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Evaluation of the Genetic Material of the Grass Pea (*Lathyrus Sativus* L.) Seed Collection in Northern Kazakhstan

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Abstract: One of the main agriculture fields in the Republic of Kazakhstan is the diversification of crop production based on the preservation of soil fertility and minimal cultivation technologies. Ensuring sustainable grain production of legumes will significantly increase and strengthen the role of grain production in the country's economy, will allow significant amounts of land resources to be involved in agricultural production, increase employment in the industry and increase the export potential of Kazakhstan. The purpose of this project was to study the genetic material of the seed collection using a comprehensive analysis of economically valuable traits based on phenotypic analysis. The study aimed to identify sources and donors of valuable traits to involve them in crosses and create new breeding lines. The object of the study was plants and grain of 39 samples of grass pea of different ecological and geographical origins. During the implementation of the project, methods certified and tested in research programs were used. The authors identified the earliest maturing samples: IFLA 479 (Ethiopia), IFLA 2026 (Bangladesh), IFLA 151 (Greece), IFLA 158 (Greece), IFLA 220 (Russia), IFLA 2460 (Bangladesh); samples with the largest number of beans per plant: IFLA 160 (Germany), IFLA 142 (Greece); by the number of grains per plant: IFLA 160 (Germany); by weight of 1,000 grains: IFLA 123 (Greece), IFLA 151 (Greece), IFLA 2282 (Bangladesh), IFLA 2475 (Bangladesh), IFLA 479 (Ethiopia); samples distinguished by yield: IFLA 2282, IFLA 2475, IFLA 2026, IFLA 2213 (Bangladesh) and IFLA 142 (Greece) 21.35; 20.92; 17.57; 17.19 and 16,76 kg/ha, respectively. The introduction of the most productive varieties of leguminous crops into modern production will solve the problem of proper nutrition, strengthen the fodder base, increase soil fertility, and economic and social sustainability of the agricultural and industrial sectors.

Keywords: *Lathyrus Sativus* L., Grass Pea, Study, Analysis, Productivity, Growing Season

Introduction

Grass pea (*Lathyrus sativus* L.) is an unconventional culture in Kazakhstan. The Mediterranean and the countries of Southwest Asia are considered to be the homeland of the grass pea. Nevertheless, due to the diversification of production and the shortage of high-grade protein (Kosev and Vasileva, 2019), the study of grass pea makes it urgent to search for economically valuable signs of this culture for breeding varieties adapted to the harsh continental conditions of Northern Kazakhstan.

To ensure food security for the people in many countries of the world (India, China, Bangladesh, Pakistan, Russia, and others) research is being conducted on the selection and testing of different types of leguminous crops from the world collection. Collections of leguminous crops from the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR) in Kazakhstan and neighboring countries is used for the introduction of new plant forms and donors to create new varieties and hybrids of crops, which are then put into production (Kiru and Rogozina, 2017).

The most important component of leguminous seeds in terms of nutrition is proteins, which are involved in the most important functions of the body and cannot be replaced by other food substances. Besides, due to climate changes, the question of expanding the area of cultivation of drought-resistant leguminous crops, one of the representatives of which is the grass pea, is particularly relevant (Lambein *et al*., 2019).

The grass pea (*Lathyrus sativus* L.) is an annual legume plant grown in various agroecological conditions of the world for food, as well as for animal feed in the form of grain, hay, and green fertilizer (Almeida *et al*., 2014). The yield of grain and green mass reaches 3.0 and 42.0 t/ha, respectively (Zykov, 1963). It is characterized by high protein content, from 23.0 to 34.2% (Rizvi *et al*., 2016), increased drought resistance, weak disease, and pest damage, high feed values, and nitrogen-fixing activity (Choudhary *et al*., 2016). Grass pea is a nectar source plant culture. Grass pea is sown mixed with white mustard to increase productivity and improve the fodder base and also for beekeeping (Donskaya *et al*., 2016; Velkova *et al*., 2016).

We did not study the peculiarities of growth, development, and formation of the yield of different types of grass pea in the Northern region of Kazakhstan. The study aimed to identify sources and donors of valuable traits to involve them in crosses and create new breeding lines.

The amount of chlorophyll is one of the main factors of adaptation to growing conditions. In this regard, for a more complete characterization of plants, it is necessary to have an idea about the content of pigments in them. Photosynthetic parameters have not been studied in the grass pea samples from the world collection. Photosynthesis is directly dependent on the content of chlorophyll in plant leaves and it plays a major role in the conversion of solar energy into chemical energy in the process of photosynthesis in plants (Taiz and Zeigez, 2006). The content and ratio of photosynthetic pigments are largely determined by environmental factors and periods of plant ontogenetic development. The intensity of photosynthesis depends on the content of chlorophyll, which was one of the points that this study aimed to study. The chlorophyll content is an indicator of organic matter production and plant growth (Lahai *et al.*, 2003). This is since increased photosynthesis is associated with increased content of chlorophyll in plants (Chowdury and Kohri, 2003). As a result, the chlorophyll content is a measure of the physiological activity of plants.

It can be noted that according to the state register of breeding achievements recommended for use in the Republic of Kazakhstan 2021, only one medium-early variety of grass pea, the Ali-bar culture, has been zoned in the Almaty region, bred by breeders of the Kazakh Research Institute of Agriculture and Crop Production (MARK, 2020).

The purpose of this project was to study the genetic material of the seed collection using a comprehensive analysis of economically valuable traits based on phenotypic analysis.

Materials and Methods

Study Location and Period

Field research was conducted in the Republic of Kazakhstan, Akmola region, Shortandinsky district, in the village of Nauchny, at the Scientific and Production Center of grain farming named after A. I. Baraev Limited Liability Partnership in 2021.

Field Experiments and Study of Samples

We studied 39 samples of grass pea of different ecological and geographical origins (Fig. 1), obtained from the International Center for Agricultural Research in the Dry Areas (ICARDA), according to the main economically valuable characteristics, such as plant height, the height of attachment of the lower bean, the number and weight of seeds from the plant, the weight of 1,000 seeds, maturity and yield. Field experiments and the study of samples were carried out following the methods of the state variety testing of crops and fieldwork, based on the methodological instructions of the VIR (Vishnyakova *et al*., 2018). In the spring, after the snow had fallen and the soil had reached physical ripeness, early spring harrowing was carried out. Immediately before sowing, pre-sowing fallow treatment was carried out to a depth of 8 to 12 cm, depending on the soil relief and weather conditions. After that, the experimental site was divided into plots and marked. Sowing was carried out by a selective fractional cone seeder of precise seeding to the recommended depth of seeding for the grass pea (4-5 cm). Immediately after sowing, for compaction of the soil and further uniform seedlings, rolling with needle and spur rollers was carried out. The content of photosynthetic pigments in grass pea leaves was also analyzed by spectrophotometry (Ivankin *et al*., 2016).

Field experiments were conducted on a fallow field that had been left under fallow during 2020. The type of soil of the experimental site is ordinary chernozem. Chernozem soils are common in the northern part of the Republic of Kazakhstan. Their humus content is 6-8%, the profile thickness is 100 cm, the humus horizon thickness is 47-50 cm, the gross phosphorus form content equals 0.16-0.20% and the nitrogen content is 0.4. During the ripening period, before harvesting plots, a structural sheaf was selected from the experimental sites. The harvesting at the experimental plots was carried out by the wintercreeper classic plot harvester (wintercreeper, Austria, is a manufacturer of small-sized plot equipment).

The content of chlorophyll a, b and carotenoids was determined by spectrophotometry based on the ability of pigments to absorb rays of a certain wavelength using a spectrophotometer.

Meteorological Conditions of Plant Vegetation

To calculate the concentration of chlorophylls a and b and carotenoids in the extract of pigments, the optical density of the extract was determined on a spectrophotometer at wavelengths corresponding to the absorption maxima of the determined pigments in this solvent. The chlorophyll content was calculated using Vernon's formula. To determine the concentration of carotenoids (mg/l) in the total extract of pigments, the Wettstein formula was used (Chakchir and Alekseeva, 2002).

The relief of the territory of the Akmola region is diverse: Most of it is occupied by steppes, small hills, slightly divided lowland, river valleys, and forest-covered mountains. The climate of the region is sharply continental. Summers are short and warm and winters are long, frosty, with strong winds and blizzards. The minimum air temperature is over -40° and the maximum reaches +44°C. The autumn period of 2020 was characterized by a moderate amount of precipitation and an elevated temperature background. Before the establishment of stable negative temperatures, 43 mm of precipitation fell, which was 80% of the average annual norm. The beginning of the winter period was also characterized by a lack of precipitation. With the practical absence of snow cover (10 cm), the average daily temperature in December was below the climatic norm by 6°C and amounted to -19.9°C. The combination of such conditions ensured intensive freezing of the arable layer beyond the one-meter depth. The increase in snow cover has been noted only since the second decade of January. From January to the second decade of March, precipitation more than doubled the annual average and amounted to 76.3 mm. Before winter in the fallow fields, the reserves of soil moisture in the meter layer were about 80-110 mm. In May, precipitation totaled 12.1 mm compared to the long-term average of 32.4 mm (Table 1).

Elevated air temperatures increased evaporation. By the beginning of the vegetation of plants, the supply of productive moisture on the fallow fields was minimal. According to the temperature regime, the spring was hot and dry. June was characterized by a minimum amount of precipitation, 18.3 mm, which is lower than the average annual value of 21.2 mm. The air temperature in June was at the level of long-term values. July was also hot and dry. Precipitation fell 25.1 mm below average. The precipitation of August adversely affected the grass pea plants. They underwent secondary flowering, which stretched their growing season.

The growing conditions of the grass pea in 2021 were contrasting, as high daytime temperatures, against the background of the absence of precipitation in the first half of the growing season, bordered on low and negative air temperatures at night, which, in different ways, reflected the productivity of samples of this crop.

Statistical Analysis

The assessment of variability and interrelationships of phenological and economically valuable traits was carried out using statistical methods. Statistical analysis was carried out using Statistical Software (SPSS 21.0) for Windows, as well as an Analysis of Variance (ANOVA), while the differences between the mean values were calculated using Tukey's test ($p<0.05$). Pearson correlation was used to study the coefficients between attributes.

Table 1: Meteorological indicators of the Shortanda agrometeorological station, 2021

		Precipitation, mm			Temperature, °C		
Month	Decade	Factual	Average long-term	Deviation	Factual	Average long-term	Deviation
May	I	3.9	10.4	-6.5	13.70	10.4	3.30
	II	1.2	9.5	-8.3	17.80	12.5	5.30
	III	7.0	12.5	-5.5	20.20	14.5	5.70
	Average, sum	12.1	32.4	-20.3	17.20	12.5	4.70
June	I	3.6	11.7	-8.1	18.30	16.7	1.60
	II	8.9	14.1	-5.2	19.50	18.6	0.90
	III	5.8	13.7	-7.9	17.50	19.5	-2.00
	Average, sum	18.3	39.5	-21.2	18.40	18.3	0.10
July	I	10.5	19.0	-8.5	23.10	20.1	3.00
	II	20.8	20.6	0.2	17.30	20.0	-2.70
	III	0.6	17.4	-16.8	20.80	19.6	1.20
	Average, sum	31.9	57.0	-25.1	20.40	19.9	0.50
August	I	21.0	13.5	7.5	21.90	18.7	3.20
	II	2.0	12.6	-10.6	18.20	18.0	0.20
	III	14.8	13.7	1.1	18.70	15.4	3.30
	Average, sum	37.8	39.8	-2.0	18.70	17.4	1.30
Total	Average, sum	100.1	168.7	-68.6	18.67	17.0	1.67

Fig. 1: IFLA 2026 (Bangladesh), IFLA 151 (Greece) and IFLA 242 (Afghanistan) samples

Results

According to the results of 2021, 20 samples from different ecological and geographical origins stood out from 39 samples of the grass pea, among which were 7 samples from Bangladesh, which is 35% of the total number of distinguished samples, and 6 from Greece (30%) and 1 each (5%) from Afghanistan, Ethiopia, Germany, Hungary, Canada, Russia, plus one sample of unknown origin (5%) (Table 2).

The duration of the entire growing season (from seedlings to maturation) and its structure are the main phenological features that determine the possibility of cultivating a variety in a particular soil and climatic zone. The study of grass pea samples in a collection nursery in 2021 showed that the growing season of 20 grass pea samples equaled from 87 to 93 days. According to our study, 5 grass pea samples had a "seedlings to flowering" period which equaled 38 days. The samples from Bangladesh and Greece distinguished themselves by this indicator, i.e., uniform flowering. The duration of the "flowering to ripening" interphase periods is of great importance in the formation of the yield of the grass pea. This period took from 55 to 61 days (Table 3).

The earliest maturing samples (IFLA 479, IFLA 2026, IFLA 151, IFLA 158, IFLA 220, and IFLA 2460) ripened by the 87^{th} day. The earliest flowering period was observed in the following samples: IFLA 151, IFLA 220, and IFLA 2460 and equaled 32 days.

The morphological analysis of the distinguished samples of grass pea, which determines the seed productivity, involves analyzing the weight of the dry biomass of the plant, the number of beans and seeds per plant, and the mass of seeds from the plant, as well as the mass of 1,000 seeds. The results are presented in Tables 4 and 5. The fitness for mechanized cultivation of grass pea plants was determined by the following important characteristics: The height of the plant and the height of the attachment of the lower bean.

According to the results of the analysis of plant productivity elements, samples with the number of beans per plant from 9.4±0.3 (IFLA 2026) to 26.9±1.8 pcs (IFLA 160) showed the best results. High indicators of the number of beans on the plant were observed in IFLA 2529, IFLA 390, and IFLA 142.

The number of grains per plant is one of the main genetically inherited traits. Among the studied samples of the collection, three samples with sufficiently high values were identified, namely IFLA 160 (95.9 ±11.9 pcs), IFLA 142 (75.7±9.1 pcs), and IFLA 2529 (58.4±6.8 pcs).

In our studies, the maximum value by weight of grain from a plant belongs to sample IFLA 160 (7.6±0.8 g) (Germany).

The indicator mass of 1,000 grains varies in quantitative terms. Thus, the fine-grained forms of grass pea include samples IFLA 160 with 79.6±1.5 g (Germany), IFLA 242 with 87.2±6.0 g (Afghanistan), IFLA 157 with 87.8±3.2 g (Greece) and IFLA 254 with 88.5±2.2 g (Afghanistan). The largest grains were observed in IFLA 123 with 256.6±10.8 g (Greece) and IFLA 151 with 225.5±9.9 g (Greece).

From our observations, it can be seen that the yield of grass pea samples did not always depend on the mass of 1,000 seeds (Fig. 2).

The highest yield was observed in IFLA 2475 (Bangladesh) with 20.92 c/ha. Of the tested samples, IFLA 2026 (Bangladesh) with 17.57 c/ha and IFLA 2213 (Bangladesh) with 17.19 c/ha had similar values, but the mass of 1,000 seeds of these samples was not the highest and amounted to 195.29; 161.67 and 173.73 g, respectively.

Correlations between the studied quantitative indicators and seed productivity have been established, expressed by the number of beans and the weight of seeds per plant (Table 6). From the structural elements that determine seed productivity, the most significant positive effect on it was observed in the indicators of plant mass by technical ripeness (r = 0.785) and the number of branches of the first (r = 0.542) and second-order (r = 0.585) and the number of beans per plant (r = 0.649), with very good statistical significance of correlation coefficients. It was found that the growth rate (r = -0.544) and the number of beans per plant (r = -0.584) negatively affected the mass of 1,000 seeds (Talukdar, 2009). We obtained a positive and statistically significant correlation between the seed yield with the components of plant height, the number of primary and secondary branches, the number of beans and the weight of 1,000 seeds, and the number of pods that had the maximum contribution to increasing productivity.

Analysis of the content of photosynthetic pigments in the leaves showed that the samples differed in the content of chlorophyll *a*, chlorophyll *b*, and the sum of chlorophylls (Table 7).

Comparison of the sum of chlorophyll *a +b* content in the leaves of the studied grass pea samples ranged from 0.75 to 1.35 mg/g. The average value of total chlorophyll was the level of 1.03 mg/g. The IFLA 390 sample had the highest total chlorophyll content (1.35 mg/g) compared to the rest of the grass pea samples. The lowest chlorophyll content was observed in sample IFLA 157 from Greece (0.75 mg/g). The results show that, regardless of the plant species, the content of chlorophyll *a* in the leaves of the studied plants is higher compared to chlorophyll *b*. This pattern was observed in all phases of plant development. The highest chlorophyll content was observed in the flowering phase of the IFLA 143 sample from Greece (1.04 mg/g). In the studied plants, in the flowering phase, the chlorophyll content was maximal.

It should be noted that the highest content of chlorophyll *b* was observed in IFLA 2213 (Bangladesh), equaling 0.54 mg/g. The lowest content of this form of chlorophyll was found in IFLA 242 (Afghanistan) and IFLA 2460 (Bangladesh) at 0.11 mg/g. For the entire complex of pigment content in the germination phase, the best results were shown by plant samples from Bangladesh, IFLA 2213 (with chlorophyll a and b content of 0.84 and 0.54, the sum of chlorophylls equaling 1.34 and carotenoid content of 0.24 mg/g).

In the flowering phase, there was an increase in the amount of chlorophyll *a + b* in those plants due to an increase in the chlorophyll b content. The data show that with the onset of the phase of mass fruiting, the content of green pigments decreases somewhat.

This trend is confirmed by studies that in field experiments found a uniform linear relationship between the content of chlorophyll and the rate of photosynthesis. In some experiments, higher chlorophyll activity was observed in young leaves before they reached the state of "photosynthetic maturity" (Šesták, 1966).

Thus, the study of the pigment content in the plant leaves, depending on the phase of their development, showed that the content of chlorophylls *a* and *b*, starting from the germination phase, increased until the flowering phase and then decreased slightly in the fruiting phase.

Grass pea can be successfully cultivated both in regions with an average annual rainfall of 380-650 mm and with excessive precipitation. Thanks to the powerful root system, grass pea can grow on various types of soils, from light ones to heavy clay-rich ones. The ability to fix atmospheric nitrogen makes grass pea a culture that adapts well when grown in unfavorable conditions. Cultivation of the grass pea leads to an improvement in soil fertility and has a positive effect on the yield of the next crop.

Table 2: Selected genotypes of the grass pea *(Lathyrus sativum L.)* for use in the study

Genotype	Origin	Genotype	Origin	Genotype	Origin
IFLA 1870	Bangladesh	IFLA 160	Germany	IFLA 122	Greece
IFLA 479	Ethiopia	IFLA 157	Greece	IFLA 220	Russia
IFLA 2475	Bangladesh	IFLA 142	Greece	IFLA 2460	Bangladesh
IFLA 276	Hungary	IFLA 254	Canada	IFLA 2213	Bangladesh
IFLA 2026	Bangladesh	IFLA 123	Greece	IFLA 2529	Bangladesh
IFLA 2282	Bangladesh	IFLA 151	Greece	IFLA390	-
IFLA 242	Afganistan	IFLA 158	Greece		

Table 3: Results of phenological observations

Genotype	Origin	From seedlings to flowering, days	From seedlings to maturation, days
IFLA 1870	Bangladesh	35	89
IFLA 479	Ethiopia	33	87
IFLA 2475	Bangladesh	35	89
IFLA 276	Hungary	34	88
IFLA 2026	Bangladesh	33	87
IFLA 2282	Bangladesh	36	88
IFLA 242	Afghanistan	38	93
IFLA 160	Germany	38	92
IFLA 157	Greece	38	93
IFLA 142	Greece	38	93
IFLA 254	Canada	38	93
IFLA 123	Greece	34	90
IFLA 151	Greece	32	87
IFLA 158	Greece	33	87
IFLA 122	Greece	36	90
IFLA 220	Russia	32	87
IFLA 2460	Bangladesh	32	87
IFLA 2213	Bangladesh	36	91
IFLA 2529	Bangladesh	35	90
IFLA 390	-	36	92

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Table 4: Biometric indicators of grass pea samples

Genotype	Origin	Plant height, cm	Dry weight, g	Stem diameter, mm	Height of attachment of the lower bean, cm
IFLA 1870	Bangladesh	39.0±1.0	7.67±0.5	1.6±0.1	22.2±0.8
IFLA 479	Ethiopia	36.8±1.4	6.94±0.8	1.8±1.2	16.4±0.5
IFLA 2475	Bangladesh	39.9±1.8	8.12±0.4	1.5±0.1	19.5±0.5
IFLA 276	Hungary	38.8±1.3	7.56±0.9	1.4±0.1	19.8±0.5
IFLA 2026	Bangladesh	40.3±1.2	6.03±0.2	1.1±0.1	23.3±1.4
IFLA 2282	Bangladesh	38.2±0.9	6.26±0.7	1.4±0.2	20.1±0.6
IFLA 242	Afghanistan	44.7±2.2	7.44±0.6	1.6±0.1	23.8±0.9
IFLA 160	Germany	47.7±0.9	13.8±0.2	2.4±0.1	26.8±1.0
IFLA 157	Greece	57.7±0.7	9.02±0.2	1.9±0.1	29.3±2.1
IFLA 142	Greece	49.2±3.3	9.21±0.4	2.5±0.1	28.5±1.8
IFLA 254	Canada	46.3±0.7	8.11±0.3	1.9±0.2	23.8±1.0
IFLA 123	Greece	35.1±1.2	9.71±0.3	2.3±0.1	20.0±1.1
IFLA 151	Greece	39.2±1.6	8.46±0.3	1.8±0.3	24.7±0.9
IFLA 158	Greece	35.6±0.6	6.98±0.7	1.6±0.1	19.2±1.1
IFLA 122	Greece	43.7±0.5	7.57±0.6	1.7±0.1	24.6±0.8
IFLA 220	Russia	33.1±0.3	5.27±0.2	1.6±0.1	18.7±0.6
IFLA 2460	Bangladesh	31.7±0.7	3.80±0.3	1.0±0.1	19.1±0.7
IFLA 2213	Bangladesh	39.6±0.4	9.45±0.3	2.0±0.1	21.9±0.6
IFLA 2529	Bangladesh	48.5±1.6	11.50±1.4	2.4±0.1	25.0±1.1
IFLA 390	-	38.0±1.1	9.58±0.4	2.0±0.1	16.5±1.3

Table 5: Characteristics of productivity of grass pea samples

		Quantity, pcs					
		Branches					
Genotype	Origin	First order	Second-order	Beans from the plant	Seeds from the plant	Weight of seeds per plant, g	Weight of 1,000 seeds, g
IFLA 1870	Bangladesh	2.4±0.2	2.0±0.1	11.3±0.6	29.1±4.4	3.8±0.4	135.7±3.9
IFLA 479	Ethiopia	2.5±0.2	2.0±0.1	11.7±0.7	28.3±4.2	5.4±1.0	154.8±4.1
IFLA 2475	Bangladesh	2.5±0.2	1.9±0.1	11.3±0.4	24.2±3.9	4.7±0.5	195.3±7.1
IFLA 276	Hungary	2.3±0.2	1.9±0.2	13.4±1.1	32.8±4.2	4.6±0.5	137.8±5.4
IFLA 2026	Bangladesh	1.6±0.2	1.4±0.1	9.4±0.3	17.0±2.2	2.7±0.4	161.7±6.7
IFLA 2282	Bangladesh	2.0±0.2	1.9±0.2	6.1±0.3	17.9±1.9	3.5±0.4	188.9±5.8
IFLA 242	Afghanistan	2.1±0.3	1.6±0.1	12.6±0.3	47.5±5.8	4.2±0.4	87.2±6.0
IFLA 160	Germany	3.3±0.3	3.0±0.2	26.9±1.8	95.9±11.9	7.6±0.8	79.6±1.5
IFLA 157	Greece	2.6±0.1	2.1±0.2	14.6±1.4	44.5±4.9	4.0±0.5	87.8±3.2
IFLA 142	Greece	3.7±0.2	3.1±0.3	18.5±1.1	75.7±9.1	5.6±0.6	74.2±1.9
IFLA 254	Canada	2.6±0.1	2.0±0.2	15.8±0.7	43.0±5.0	3.8±0.4	88.5±2.2
IFLA 123	Greece	2.4±0.1	2.1±0.1	12.4±0.4	27.9±3.6	7.1±0.4	256.6±10.8
IFLA 151	Greece	2.5±0.6	1.9±0.4	7.2±1.1	19.5±3.6	4.4±1.1	225.5±9.9
IFLA 158	Greece	2.2±0.2	1.8±0.2	15.7±0.6	29.7±4.7	4.3±0.4	147.9±2.4
IFLA 122	Greece	4.3±0.2	3.9±0.4	17.9±0.9	36.1±4.9	4.0±0.2	114.7±2.0
IFLA 220	Russia	1.9±0.1	1.4±0.1	9.3±0.54	22.6±2.4	3.1±0.1	142.4±8.0
IFLA 2460	Bangladesh	1.8±0.2	1.4±0.1	7.1±0.8	15.2±1.4	1.9±0.2	125.1±5.0
IFLA 2213	Bangladesh	2.9±0.1	2.3±0.2	13.7±0.6	29.4±3.47	5.1±0.3	173.7±4.0
IFLA 2529	Bangladesh	2.9±0.1	2.9±0.1	21.0±1.7	58.4±6.8	6.0±0.6	100.3±1.1
IFLA 390	-	2.8±0.1	2.7±0.2	18.1±1.4	45.7±4.8	4.4±0.5	92.2±3.2

Table 6: The relationship between the studied features

	Plant height, cm	Dry weight, g	Stem diameter, mm	Height of attachment of the lower bean, cm	Number of branches of the first order, pcs.	Number of branches of the second order, pcs.	Number of beans per plant, pcs.	Number of seeds per plant, pcs.	Weight of seeds from the plant, g
Plant height, cm	1								
Dry weight, g	0.549**	1							
Stem diameter, mm	0.279**	0.603**	1						
Height of attachment of the lower bean, cm	0.649*	0.140	0.038	1					
Number of branches of the first order, pcs.	0.427*	0.523**	0.608**	0.200**	1				
Number of branches of the second order, pcs.	0.396**	0.563**	0.609**	0.168*	0.857**	1			
Number of beans per plant, pcs.	0.602**	0.779**	0.527**	0.1	0.542**	0.601**	1		
Number of seeds per plant, pcs	-0.115	0.092	0.174*	-0.126	0.078	0.153*	0.213**	1	
Weight of seeds per plant, g	0.336**	0.785**	0.669**	0.009	0.542**	0.585**	0.649**	-0.003	1
Weight of 1,000 seeds, g	-0.544**	-0.241**	-0.102	-0.271**	-0.272**	-0.276**	-0.584**	-0.179*	0.003

** Correlation is significant at 0.01. * at the level of 0.05

Table 7: The effect of photosynthetic pigments on the leaves of the grass pea samples. The error bars represent the standard deviation (n = 3). The same letters mean a significant difference at $p<0.05$

Genotype	Origin	Chla ($mg \cdot g^{-1}$)	Chlb ($mg \cdot g^{-1}$)	Chl (a + b) ($mg \cdot g^{-1}$)	Chl (a + b/car) ($mg \cdot g^{-1}$)	Chla/b	Carotenoid ($mg \cdot g^{-1}$)
IFLA 1870	Bangladesh	0.76^{abc}	0.23^{cdef}	0.99^{ab}	4.07^{bcd}	3.45^{a}	0.24^{abc}
IFLA 479	Ethiopia	0.86^{abc}	0.24^{cdef}	1.1^{ab}	4.04^{bcd}	3.53^{a}	0.27^{ab}
IFLA 2475	Bangladesh	0.98^{ab}	0.34^{bcd}	1.32^{a}	-4.83^{bcd}	2.84^{a}	0.17^{abc}
IFLA 276	Hungary	0.97^{abc}	0.37^{abc}	1.34^{a}	4.94^{bcd}	2.75^{a}	0.28^{ab}
IFLA 2026	Bangladesh	0.76^{abc}	0.51^{ab}	1.27^{a}	6.0^{bcd}	1.74^{a}	0.22^{abc}
IFLA 2282	Bangladesh	0.55^{bc}	0.36^{abc}	0.91^{ab}	3.46^{bcd}	1.8^{a}	0.26^{ab}
IFLA 242	Afganistan	0.72^{abc}	0.11^{f}	0.83^{b}	3.98^{bcd}	-23.26^{b}	0.22^{abc}
IFLA 160	Germany	0.58^{ac}	0.29^{cdef}	0.87^{b}	12.47^{bcd}	2.44^{a}	0.14^{bc}
IFLA 157	Greece	0.51^{abc}	0.24^{cdef}	0.75^{c}	-5.46^{bcd}	3.74^{a}	0.13^{bc}
IFLA 142	Greece	0.73^{abc}	0.2^{cdef}	0.93^{ab}	39.36^{ab}	3.72^{a}	0.15^{abc}
IFLA 254	Canada	0.77^{abc}	0.21^{cdef}	0.98^{ab}	6.58^{bcd}	3.74^{a}	0.18^{abc}
IFLA 123	Greece	0.57^{abc}	0.27^{cdef}	0.84^{b}	-18.88^{cd}	21.9^{a}	0.19^{abc}
IFLA 151	Greece	0.63^{abc}	0.19^{cdef}	0.82^{bc}	8.04^{bcd}	3.35^{a}	0.13^{bc}
IFLA 158	Greece	0.75^{abc}	0.22^{cdef}	0.97^{ab}	59.55^{a}	3.65^{a}	0.14^{bc}
IFLA 122	Greece	0.79^{abc}	0.25^{cdef}	1.04^{ab}	7.0^{bcd}	3.26^{a}	0.2^{abc}
IFLA 220	Russia	0.76^{abc}	0.21^{cdef}	0.97^{ab}	4.23^{bcd}	3.67^{a}	0.23^{abc}
IFLA 2460	Bangladesh	0.65^{abc}	0.11^{ef}	0.76^{c}	3.87^{bcd}	-23.69^{b}	0.22^{abc}
IFLA 2213	Bangladesh	0.84^{abc}	0.54^{a}	1.34^{a}	6.1^{bcd}	1.74^{a}	0.24^{abc}
IFLA 2529	Bangladesh	1.04^{a}	0.29^{cdef}	1.33^{a}	5.91^{bcd}	3.73^{a}	0.26^{ab}
IFLA390	-	0.99^{ab}	0.36^{abc}	1.35^{a}	5.05^{bcd}	2.73^{a}	0.27^{ab}

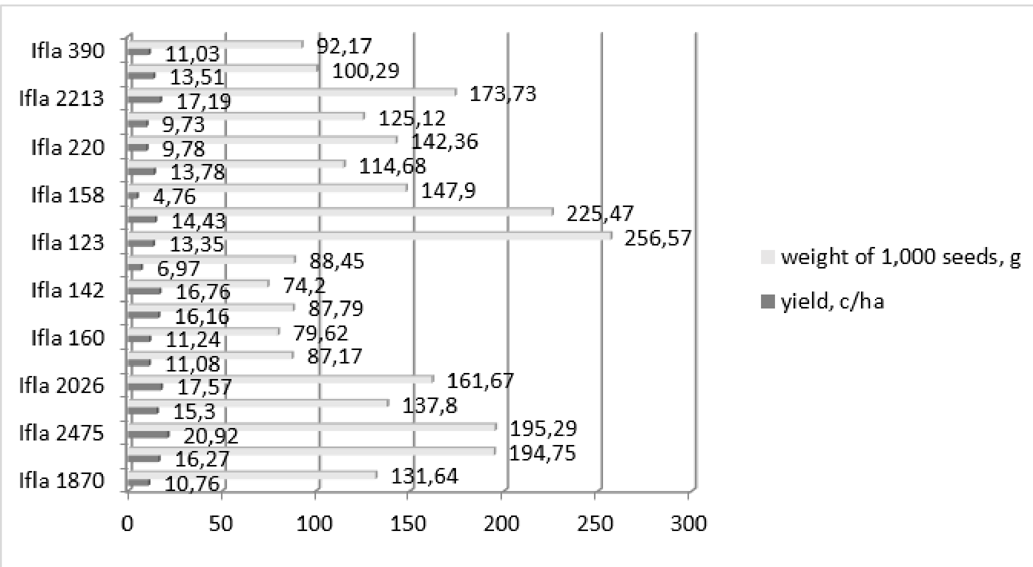

Fig. 2: Yield and weight of 1,000 seeds of grass pea samples

In the process of studying crop samples, the most interesting for further breeding work are the samples that differ in several economically valuable features: (1) By early maturity, such as IFLA 479 (Ethiopia), IFLA 2026 (Bangladesh), IFLA 151 (Greece), IFLA 158 (Greece), IFLA 220 (Russia) and IFLA 2460 (Bangladesh) that ripened in 87 days; (2) by the number of grains per plant, among which one can distinguish IFLA 160 (Germany) (26.9 pcs.) and IFLA 142 (Greece) (18.5 pcs.); (3) by the number of seeds per plant: IFLA 390 (unknown origin, 19 pcs), IFLA 2529 (Bangladesh,18 pcs.) and IFLA 2213 (Bangladesh, 17.5 pcs.); (4) by weight of seeds per plant: IFLA 160 (Germany, 7.6 g); IFLA 123 (Greece, 7.1 g); IFLA 2529 (Bangladesh, 6 g); (5) by weight of1,000 seeds: IFLA 123 (Greece, 256.57 g), IFLA 151 (Greece, 225.5 g) and IFLA 2475 (Bangladesh, 195.3 g); and 6) by yield, such as IFLA 2475 (Bangladesh) with 20.92 c/ha.

Comparison of the amount of chlorophyll a + b content in the leaves of the studied culture samples ranged from 0.92 to 1.57 mg/g. The average value of total chlorophyll was 1.28 mg/g.

Discussion

The results of our study are the initial stage of the search for genotypes of the grass pea with the most valuable economic characteristics for use in the selection of leguminous crops. The grass pea (*Lathyrus sativus* L.) is a leguminous crop with great potential for ensuring global food security due to its exceptional resistance to drought and floods (Emmrich, 2017). Its relatives are considered sustainable legumes due to their high ability to cope with various stresses (Aci *et al*., 2020). A hardy, deeply penetrating root system allows growing grass pea on various types of soils. As an effective nitrogen fixator, it satisfies its own nitrogen needs and has a positive effect on subsequent crops (Lambein *et al*., 2019). Grass pea is a crop that is considered one of the most resistant ones to climate change. With its protein-rich seeds and leaves, it has great potential as food for humans as well as animal feed. Nevertheless, the genetic improvement of this culture remains at the same level due to insufficient knowledge of its genetic resources (Gupta *et al*., 2018). In Southern Italy, during three growing seasons (2003-2006) eight lines of grass pea were evaluated for the stability of the seed yield, the mass of 1,000 seeds, plant height, and biomass. Significant differences existed between the years and the lines in the interaction of all features, except for the mass of 1,000 seeds. The results obtained during the study gave an idea of the relative stability of the selected lines in three different growing seasons (Polignano *et al*., 2009).

The main pigments involved in the photosynthesis of higher plants are chlorophylls. In addition, carotenoids are present in plants, which, in addition to participating in the processes of photosynthesis, provide the coloring of flowers and fruits. The content of photosynthetic pigments in plants depends on the general physiological state of plants, the characteristics of the light regime, the duration of the action of toxicants, the chemical composition of pollutants, and their combined effects. The high content of chlorophyll a and b and the value of the chlorophyll a/b ratio can serve as a sign of favorable plant growth conditions. In areas with anthropogenic pollution, the amount of carotenoids in plant leaves increases, which protects chlorophyll molecules from destruction and reduces the effect of stress (Ryabukhina *et al*., 2015).

The mass of 1,000 seeds is an important sign of the commercialization of the grass pea since large varieties of this crop are preferred in the markets of Western countries (Ulloa and Mera, 2010). According to the results of our study, a single large-seeded specimen from Greece (IFLA 123-256.6 g) with a mass of 1,000 seeds of more than 250 g was distinguished in this aspect. Average seed samples are IFLA 479 (Egypt), IFLA2026, 2313, 2282.2475 (Bangladesh), and IFLA 151 (Greece), where the seed weight is from 161.7 to 225.5 g. The remaining 13 samples from the collection of the grass pea turned out to be small-seeded with a mass of 1,000 seeds from 47.2 to 147.9 g.

According to the complex of economically valuable features in the conditions of the Akmola region, the following collection samples were distinguished: IFLA 157 (Greece), IFLA 142 (Greece), IFLA 123 (Greece), IFLA 151 (Greece), IFLA 2475 (Bangladesh) and IFLA 2282 (Bangladesh).

Work to improve L. sativus should focus on the development of publicly available joint and basic collections, as well as on high-resolution genotyping (Vaz Patto and Rubiales, 2014). Such coordinated international efforts could lead to more efficient and faster approaches to breeding new varieties of leguminous crops, which are especially necessary for underutilized species like Lathyrus.

Conclusion

The planned scope of the study has been fully completed, and the goal and expected results have been achieved. The results of the conducted studies allow us to conclude that the soil and climatic conditions of Northern Kazakhstan correspond to the biological characteristics of the crop and are favorable for its cultivation.

The samples of the grass pea in our study conditions were distinguished by good productivity indicators. These samples are of particular interest for the creation of new promising varieties of grass pea. The samples selected according to economically valuable characteristics and properties, in the future, will be used as parent forms when creating a new source material by hybridization methods.

The results of this study obtained during the implementation of the project can be used to develop a strategy for the development of agriculture in the face of climate change and increase the sustainability of agriculture.

The obtained study results are planned to be used in the future for breeding new varieties, using methods of traditional breeding and molecular genetics to identify the most economically valuable traits to accelerate the breeding process of the grass pea. The introduction of the most productive varieties of leguminous crops into modern production will accelerate the solution of the problem of proper nutrition, strengthening the feed base, increasing soil fertility, and economic and social sustainability of the agricultural and industrial sectors.

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Author's Contributions

All authors equally contributed to this study.

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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