OnLine Journal of Biological Sciences

Research Article

Optimizing Pea Cultivation in Kazakhstan: Breeding Drought-Resistant Varieties for Sustainable Agriculture

Kudaibergenov Mukhtar Sarsenbekovich, Kanatkyzy Makpal, Saken Gaukhar Sakenkyzy, Nussipbay Karkyn, Abildaeva Juldyz Bakaevna, Saikenova Alma Zhumabaevna and Baitarakova Kuralai Zhumanovna

Department of Legume Crops, Kazakh Research Institute of Agriculture and Plant Growing, Almalybak, Almaty, Kazakhstan

Article history
Received: 29-01-2025
Revised: 07-04-2025
Accepted: 17-04-2025

Corresponding Author:
Saken Gaukhar Sakenkyzy
Department of Legume Crops,
Kazakh Research Institute of
Agriculture and Plant Growing,
Almalybak, Almaty, Kazakhstan
Email: gaukharsaken@mail.ru

Abstract: Peas (*Pisum sativum* L.) are a vital legume for global food security, yet its cultivation in Kazakhstan faces challenges due to arid conditions and limited moisture availability. Breeding high-yielding, stress-resistant varieties is critical to enhance agricultural productivity in the region. This study aimed to develop pea varieties with improved yield, drought resistance, and mechanization adaptability under Kazakhstan's agroecological conditions. We evaluated 113 pea variety samples using advanced statistical methods (correlation analysis, ANOVA) and hybridization techniques, focusing on leafless morphotypes with determinate growth. Field trials were conducted from 2010 to 2022, with Aksari and Zhasylai as control varieties. Three new varieties, Aksari, Asylai, and Zhasylai, were developed, exhibiting 15-20% higher yields (19.7-25 c/ha) than existing cultivars (e.g., Shal, ZH-55/1) under drought and biotic stress. Correlation analysis revealed a strong positive relationship between bean number and yield ($r = +0.88$, $p < 0.001$). These varieties offer a genetic foundation for pea breeding in Central Asia, enhancing Kazakhstan's potential to improve agricultural sustainability and food security.

Keywords: Peas, Breeding, Drought Resistance, Mechanization, Hybridization, Control Variety Testing

Introduction

Pea (*Pisum sativum* L.) is a globally significant legume, valued for its high protein content (23–26%), dietary fiber, and adaptability to diverse climates (Zotikov *et al.*, 2018). With annual global production exceeding 17 million tons (Uskutoglu *et al.*, 2023), peas contribute to sustainable agriculture through nitrogen fixation and soil fertility enhancement.

The state of the art in pea breeding has evolved significantly. Globally, efforts have focused on improving yield, disease resistance, and nutritional quality, with notable advancements in the United States and Europe, where collections like the U.S. National Seed Collection (>5,000 accessions) target resilience to climate change (Richard *et al.*, 2021). In Russia, breeding has emphasized leafy varieties for higher photosynthetic potential, though these are prone to lodging (Pislegina and Chetvertnykh, 2021). Kazakhstan’s pea breeding, however, remains underexplored, with limited focus on locally adapted, drought-resistant cultivars. Previous studies have not adequately addressed the region’s specific needs, such as mechanization adaptability and resistance to abiotic stresses like drought and heat.

This research bridges this gap by developing pea varieties tailored to Kazakhstan’s agroecological conditions. Leveraging a collection of over 113 local and imported pea accessions, we targeted leafless (whiskered) morphotypes with determinate growth to enhance drought resistance, lodging resistance, and suitability for mechanized harvesting. Our objectives were to: (1) identify key traits for high yield and stress tolerance, (2) develop superior varieties through hybridization and selection, and (3) assess their economic potential for Kazakhstan’s agricultural sector. In Kazakhstan, particularly in Northern Kazakhstan, where grain crops occupy 12-14 million hectares and approximately one-third of cultivated land remains fallow, there is a growing opportunity to utilize these fallow areas for leguminous crops like peas. Peas not only enhance soil fertility through nitrogen fixation but also provide additional food and feed products, making them a strategic crop for sustainable agriculture and economic growth.

Kazakhstan's agroecological conditions differ significantly from those of Russia, particularly in terms of moisture availability. The country experiences less rainfall and lower humidity levels, which poses unique challenges for crop cultivation. In response to these conditions, our research is specifically aimed at breeding baleen (whiskered) forms of peas, which are better adapted to drier environments and exhibit higher resistance to lodging. These morphotypes are particularly suited for mechanized harvesting and are more resilient to the abiotic stresses prevalent in Kazakhstan's climate.

Furthermore, our research is conducted primarily on local pea varieties, which have been collected and preserved in Kazakhstan's extensive pea collection. These local varieties serve as valuable genetic resources for developing new cultivars that are tailored to the specific agroecological conditions of the region. By focusing on local varieties, we ensure that the new cultivars are well-adapted to Kazakhstan's unique climate and soil conditions, thereby enhancing their productivity and sustainability.

Kazakhstan's vast agricultural lands, favorable climatic conditions, and light-chestnut soils—which contain 30% more organic matter than comparable soils in Russia—create an ideal environment for expanding pea production. However, only 12% of fallow land is currently dedicated to legumes, indicating significant untapped potential. By increasing pea cultivation and developing drought-resistant varieties tailored to Kazakhstan's diverse climates, the country can address domestic demand while positioning itself as a key player in the global pea market (World Bank, 2023).

As of now, Kazakhstan's pea exports remain modest compared to global leaders like Canada (2.1 million tons/year) and Russia (1.5 million tons/year). However, recent data shows promising growth. In July-January 2022/23, Kazakhstan exported 35.8 thousand tons of peas, a 33% increase compared to the same period in 2021/22. This growth highlights the country's potential to expand its presence in international markets. Currently, Kazakhstan primarily exports peas to neighboring Central Asian nations and some European markets, but its share in the global pea trade is still minimal. This underperformance is attributed to limited production volumes, insufficient processing infrastructure, and a lack of targeted export strategies (World Bank, 2023).

Despite these challenges, Kazakhstan's export potential is significant, given its proximity to major importers like China, which has an annual pea import market valued at $800 million. By increasing production volumes, improving quality, and enhancing logistical capabilities, Kazakhstan could capture 5–7% of China's market and expand its presence in other Asian and European markets. To realize this potential, Kazakhstan must address several challenges, including diversifying crop rotation systems, investing in research for resilient pea varieties, improving storage and transportation infrastructure, and establishing trade agreements with key importers (World Bank, 2023).

The recent 33% increase in pea exports during July-January 2022/23 demonstrates the country's growing potential in this sector. By leveraging its favorable soil conditions, vast agricultural lands, and strategic location, Kazakhstan can position itself as a competitive player in the global pea market. With targeted investments in research, infrastructure, and market development, Kazakhstan has the potential to significantly increase its pea exports, contributing to both economic growth and agricultural sustainability.

Due to the long shelf life of seeds (up to 10-12 years), which retain their nutritional and taste qualities, peas are becoming a valuable product for creating reserve funds (Shelepina, 2016). Thus, peas are not only an important food crop, but also a significant agricultural crop that contributes to improving the environment, increasing agricultural productivity and ensuring food security (Zotikov, 2017).

At the end of the 20th century, there was a decline in pea production, which was associated with the morphobiological characteristics and low technological effectiveness of this crop. However, at present, there is a reverse trend - an increase in pea production volumes throughout the world (Malysheva *et al.*, 2009).

Pulse crop collections in various countries are important sources of genetic material for breeding and improving various traits of these crops, such as peas, chickpeas, lentils, and beans. These collections contain accessions collected both domestically and internationally and are used to develop pea varieties that are resistant to pests, diseases, and abiotic stressors such as extreme temperatures and drought (Saikenova *et al.*, 2021).

For example, in the United States, the National Seed Collection contains more than 5,000 pea accessions, including both food and forage varieties. Key areas of work include developing varieties that are resistant to disease, drought, and climate change, as well as improving the nutritional value of the crop (Richard *et al.*, 2021).

Pea collections containing hundreds of accessions are being actively developed in the European Union, including countries such as Germany, France and the United Kingdom. Key areas of work include increasing resilience to climate change, pathogens and pests, as well as improving forage value and creating varieties suitable for organic farming (Richard *et al.*, 2021).

Kazakhstan also has a significant collection of peas, which is an important resource for breeding and scientific research. The collection contains more than 3,000 samples of peas of various subspecies and forms, both local and imported.

In Kazakhstan, pea breeding is carried out according to the full breeding scheme in such institutions as the Karabalyk Agricultural Scientific and Production Center

(Kostanay), the A.I. Barayev Scientific and Production Center for Plant Growing (Astana), and the Kazakh Scientific Research Institute of Plant Growing (Almaty). In the southeastern part of the country, pea breeding research has been conducted at the Kazakh Scientific Research Institute of Agriculture and Plant Growing since 1971, with some interruptions. This institution is the coordinator of scientific research in this area. The collection nursery includes more than 113 variety samples, including samples from VIR (Russia).

Currently, the main direction in pea breeding is the development of leafless grain forage varieties. Such varieties should have a short and strong stem, as well as a whiskered leaf type, which ensures high resistance to lodging. One of the significant advantages of leafless varieties is the possibility of growing them in single-species crops (Oshergina and Ten, 2023).

Given the growth of livestock farming, the task of breeding grain-cutting long-stemmed leafy varieties intended for animal feed remains relevant. Due to the variety of uses of peas, it is advisable to have both long-stemmed leafy varieties and short-stemmed whiskered varieties in production (Ashiev *et al.*, 2019).

The aim of our research is to create whiskered (leafless) varieties of peas with a determinate type of stem growth, resistant to both biotic and abiotic stresses. Also, as part of the research, high-yielding varieties with high-quality seeds suitable for mechanized harvesting are being developed. An important aspect is the creation of models of future pea varieties that will be adapted to various ecological zones of Kazakhstan.

Materials and Methods

Field experiments were conducted from 2010 to 2022 at the Kazakh Research Institute of Agriculture and Plant Growing (KazRIAPG) experimental field in Ascotia in the Almaty region, Kazakhstan. The soil consisted of light-chestnut loamy soils (organic matter 30% higher than Russian equivalents) with occasional sandy loam patches.

Plant Material: We evaluated 113 pea variety samples from Kazakhstan's pea collection, including local and VIR (Russia) accessions. Aksari and Zhasylai, established high-performing varieties, served as controls.

Experimental Design: Trials followed a randomized block design with three replications per variety, as per Dospekhov's "Methodology of Field Experiments" (Dospekhov, 1985). Plots were sown mechanically at 650–700 thousand seeds/ha, with winter and spring grain crops as predecessors.

Breeding Approach: Hybridization followed Dorofeyev *et al.* (1990), targeting leafless morphotypes with short, strong stems and whiskered leaves. Two generations (F1, F2) were grown annually in greenhouses to accelerate selection, followed by field evaluation (F3–Fn). Selection criteria included yield, lodging resistance, disease resistance, and mechanization adaptability.

Data Collection: Phenological observations followed VIR guidelines (Vishnyakova *et al.*, 2010). Structural traits (e.g., stem length, bean number, seed weight) were measured pre-harvest from 10 plants per plot. Protein content was assessed per GOST standards (Skokbaeva, 2002). Climatic data were sourced from KazRIAPG's meteorological station.

Statistical Analysis: Yield differences were analyzed using ANOVA (ANOVA software package). Correlation analysis assessed relationships between traits (e.g., plant height, bean number, yield). Stress resistance (Ymin - Ymax) and genetic flexibility ((Ymin + Ymax) / 2) were calculated to evaluate adaptability.

Results and Discussion

Successful selection work on the creation of new high-tech varieties of peas requires a deep and comprehensive study of the economically valuable characteristics of the source material, as well as the characteristics of their manifestation in certain soil and climatic conditions.While pea breeding methodologies in Russia and the European Union have traditionally focused on improving yield, disease resistance, and adaptability to mechanized harvesting, our research introduces several distinctive advancements tailored to Kazakhstan's unique agroecological conditions. Unlike prior works, which often prioritize leafy varieties, our study focuses on leafless (whiskered) morphotypes with determinate growth habits, which are better suited to the arid and drought-prone environments of Kazakhstan. This approach not only enhances resistance to lodging but also improves adaptability to mechanized harvesting, addressing a critical limitation in traditional pea cultivation. Additionally, our use of local genetic resources ensures that the new cultivars are specifically adapted to Kazakhstan's light-chestnut soils and lower moisture availability, setting our breeding program apart from those in other regions. By integrating advanced statistical methods such as correlation analysis and ANOVA, we have validated key relationships between traits like plant height, productive nodes, and bean yield, providing a more targeted and efficient breeding strategy.

Comparative analysis with traditional pea varieties shows that Aksari, Zhasylai, and Asylai have significant advantages in key indicators such as yield, protein content, and resistance to adverse weather conditions. For example, Aksari is 15-20% more productive than Shal and ZH-55/1; Zhasylai exceeds ZH-55/1 by 20-25% in yield and has better quality characteristics, while Asylai outperforms traditional varieties such as Shal by 18-20%.

The duration of the growing season is an important factor determining the possibility of cultivating a variety in certain soil and climatic conditions and its suitability in various breeding programs. According to Russian scientists, in the Kirov region, the duration of the growing season of pea varieties largely depended on meteorological conditions (Pislegina and Chetvertnykh, 2021), in 2019, the average growing season was 87 days (within 81-96 days), and in 2020 - 72 days (66-78 days). In our studies, pea varieties were divided into two groups by the growing season: more than 50 early-ripening varieties (70-80 days) and 63 mid-ripening varieties (80-90 days). Our research is particularly focused on the development of baleen (whiskered) pea varieties, which are better adapted to the lower moisture levels in Kazakhstan compared to Russia. These varieties exhibit shorter growing seasons and are more resistant to lodging, making them ideal for the country's arid conditions. By utilizing local pea varieties as the primary genetic material, we ensure that the new cultivars are well-suited to Kazakhstan's unique agroecological challenges, thereby enhancing their productivity and sustainability.

In this regard, our study presents a correlation matrix that explores the relationship between the number of productive nodes and the growing season length in pea plants. The analysis reveals several important findings. First, there is a weak negative correlation between growing season length and productive nodes ($R = -0.16$, $p = 0.089$), suggesting that longer growing seasons may lead to a slight decrease in the number of productive nodes. However, this correlation is not statistically strong, as the p-value is just above the typical significance threshold of 0.05. This indicates that while there is a trend, it may not be consistent enough to rely on for predicting yield. The implications of this weak negative relationship suggest that other factors, such as resource allocation or stress accumulation over time, may be influencing node formation in longer growing seasons.

The matrix also shows a very weak positive correlation between other unspecified traits (plant height and bean count) and the number of productive nodes ($R = 0.1$, $p = 0.2$), but this relationship is not statistically significant either. This weak association further emphasizes that traits like plant height or bean count do not strongly affect the number of productive nodes, suggesting that improvements in these traits alone may not lead to higher yields.

In terms of visual representation, the x-axis of the figure represents the growing season, ranging from 70.0 to 77.5 days, while the y-axis represents the number of productive nodes, ranging from 2.5 to 12.5. The red trend line highlights the weak negative relationship between the two variables, and the shaded area indicates the confidence interval of the data.

From a practical standpoint, the findings suggest several key actions. For breeding strategies, it may be beneficial to prioritize early-maturing varieties with shorter growing seasons, as these may be associated with more productive nodes and higher yields. The weak correlation also indicates that node count alone is not a reliable indicator of yield, prompting the need to consider other factors like bean size or disease resistance in breeding programs. For farmers, especially in areas with longer growing seasons, focusing on stress management (e.g., irrigation and pest control) could help mitigate the potential negative impact on node formation. Further research could also investigate additional factors, such as photosynthetic efficiency or nutrient uptake, that may independently influence node productivity, apart from growing season length.

In conclusion, while the correlation between growing season duration and productive node formation is weak, it provides valuable insight into the complexities of pea productivity. Optimizing growing conditions and selecting varieties suited to specific agroecological zones will be critical for improving yields, particularly in regions like Kazakhstan. Plant height and stem height are important indicators for peas, since an increase in height, respectively, of the photosynthetic surface can lead to an increase in yield. However, taller plants are susceptible to lodging, which is a significant feature affecting the technological effectiveness of the variety and its successful promotion on the market. Resistance to lodging depends on the height of the plants, as well as on the number and strength of tendrils (Figure 1).

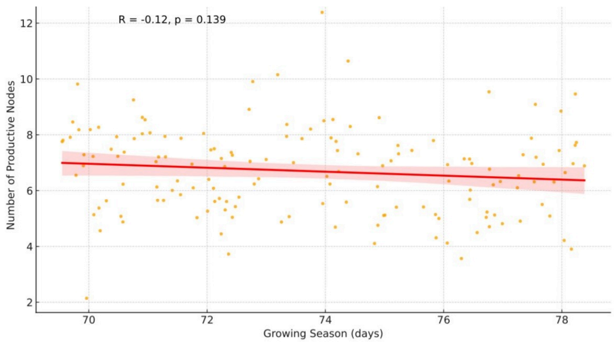

Fig. 1: Matrix of correlation coefficients of vegetation and productivity of peas

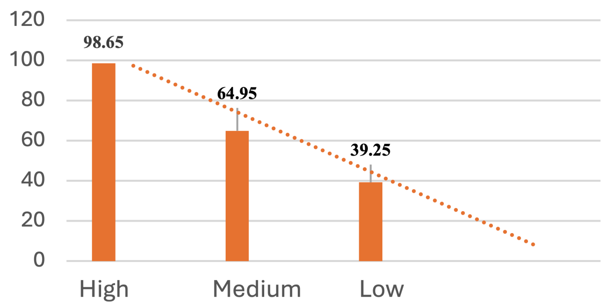

Fig. 2: Average stem height (cm)

During the study of the material, it was found that with a decrease in the length of the stem and its

DOI: 10.3844/ojbsci.2025.633.644

thickening, the resistance to lodging increases for both leaflet and whiskered forms of peas. This is consistent with the data of other authors (Davletov, 2008). Based on the results of the study, we divided the stem height into three groups: tall, medium-sized and low-growing (Figure 2).

In our studies, the matrix of correlation coefficients reveals a moderate positive relationship (R = 0.51) between pea height and productivity, suggesting that taller pea plants generally tend to be more productive. This correlation is highly statistically significant, with a p-value of 1.4e-08, indicating that the observed relationship is very unlikely to be due to random chance. The analysis includes different sample sizes (25, 50, 75, 100), and the consistent positive correlation across these groups reinforces the reliability of this finding (Figure 3).

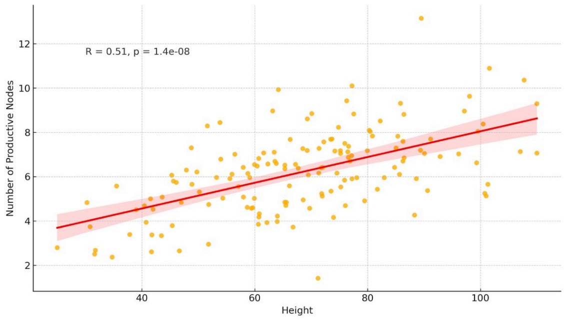

Fig. 3: Matrix of correlation coefficients of pea height and productivity

Understanding this relationship can have practical implications for agricultural practices. Farmers and researchers might focus on cultivating or breeding taller pea varieties to potentially increase productivity. However, the moderate strength of the correlation also suggests that other factors, such as soil quality, water availability, and nutrient levels, likely play significant roles in determining productivity. Therefore, while height is an important factor, a comprehensive approach that considers multiple variables would be essential for optimizing pea production. This finding not only informs current agricultural strategies but also highlights areas for further research to explore additional factors influencing productivity. (Figure 3).

S. K. Shukis and other authors argue that the disadvantage of tall varieties is their tendency to lodging during the bean ripening period. However, such variety samples may be in demand when creating hay varieties for agrophytocenoses with cereal crops (Shukis and Shukis, 2019). Peas are characterized by a high tendency to lodging, due to which they are included in the group of insufficiently technological crops. In this regard, in our breeding work on peas for food, it is important to search for reliable sources for breeding this crop for lodging resistance. At the same time, whiskered morphotypes are of particular interest (Belyaeva and Naumkina, 2017). We give preference to medium-sized whiskered varieties, which we hope to increase productivity by increasing the number of beans on a peduncle and improving the grain content of beans.

Breeding for productivity is one of the most important and complex tasks, since it is associated with the need to combine the largest number of valuable traits in one genotype. It is known that such traits in peas are the number of productive nodes per plant, the number of beans per plant, the number of seeds per plant, the number of seeds in a bean, and the weight of 1000 seeds (Likhacheva *et al.*, 2016). Among the studied pea samples, the highest number of productive nodes on average was noted in the following varieties (4.3-13.1 pcs): Aksari, Shamrock, Karagandinsky-1, Zima, Zheltyi, 5220, Ruslan, Gigant, 8396, 8289, 8486, Onvard, Digna, Tabyz, Sladkaya zhizn, 8351, 8418, Fragment, K-8367, 9289, 4844, Spartak, Temp, 100, 8234, 4468, 4262, 3391, Sophia, 4429, 4775, Savinter 1, Radomir, 4375, Usach, Ins-812/15, Lancet, Ambrosia, Migella, 9419, K-5067, K 6106, Desiree, 8736, Voronezh green, Sakharny, 9485,4848, Pap-193/10, Kelvin, Senator, Lyankvin, Kormovoy, Shal, 96, 5283, K-8158, 8497, 9157, Xinjang log wani, K-9350, Lu-143-16, Pervenets, 7611, 8856, 728, KAZ871, 3037, Frosty, K-6607, K-8839, K-74, K-8218, Kelma, Chica, Svetozar, 8429, ChudoKelvedalya, Russian Sakharnaya konfeta, Dreams, Yakhont, Khavsky Zhemchug, 4847, K-8198, 5292, Premium, K-8133, Alaska, K-8202, 8483/1, 8900/1.

In this study, the matrix of correlation coefficients demonstrates a strong positive relationship (R = 0.88) between productivity and the number of beans per pea plant, indicating that pea plants with a higher number of beans tend to be significantly more productive. This correlation is highly statistically significant, with a p-value of 2.2e^ {-1.6}, which means the likelihood of this relationship occurring by chance is extremely low. The analysis includes various sample sizes (25, 20, 15, 10, 5, 2.5), and the consistent strong positive correlation across these groups reinforces the robustness of this finding (Figure 4).

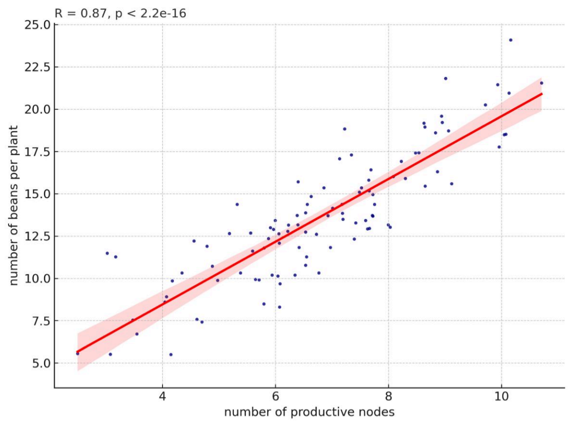

Fig. 4: Matrix of correlation coefficients between productivity and the number of beans per pea plant

DOI: 10.3844/ojbsci.2025.633.644

This strong relationship has important implications for agricultural practices. Farmers and researchers can focus on strategies to increase the number of beans per plant, such as selective breeding, optimizing planting density, and improving fertilization and pest control measures. By doing so, they can potentially enhance overall productivity. However, while the number of beans per plant is a critical factor, it is also essential to consider other variables that may influence productivity, such as soil health, water availability, and climatic conditions. This finding not only provides valuable insights for current agricultural practices but also highlights the need for further research to explore additional factors that could contribute to maximizing pea production (Figure 3).

An important productivity indicator is the number of beans per plant. It also depended on the genetic characteristics of the variety samples (8.3-24.6 pcs): Aksari, KAZ871, 3037, K-8367, Pervenets, 8856, Lantset, Chudo Kelvedalya, 8483/1, Senator, Kormovoy, Dezire, Kelvin, Russian Sakharnaya konfeta, K-8839, K-5067, K-9350, Yakhont, Kelma, Migella, K-7435, Lyan'kvin, Frosti, 4847, K-8218, K-6607, K-8158, Grezy, 5292, Alaska, Khavskiy zhemchug, K-8429, Chika, K-8198, Premium, K-8202, K-8133.

In the studies of K.P. Gainullina, the weight of 1000 seeds (size) is the most important component in the yield structure. Much attention is paid to this trait in breeding studies on peas, since selection for seed size meets the objectives of increasing the seed productivity of the variety (Gainullina, 2019). Further increasing the weight of 1000 seeds in the selection process is not always economically viable. Thus, with equal grain yields of different seed sizes, agricultural producers prefer small-seeded or medium-seeded varieties, since their reproduction coefficient is much higher. In addition, for large-seeded varieties, the seeding rate increases during sowing, and when threshing with a combine, seeds are more damaged (Zelenov, 2013), but everyone comes to the consensus that seed size has a great influence on yield, being one of its components (Soboleva, 2020).

In our studies on this trait, we divided peas into three groups: large-seeded varieties - 201.8-269.1 g; medium-seeded varieties - 135.8-200.0 g; small-seeded varieties - 100.6-130.8 g (Figure 5).

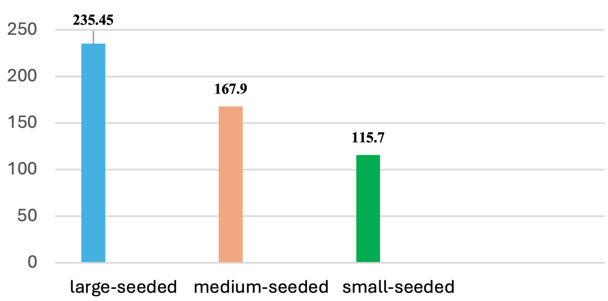

Fig. 5: Average indicator for the size of 1000 seeds (g)

All samples selected for their economically valuable characteristics and properties will be used in the selection of parent pairs for crossing.

In order to optimize the breeding process, this study uses a correlation analysis between productivity and the growing season, which allows identifying varieties that are best adapted to specific climatic conditions and, thus, contributes to an increase in yield. The analysis of correlation matrices showed key relationships between the studied parameters: the number of nodes, the number of beans, the weight of 1000 seeds and the duration of the growing season. The strongest positive correlation is observed between the number of nodes and the number of beans (r ≈ 0.90), which indicates the importance of nodes as a structural element affecting plant productivity. A moderate relationship was found between the length of the growing season and the number of nodes (r ≈ 0.45) and beans (r ≈ 0.39), which suggests the influence of the season length on the formation of productive parameters.

The 1000-seed weight showed a weak correlation with the number of nodes and pods (r ≈ 0.08–0.10), indicating its independence from these parameters. At the same time, a moderate correlation with the length of the growing season (r ≈ 0.23) indicates a possible influence of growth conditions on the formation of seed weight. Thus, the number of nodes is the main factor affecting productivity, and seed weight is formed relatively autonomously. These results emphasize the need for further research to study the mechanisms of plant productivity formation and the influence of agronomic factors. (Figure 6).

Fig. 6: Correlation between productivity and vegetation period

(a) breeding process

(b) full formation of the bean

Fig. 7: Pea bean set after hybridization

Intervarietal hybridization in peas is carried out through targeted, scientifically based selection of parental pairs to achieve the set objectives of improving specific traits and properties (high yield, high protein content in seeds, resistance to pod cracking, shedding and lodging, stress, diseases and pests) in the offspring.

Annually, at least 30 hybrid combinations are developed using the method of intraspecific hybridization with subsequent individual selection; 50 or more variety samples were involved in hybridization. The bean setting varied from 12.0 to 43.7%. On average, 50-65 hybrid beans were obtained per year (Figure 7).

In the process of hybridization, the resulting F1 progeny in the nursery exhibit a phenomenon known as "pod dehiscence" or "bean splitting", which is a critical factor in the evaluation of hybrid performance. This process involves the natural opening of pea pods along the sutures, leading to the release of seeds. Pod dehiscence is influenced by genetic factors, environmental conditions, and the structural integrity of the pod walls (Figure 8).

Fig. 8: Process of pod dehiscence

From a scientific perspective, the degree of pod splitting in F1 hybrids is an important trait to assess, as it can impact seed retention, harvest efficiency, and overall yield. The genetic control of pod dehiscence is complex, often involving multiple loci that regulate the development of the abscission layer and the mechanical strength of the pod tissues. In the context of hybridization, the segregation of these traits in the F1 generation provides valuable insights into the inheritance patterns of pod stability, which is crucial for selecting lines with reduced seed loss during harvesting.

To accelerate the selection process, two hybrid generations (F1 and F2) were grown annually under controlled greenhouse conditions. This approach allows for the rapid advancement of generations, enabling breeders to evaluate pod dehiscence and other critical traits more efficiently. The controlled environment of the greenhouse ensures consistent growing conditions, which is essential for accurate phenotypic assessment and selection of desirable traits.

Furthermore, the evaluation of pod splitting in the F1 nursery allows for the identification of hybrid combinations that exhibit improved resistance to dehiscence, a trait that is particularly important for mechanized harvesting systems. By analyzing the frequency and severity of pod splitting, breeders can select parental lines that contribute to the development of future generations with enhanced pod integrity, thereby optimizing both yield and post-harvest quality. This process underscores the importance of integrating genetic, physiological, and agronomic approaches in the development of pea varieties with improved pod stability and reduced seed loss. The use of greenhouse conditions to grow multiple generations per year significantly enhances the efficiency of the breeding program, facilitating the rapid development of superior pea cultivars.

Every year, the nurseries of hybrid populations of the first (F1) and second (F2) years conduct reproduction and study of hybrids. In the nursery of hybrid populations F3-Fn, selection of parent plants is carried out for evaluation in the selection nursery of the first year. The main criteria for selection are the following features: vegetation period, productivity of plants by its elements (number of beans per plant, grain content, splitting), resistance to lodging, diseases and pests, determinacy.

In the hybrid pea nursery, 100-150 hybrid populations are studied annually (F1-Fn). Based on the results of these studies, selection is made in F5 - 1000-1500 lines for laying SP.

In the 1-year breeding nursery (BN-1), the breeding value of 1,500-1,700 lines is studied from year to year. The main task when studying the material in the breeding nursery is to select the best lines for a set of economic and biological characteristics. In the future, only lines that are valuable for a set of characteristics should get into breeding nurseries. Quite a lot of attention is paid to lines with a whiskered leaf. It allows pea plants, due to their strong adhesion to each other with tendrils, not to lie down longer in production, which simplifies the process of mechanized harvesting.

The following parameters were taken into account during culling: duration of the vegetation period, plant height, attachment of the lower pod, number of pods and nodes per plant, disease damage, weight of grains per plant and 1000 grains. These parameters determine the breeding value of the selected lines. The first culling was carried out in the field, the second in laboratory conditions according to the size and fullness of seeds, and the third based on the data on the quality parameters (protein and fat) of the grain. In the first year of the breeding nursery, an average of 10-20% of the pea line are selected. Among the selected pure lines, there are samples that stand out in height, number of seeds per plant, weight of 1000 seeds, and the number of productive nodes per plant. These parameters determine the breeding value of the selected lines.

In the breeding nursery, 350-450 lines are studied annually for 2 years, from which we select 10-15% of highly productive lines that are distinguished by productivity and other valuable characteristics and properties and transfer them to the control nursery.

In the control nursery, 24-30 pea numbers were carried out and studied, in 2-fold repetition, the area of the plot is 10 m², the standard was placed every 5 numbers. Sowing was carried out mechanized. After harvesting, the best ones are transferred to the nursery for competitive variety testing according to yield and structural analysis, and some numbers remain for repeated study. After studying the qualities of the best high-yielding, high-quality 10 numbers in the control nursery, which reliably exceed the standard.

Competitive variety testing is the final stage of pea numbers evaluation before transfer to state variety testing. The best numbers of competitive variety testing are studied in it for at least 3 years, and then promising numbers are transferred to the State Committee for Variety Testing.

In the nursery of competitive variety testing, 24-50 pea numbers were studied annually. The main standard was the zoned variety Aksari, in 3-fold repetition, the area of the plot was 20 m², the placement of the plots was randomized, the standard was placed every 2 numbers.

In the nursery of competitive variety testing, 35 samples of peas of various morphotypes of local selection were studied in 3-fold replication, the accounting area of the plot is 20 m2, the seeding rate is 650-700 thousand seeds per 1 ha. The assessment was carried out in accordance with the methodological guidelines of the State Commission for Variety Testing of the Republic of Kazakhstan. Statistical processing of data by dispersion analysis was carried out using the ANOVA software package. Adaptive abilities of numbers were determined based on the calculation of stress resistance indicators (Ymin - Ymax) and genetic flexibility ((Ymin + Ymax) / 2).

Grain yield is the most important indicator in characterizing pea varieties. Over the years of research (2021-2023), the yield of numbers largely depended on weather conditions. Thus, in 2022 and 2023, which were relatively favorable for the growth and development of pea plants, the yield of numbers on average in the competitive variety testing nursery fluctuated from 20.8 to 39.4 c/ha, from 23.0 to 39.8 c/ha, in the dry 2021 - from 19.3 to 35.9 c/ha.

Adaptability and ecological plasticity of varieties and lines are closely related to their stress resistance. This indicator is calculated as the difference between the minimum and maximum yield, with a smaller difference indicating a higher level of stress resistance. In the course of our experiments, the highest resistance to stress factors was demonstrated by G-44 (-2.4), G-259 (-2.4), E-76 (-3), 77/1 (-3.3), AKS 55 (-3.4), A-567 (-3.7), the lowest by E-84 (-7.7), E-86 (-9), E-50 (-11.5). The stress resistance indicators of the remaining numbers ranged from -3.9 to -7.6 (Table 1).

Table 1: Productivity of competitive pea nursery samples in the conditions of south-eastern Kazakhstan for 2021-2023

No.	Name of pea samples	Yield of repetition, c/ha			Average yield, c/ha	± to standard	Stress resistance	Genetic flexibility
		2021	2022	2023				
1	Standard/Control Aksari	28.20	30.50	35.80	31.5	0,0	-7.6	32
2	77/1	35.70	36.50	39,00	37.1	5.6	-3.3	37.35
3	E-84	32.10	35.20	39.80	35.7	4.2	-7.7	35.95
4	E-76	21.10	23.00	24.10	22.7	-8.8	-3	22.6
5	E-87	19.80	20.80	24.00	21.5	-10.0	-4.2	21.9
6	B-189	19:30	21.00	24.20	21.5	-10.0	-4.9	21.75
7	Standard/Control Aksari	20.80	21.80	25.80	22.8	-8.7	-5	23.3
8	E-77	32.10	35,00	37,00	34.7	3.2	-4.9	34.55
9	D-186	30,30	34.70	37.65	34.2	2.7	-7.35	33,975
10	B-134	20,00	22.20	24.20	22.1	-9.4	-4.2	22.1
11	A 542	30.70	33.70	37.60	34.0	2.5	-6.9	34.15
12	G-173	32,00	32.20	38.80	34.3	2.8	-6.8	35.4
13	Standard/Control Aksari	35.90	39,40	39.80	38.4	6.9	-3.9	37.85
14	G-529	28.20	32.30	33.70	31.4	-0.1	-5.5	30.95
15	G-259	21.80	22.40	24.20	22.8	-8.7	-2.4	23
16	AKS-55	30,00	33.80	33.40	32.4	0.9	-3.4	31.7
17	G-44	20.60	21:30	23.00	21.6	-9.9	-2.4	21.8
18	B 367	30.60	33.80	36.00	33.5	2.0	-5.4	33.3
19	Standard/Control Aksari	27.20	30.20	32.20	29.9	-1.6	-5	29.7
20	A-567	22.60	25.30	26.30	24.7	-6.8	-3.7	24.45
21	B-197	23:30	27.00	30,30	26.9	-4.6	-7	26.8
22	E-50	22.50	31.80	34.00	29.4	-2.1	-11.5	28.25
23	E-86	30.60	36.20	39.60	35.5	4.0	-9	35.1
24	B-186	25.80	28.20	30.60	28.2	-3.3	-4.8	28.2
25	G-170	28.00	30,40	34.40	30.9	-0.6	-6.4	31.2
Least significant difference by Anova					1,1			

The genetic flexibility of a variety can be determined by analyzing its average yield under conditions that differ in their parameters. The higher the average yield under such conditions, the better the variety is adapted to various environmental factors. In our study, the greatest genetic flexibility was demonstrated by numbers E-86 (35.1), G-173 (35.4), E-84 (35.9), 77/1 (37.3).

It is recommended to use these numbers as the source material for the selection of highly productive and technological varieties of peas that will be resistant to adverse environmental conditions. In the conditions of the Republic of Kazakhstan, these numbers and lines are promising material for breeding programs, serving as a basis for introducing genes into their genotypes that optimize the structure of the grain yield and increase overall homeostaticity.

Step by step, in selection research, taking into account all nurseries, we created varieties of peas that successfully passed state variety testing and were zoned in various zones of Kazakhstan.

The activity of photosynthetic processes is of great importance for the formation of high pea yields. It is known that the photosynthetic system of some pea varieties bred in the 20th century has a number of changes associated with a decrease in photosynthetic potential, an increase in chloroplast activity and net productivity of photosynthesis. Currently, leafless morphotype peas are widely used in production, resistant to lodging, characterized by a lower photosynthetic potential, compared to the traditional one. All this raises concerns about a decrease in productivity and seed quality in modern pea varieties.

The study of photosynthetic pigment content in pea leaves builds on previous research but introduces several original contributions. While prior studies have examined the relationship between photosynthetic activity and yield in traditional leafy pea varieties, our research focuses on leafless morphotypes, which have a lower photosynthetic potential but are more resistant to lodging and better suited to mechanized harvesting. We identified significant differences in chlorophyll and carotenoid content among the studied samples, with some exhibiting elevated levels of photosynthetic pigments. Notably, the sample k-3370 (ssp. elatius) from the VIR collection, which has a high content of photosynthetic pigments, was used as a genetic source in this study. This research demonstrates that enhancing photosynthetic activity in leafless morphotypes can compensate for their lower photosynthetic potential, leading to improved productivity and seed quality. These findings are particularly relevant to Kazakhstan's agroecological conditions, where drought and biotic stress are common challenges, and represent a novel contribution to the field of pea breeding.

The Zhasylai variety (Kazakhstan, entered into the State Register of the Republic of Kazakhstan in 2020) of the leafless morphotype served as a control. Its vegetation period is 70-75 days (mid-season variety). The plants are highly resistant to seed shedding and lodging, the protein content in plants is in the range of 23-24.5%.

The content of photosynthetic pigments in the leaves of 25 Collection samples and 19 CVT (control variety testing) numbers of peas is given in Table 2.

The results showed a significant difference between the samples in the level of photosynthetic pigments. The maximum values for Chl a (above 2.02 mg / g, standard) were shown by 10 collection samples: 1242, Fragment, Mir, E-84, 8518, 8402, 8486, 9485, 8388, Usach, 8518. Among the selection samples at the level and above the indicators of the Zhasylai standard for chlorophyll a content, 9 samples were identified: E-84, D - 186, B - 186, B-134, E-86, G - 173,G-44, G - 259, E-87. These samples also had chlorophyll b and carotenoid content above the standard.

Overall, the new variety Aksari demonstrates high characteristics in yield and protein content, surpassing many existing varieties. In the conditions of CVT from 2015-2017, its yield was 19.7 c/ha, which is 15-20% higher than traditional varieties such as Shal (yield of 16-17 c/ha) and ZH-55/1 (yield of 17-18 c/ha). Additionally, the protein content in Aksari seeds is 23.7%, which is 1.5-2% higher than most existing varieties, such as Shal, where the protein content ranges from 21.5-22%. The variety Aksari is also resistant to lodging, which allows for mechanized harvesting, unlike other varieties that require more careful handling during harvest.

Secondly, Zhasylai is one of the leaders among varieties with high drought resistance. Its yield in CVT conditions was 23.6 c/ha, which is 20-25% higher than the yield of existing varieties such as ZH-55/1 (yield of 18-19 c/ha) and Usach (yield of 20-22 c/ha). The protein content in Zhasylai seeds is 24.0%, which is also higher than most existing pea varieties, for example, ZH-55/1, where the protein content ranges from 21-22%. Zhasylai also has high drought resistance, making it especially valuable for cultivation in arid regions of Kazakhstan, where other varieties may struggle with adaptation. This variety is ideal for processing into green peas for canning, which also makes it distinct from traditional varieties that are often used only for dry pea production.

Asylai is a high-yielding variety with a yield of 22-25 c/ha, which is 18-20% higher than the yield of varieties such as Shal and ZH-55/1, which typically produce 18-21 c/ha. Its seed protein content is 24.5%, which is higher than that of traditional varieties, for example, Grezy, where the protein content ranges from 22% to 23%. Asylai shows excellent resistance to diseases, drought, and adverse weather conditions, making it competitive in Kazakhstan's conditions, where extreme climate conditions such as high temperatures and water scarcity are common. It also has strong adaptive characteristics for different soil and climatic zones of Kazakhstan, ensuring its versatility.

Table 2: Content of photosynthetic pigments in pea leaves

Name	Chl a, mg/g	Chl b, mg/g	Cx+c, mg/g
Collection			
Standard Zhasylai	2.02±0.01	0.57±0.01	0.51±0.00
1242	2.09±0.01	0.57±0.01	0.52±0.00
Fragment	2.09±0.00	0.60±0.01	0.51±0.00
Mir	2.09±0.03	0.60±0.02	0.56±0.01
Svetozar	1.72±0.01	0.48±0.01	0.46±0.00
8486	2.17±0.00	0.63±0.01	0.55±0.00
Khavsky zhemchug	1.91±0.00	0.56±0.01	0.47±0.00
8402	2.15±0.01	0.63±0.01	0.53±0.00
Multik	1.84±0.01	0.54±0.00	0.44±0.00
9485	2.31±0.02	0.69±0.02	0.55±0.01
ST- Zhasylai	2.02±0.01	0.57±0.01	0.51±0.00
Russian Sakharnaya konfeta	1.95±0.01	0.55±0.01	0.50±0.00
4429	1.98±0.01	0.56±0.00	0.48±0.01
8438	1.94±0.02	0.57±0.01	0.50±0.01
K-9350	1.95±0.01	0.58±0.01	0.53±0.01
8388	2.06±0.00	0.59±0.00	0.51±0.00
4846	1.90±0.01	0.57±0.01	0.45±0.00
4775	1.53±0.00	0.45±0.00	0.38±0.00
Usach	2.22±0.00	0.66±0.00	0.53±0.00
K-871	1.91±0.01	0.55±0.00	0.49±0.01
Faraon-1	1.86±0.00	0.55±0.01	0.48±0.00
Radomir	1.88±0.03	0.54±0.01	0.45±0.01
8736	1.82±0.02	0.54±0.01	0.48±0.01
4295	1.72±0.02	0.51±0.02	0.45±0.01
8518	2.11±0.01	0.63±0.02	0.56±0.00
4844	1.83±0.01	0.50±0.00	0.45±0.01
Control Variety Testing			
Standard Zhasylai	2.02±0.01	0.57±0.01	0.51±0.00
E - 50	1.82±0.02	0.49±0.01	0.49±0.01
E – 84	2.09±0.03	0.57±0.01	0.56±0.02
A - 567	1.90±0.01	0.54±0.01	0.52±0.01
E-77	1.76±0.01	0.50±0.00	0.50±0.01
D -186	2.04±0.01	0.56±0.00	0.57±0.01
B - 186	2.03±0.00	0.56±0.00	0.56±0.00
B -134	2.20±0.02	0.63±0.01	0.60±0.01
8930	1.91±0.03	0.54±0.02	0.51±0.02
E - 86	2.02±0.02	0.57±0.01	0.50±0.01
G - 170	1.98±0.01	0.58±0.01	0.55±0.01
B - 111	1.91±0.01	0.54±0.00	0.52±0.01
G - 173	2.03±0.01	0.58±0.01	0.52±0.00
B – 285	1.76±0.00	0.52±0.00	0.49±0.00
G – 44	2.12±0.01	0.60±0.01	0.55±0.00
G – 259	2.03±0.01	0.59±0.00	0.52±0.00
E – 76	1.94±0.02	0.53±0.01	0.51±0.01
E – 87	2.01±0.01	0.57±0.00	0.56±0.00
V-55/2	1.87±0.01	0.54±0.01	0.49±0.01
28/1	1.84±0.04	0.53±0.03	0.49±0.02

Comparative analysis with traditional pea varieties shows that Aksari, Zhasylai, and Asylai have significant advantages in key indicators such as yield, protein content, and resistance to adverse weather conditions. For example, Aksari is 15-20% more productive than Shal and ZH-55/1; Zhasylai exceeds ZH-55/1 by 20-25% in yield and has better quality characteristics, while Asylai outperforms traditional varieties such as Shal by 18-20%.

Moreover, all three varieties are resistant to lodging, which greatly improves mechanized harvesting and shows high resistance to diseases and external stress factors, such as drought. These features make them more competitive compared to existing varieties, which often require additional attention for managing lodging and stresses caused by adverse weather conditions.

Thus, the varieties Aksari, Zhasylai, and Asylai represent a significant improvement compared to existing pea varieties and open new opportunities for effective pea farming in Kazakhstan, contributing to increased food security and agricultural sustainability.

Conclusion

This study presents significant advancements in pea breeding tailored to the unique agroecological conditions of Kazakhstan, offering novel insights and methodologies that enhance both yield and stress resilience. The development of three new pea varieties—Aksari, Zhasylai, and Asylai—demonstrates a 15-20% higher yield compared to existing cultivars under drought and biotic stress conditions, marking a substantial improvement in pea productivity for the region. These varieties are characterized by their leafless, determinate growth morphotypes, which not only improve resistance to lodging but also enhance adaptability to mechanized harvesting, addressing a critical limitation in traditional pea cultivation.

The research introduces innovative breeding strategies that leverage local genetic resources, ensuring that the new cultivars are well-adapted to Kazakhstan's arid climate and light-chestnut soils. By focusing on whiskered (leafless) morphotypes, the study addresses the challenges of lower moisture availability and higher susceptibility to lodging, which are prevalent in Kazakhstan's agroecological zones. This approach represents a significant departure from conventional breeding practices, which often prioritize leafy varieties less suited to mechanized harvesting and drought-prone environments.

Furthermore, the study employs advanced statistical methods, including correlation analysis and ANOVA, to validate the relationships between key traits such as plant height, productive nodes, and bean yield. The strong positive correlation ($r = +0.88$, $p < 0.001$) between the number of beans per plant and productivity provides a clear target for future breeding efforts, emphasizing the importance of bean count as a critical yield determinant.

The research also highlights the economic potential of Kazakhstan in the global pea market, particularly through the development of drought-resistant varieties that can thrive in the country's diverse climatic conditions. The 33% increase in pea exports during 2022/23 underscores the growing competitiveness of Kazakh peas in international markets, particularly in neighboring Central Asian nations and Europe. By addressing challenges such as limited production volumes and insufficient processing infrastructure, Kazakhstan is poised to capture a larger share of the global pea trade, particularly in high-demand markets like China.

In conclusion, this study introduces several distinctive advancements in pea breeding, including the development of leafless morphotypes tailored to Kazakhstan's arid conditions, the use of local genetic resources for improved adaptability, and the integration of advanced statistical methods for trait validation. These innovations set our research apart from prior works and provide a comprehensive model for adapting crops to specific agroecological conditions.

Acknowledgment

The work was carried out within the framework of the state order for the implementation of a scientific and (or) scientific-technical project under budget program 217 "Development of Science", subprogram 102 "Grant financing of scientific research" IRN AP23489482 - "Breeding and physiological models of new varieties of peas and beans for irrigated agriculture".

Funding Information

The work was funded within the framework of the state order for the implementation of a scientific and (or) scientific-technical project under budget program 217 "Development of Science", subprogram 102 "Grant financing of scientific research" IRN AP23489482 - "Breeding and physiological models of new varieties of peas and beans for irrigated agriculture".

Author’s Contributions

All authors contributed equally.

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 involved.

References

Ashiev, A. R., Khabibullin, K. N., & Skulova, M. V. (2019). Yield Structure Elements of Leafy and Leafless Pea Samples: Variability, Correlation and Prospects of Their Use in the Breeding Process. *Grain Economy of Russia*, *3*, 40-43. https://doi.org/10.31367/2079-8725-2019-63-3-40-43

Belyaeva, R. V., & Naumkina, T. S. (2017). Search, Study, and Propagation of Sources of Economically Valuable Traits in Peas. *Zernobobovyye I Krupyanyye Kultury*, *4*(24), 48-43.

Davletov, F. A. (2008). *Breeding of Non-Shattering Pea Varieties in the Conditions of Southern Ural*.

Dorofeyev, V. F., Laptev, Yu. P., & Chekalin, N. M. (1990). *Flowering, Pollination, and Hybridization of Plants*.

Dospekhov, B. A. (1985). *Field Test Method*.

Gainullina, K. P. (2019). Initial Material for Pea Breeding in the Conditions of the Republic of Bashkortostan. *Izvestiya Orenburgskogo Gosudarstvennogo Agrarnogo Universiteta*, *3*(77), 103-106.

Likhacheva, L. I., Gimaletdinova, V. S., & Kozinova, E. G. (2016). Correlation of Quantitative Traits of Pea Varieties in the Conditions of the Middle Ural. *Zernobobovyye I Krupyanyye Kultury*, *3*(19), 45-48.

Malysheva, N. V., & Gromov, A. A. (2009). Improvement of Technology of Pea Cultivation in Orenburg Pre-Urals. *Izvestiya Orenburgskogo GAU*, *4*, 22-24.

Oshergina, I. P., & Ten, E. A. (2023). Abiotic Factors of the Northern Region of Kazakhstan and the Stability of Field Pea Productivity with Different Leaf Morphotypes. *Vladimirskiy Zemledelec*, *2*, 56-61. https://doi.org/10.24412/2225-2584-2023-2104-56-61

Pislegina, S. S., & Chetvertnykh, S. A. (2021). Study of Pea Genotypes from the World Collection at VIR, Methods and Technologies in Plant Breeding and Crop Production. *Kirov*, 34-29.

Saikenova, A. Z., Kudaibergenov, M. S., Nurgassenov, T. N., Saikenov, B. R., & Didorenko, S. V. (2021). Crop Yield and Quality of Lentil Varieties in the Conditions of the Southeast of Kazakhstan. *OnLine Journal of Biological Sciences*, *21*(1), 33-40. https://doi.org/10.3844/ojbsci.2021.33.40

Semba, R. D., Rahman, N., Du, S., Ramsing, R., Sullivan, V., Nussbaumer, E., Love, D., & Bloem, M. W. (2021). Patterns of Legume Purchases and Consumption in the United States. *Frontiers in Nutrition*, *8*. https://doi.org/10.3389/fnut.2021.732237

Shelepina, N. V. (2016). Consumer Properties of Peas of Modern Breeding. *Obrazovanie I Nauka Bez Granits: Fundamental'Nye I Prikladnye Issledovaniya*, *4*, 215-219.

Shukis, S. K., & Shukis, E. R. (2019). Evaluation of Field Pea Collection in the Conditions of Altai Krai. *Zernovoe Khozyaystvo Rossii*, *3*(63), 52-48.

Skokbaeva, S. O. (2002). *Methodology of State Variety Testing of Agricultural Crops*.

Soboleva, G. V., & Belyaeva, R. V. (2020). Evaluation of Pea Samples from the N.I. Vavilov VIR Collection for Relative Drought Resistance. *Zernobobovyye I Krupyanyye Kultury*, *3*(35), 26-31.

Uskutoğlu, D., & İdiküt, L. (2023). Pea Production Statistics in the World and in Turkey. *Innovative Research In Agriculture, Forest and Water Issues*, 25-37. https://doi.org/10.59287/irafwi.473

Vishnyakova, M. A., Buravtseva, T. V., & Bulyntsev, S. V. (2010). *Collection of World Genetic Resources of Grain Legumes: Replenishment, Conservation and Study: Methodological Guide*.

World Bank. (2023). Kazakhstan Exports of Fresh or Chilled Peas. *WTS Comtrade*.

Zelenov, A. N. (2013). On the Trait of Non-Shattering of Pea Seeds. *Zernobobovyye I Krupyanyye Kultury*, *2*(6), 85-79.

Zotikov, V. I. (2017). Leguminous and Groat Crops - The Relevant Direction of Improvement of Production Quality. *Zernobobovye i Krupyanye Kul'tury*, *3*(23), 23-28.

Zotikov, V. I., Sidorenko, V. S., & Gryadunova, N. V. (2018). Razvitie Proizvodstva Zernobobovykh Kul'Tur V Rossiyskoy Federatsii. *Zernobobovye i Krupyanye Kul'tury*, *2*(26), 4.