oil, and bio-based products. These results provide useful information for soybean breeding programs in Uzbekistan and can help improve local soybean production and support agricultural development.

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