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DEVELOPMENT OF VARIETAL TECHNOLOGY FOR NEW VARIETIES OF PEAS UNDER IRRIGATION CONDITIONS OF SOUTH-EAST KAZAKHSTAN

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SUMMARY

The latest research on pea (*Pisum sativum* L.), carried out on irrigated land, commenced at the Kazakh Research Institute of Agriculture and Plant Growing, Almaty Region, Kazakhstan. The presented study sought to investigate how different agriculture techniques can affect the economically valuable traits of two cultivars of peas. The research layout in a correlational design had three factors each, with three replications. The first factor comprised seed rates of 600,000, 700,000, and 800,000 seeds ha^{-1}, with the second factor as the row spacing of 15 and 30 cm. Meanwhile, the third factor was the application of NPK fertilizer with three doses (30, 60, and 80 kg ha^{-1}). Three factors based on various cultivation technologies and fertilizer doses revealed considerable differences for plant height, beans per plant, beans weight per plant, and 1000-seed weight in peas. The results showed optimal outcomes by ensuring favorable conditions for plant nutrition by providing the right space for plant nutrition, maximizing solar energy absorption, applying appropriate doses of mineral nutrients, and considering the genetic traits of the pea genotypes.

Keywords: Pea (*P. sativum* L.), plant population, spacing, mineral fertilizers, economically valuable traits, plant height, beans per plant, beans weight per plant, 1000-seed weight

Key findings: The impact of various agricultural methodologies on the economically significant traits of two pea (*P. sativum* L.) cultivars demonstrated optimal results through enhancement of favorable conditions for plant nutrition. With employment of agrotechnical factors, the variability in economically valuable traits ranges from 27.7% to 34.26%.

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INTRODUCTION

Pea (*P. sativum* L.) is a leguminous crop, belonging to the Fabaceae (also known as the legume family, Leguminosae), cultivated worldwide. Peas served as food, protein source, green peas, feed for the canning industry, feed production, and the best green manure crop. In addition, peas are crucial as a precursor, in symbiosis with nodule bacteria, in synthesizing nitrogen from the air, and keeping it for the next crop. Being a nitrogen-fixing crop, peas are of great agrotechnical importance (Agrarian Bulletin, 2021). Pea growing covers more than 110,000 hectares, mainly in the regions of Akmola, Kostanay, and North Kazakhstan.

The peas' introduction in animals feed significantly reduced the feed consumption, increased the yield of livestock products, and lowered its cost. On average, pea seeds contain 22.5% digestible protein. Per one feed unit, peas contain 170 g of digestible protein, with a zootechnical norm of 120 g, being recognized as a protein donor in the compound feeds. Every ton of pea seeds introduced into the animal diet saves 2.5 tons of concentrates. In crop rotation, the pea inclusion increases soil fertility and accumulates up to 130 kg of nitrogen per hectare in the soil due to the symbiotic activity of nitrogen-fixing microorganisms (Korepanova *et al*., 2018).

Nowadays in plant breeding, pea technology development is in parallel, especially the pea varietal development technology. The innovation in agrotechnical methods for cultivating peas makes it possible to use full genetic potential of promising genotypes. In varietal technology, improving the elements of pea cultivation is a reserve for expanding the area under this crop, increasing net and gross yields. By cultivating peas and formation of crop, special importance should focus on the genotypes, seeding rates, sowing methods, and mineral fertilizer doses (Saikenova *et al*., 2021).

The presented research also devoted to the study of these technology elements in relation to the pea genotypes. The passport data complements with the seeds that determine the composition of peas recommended for cultivation, and to identify the parameters of the main agrotechnological techniques (seeding rate, sowing pattern, and rate of mineral fertilizer) for planting new cultivars of peas recommended for cultivation in Kazakhstan. However, the pea cultivar Aksari emerged recommendable for food purposes, while the genotype Zhasylai was better in the canning industry.

In the latest research, the main task of varietal technology were the seed rate, sowing methods, and the rate of mineral fertilizers' application during irrigation by cultivating the new pea cultivars Aksari and Zhasylai. The object of the presented investigation was the two new pea cultivars recommended for cultivation in various regions of Kazakhstan and to investigate how different agriculture techniques can affect the economically valuable traits of these pea genotypes.

MATERIALS AND METHODS

The study on pea (*P. sativum* L.) commenced on irrigated land of the Kazakh Research Institute of Agriculture and Plant Growing, Almaty Region, Kazakhstan. The presented study aimed to investigate how different agricultural techniques can affect the economically valuable traits of two pea cultivars. The research layout in a correlational design had three factors, each with three replications. The first factor comprised seed rates of 600,000, 700,000, and 800,000 seeds ha^{-1}, the second factor was row spacing of 15 and 30 cm, while the third was applying NPK fertilizer with three doses (30, 60, and 80 kg ha^{-1}).

Research methods involved field experimental and laboratory studies. Following the methodology of Dospehov (2012) laid out the experiments with corresponding observations. The experiments continued according to the methodology of observing all the agrotechnical measures and scrutinizing field crops. The elements of the crop structure studied relied on selecting sheaves before harvesting each option in three replications (Dospehov, 2012).

Phenological observations of plant growth and development phases and censuses proceeded using methodological guidelines (AkhmadullinaII, 1998). Structural analysis ensued according to the main economically valuable characteristics. The recorded data consisted of the plant height, the number of beans per plant, beans' weight per plant, and 1000-seed weight. The laboratory analysis considered the yield components, as described above.

Statistical analysis

Statistical analysis of peas is a research method often used in biology and genetics to study hereditary properties. Peas were the choice for the first genetic experiments of Johann Mendel in the middle of the 19th century, which made it a model object for studying plant heredity (Bobkov *et al.,* 2016). Statistical analysis of peas enabled Mendel to establish fundamental laws of heredity, including the principles of monohybrid and dihybrid crosses, which significantly influenced the evolution of genetics as a scientific discipline (Bulletin of the Izhevsk, 2018).

RESULTS AND DISCUSSION

Plant height is an important trait, vital in boosting the number of branches and yield. However, if plants are taller, then lodging may occur. The plant height is a varietal characteristic; although, it varies under the influence of various agricultural techniques and factors in pea (*P. sativum* L.). The plant growth rate is highly dependent on the weather and irrigation conditions. Moreover, plant height is an effective indicator of the growth and development of any crop. In peas, the plant height bore influences from environmental factors, such as, temperature, soil type, light, and the moisture in the soil, as well as, the genetic makeup of the pea genotypes (Zhogaleva and Strel'cova, 2021).

The results also revealed the optimal height at which the best pea yield develops in the conditions of the Almaty Region, Kazakhstan, ranged around 80–90 cm. Taller plants are also prone to lodging, leading to loss of yield when combined with harvesting. Thus, after conducting structural analysis, the study relied on medium-growing cultivars. As a result of this research, the optimal plant height was visible for the pea cultivar Aksari (80–90 cm), combined with a seed rate 600,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 30 kg ha^{-1}. However, cultivar Zhasylai proved best suitable with a seed rate of 800,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 80 kg ha^{-1}. The lower beans' height enhanced in the studied cultivars under the influence of ORMISS Cu–B (51.2–66.1 cm) and ORMISS Cu–Mo (52.7–64.6 cm) (Zhogaleva and Strel'cova, 2021).

The shorter plant height (80 cm and below) was notable in pea cultivar Aksari with a seed rate of 700,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 30 kg ha^{-1}. Meanwhile, in cultivar Zhasylai, it was with a seed rate of 700,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 30 kg ha^{-1}. However, taller plants (above 90 cm) were evident in the cultivar Aksari with a seed rate of 800,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 80 kg ha^{-1}. The results also exhibited a negative value for plant height (low and tall) and due to more plant population, a lack of nutritional area and insufficient solar energy received for photosynthesis occurred (Table 1). Based on the biometric assessment, past findings revealed these microfertilizers had a positive effect on the lower pods' height in the studied pea cultivars. In studies conducted in the Orenburg region, pea plants reached the highest height in 2017: in the budding phase – 45.7 cm and bean formation – 58.1 cm. The cool weather of the first half of the vegetation and the favorable relative humidity of the air during this period contributed to the growth of plants. The yield of the green mass of Samarius peas in the budding phase increased when raising the seeding rate, from 7.6 at 0.6 million germinating seeds per 1 ha to 10.5 t per 1 ha at 1.4 million. Since the height of the Samarius variety plants was insignificant, the difference between the variants was insignificant. The formation of an above ground mass in the variant with a seeding rate of 1.4 million germinating seeds per 1 hectare occurred due to more plants. The same pattern

Table 1.The influence of agrotechnological methods on the plant height of peas.

Cultivars	Mineral fertilizers	Seeding rate	Plant height (cm)	
			2022	2023
Row spacing of 15 cm				
Aksari	30	600	89.6	86
		700	82.5	80
		800	91.9	87
Aksari	60	600	87	89
		700	78.7	75
		800	85.5	83
Aksari	80	600	92.3	90
		700	87.9	80
		800	93	87
Zhasylai	30	600	86.5	76
		700	69.7	60
		800	89.6	86
Zhasylai	60	600	82.5	80
		700	90.9	87
		800	90.5	91.3
Zhasylai	80	600	78.7	75
		700	85.5	83
		800	90.3	90
Row spacing of 30 cm				
Aksari	30	600	86.9	85.6
		700	81	80
		800	84.7	83.2
Aksari	60	600	93	94.5
		700	92.1	92.5
		800	81.9	80.7
Aksari	80	600	82.3	80.3
		700	86.9	85.6
		800	81	79
Zhasylai	30	600	84.7	83.2
		700	89.7	86.5
		800	94.3	94.3
Zhasylai	60	600	81.9	80.7
		700	82.3	80.3
		800	86.9	85.6
Zhasylai	80	600	81	79
		700	84.7	83.2
		800	89.7	86.5

Table 2. Regression analysis of the factors affecting plant height in peas.

Factors	Estimate	Std. Error	t value	Pr (>|t|)
Cultivar Aksari	21.700804	1.881695	11.533	< 2e-16 ***
Cultivar Zhasylai	1.686111	0.392136	4.300	5.67e-05 ***
Fertilizers	0.035329	0.009542	3.702	0.000434 ***
Seeding rate	0.011708	0.002401	4.876	6.98e-06 ***
Row spacing	0.007593	0.026142	0.290	0.772383
Signif. Codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			
Residual standard error	1.664 on 67 degrees of freedom			
Multiple R-squared	0.4555, Adjusted R-squared: 0.423			
F-statistic	14.01 on 4 and 67 DF, p-value: 2.325e-08			

manifested in the variants of Flagship 12 peas: with a lower plant height in the variant with a seeding rate of 1.4 million germinating seeds per 1 ha, the yield of green mass was at the level of 0.6 million germinating seeds per 1 ha with a higher plant height (Voskobulova., 2016; Karabayev *et al.,* 2024).

The regression analysis showed the influence of seed rate, row spacing, and NPK fertilizer on the plant height in pea genotypes (Table 2). The coefficient of determination (Multiple R-squared) was 0.2775, which means approximately 27.75% of the variability in the number of beans reached probing by the agriculture techniques used. The Adjusted R-squared was 0.2344, given the number of predictors in Table 2. Regression analysis data indicated the reliability of the influence of the three factors on the pea cultivar Aksari, however, not on the cultivar Zhasylai. Pea regression analysis usually refers to the use of statistical methods to study the relationships between various variables related to pea plants. In the context of pea research, such an analysis can help identify links between various physiological or genetic characteristics of plants (Ponomareva, 2018).

Examples of regression analysis in pea studies may include analyzing the effect of different fertilizer levels on yield, or investigating the relationship between genetic markers and the expression of certain phenotypic traits. Regression analysis enables understanding of the nature of the relationships in the data, which can be useful for predicting or optimizing pea growing conditions (Ponomareva, 2018).

The fertilizer levels also have a significant (P < 0.001) positive effect on the plant height. As the fertilizer dose increases by one unit, the amount rises by 0.076656 units. Seeding density and row spacing do not have a considerable (P > 0.05) effect on plant height. This analysis considered average seeding rates and row spacing values. Therefore, the regression analysis showed the ineffectiveness of the influence of these factors on the plant height in pea cultivars. In a separate study for the influence of different seeding rates, results revealed at row spacing of 15 cm, the low seed rates influenced the said trait. However, at row spacing of 30 cm, favorable conditions supported the plant height with an increased seeding rate. The cultivar Ataman was inferior to the standard by using ORMISS Cu–B in the OR1 option and with ORMISS Cu–Mo in the OR2 option. In the remaining experimental options, it had indicators at the control level of the standard cultivar (Zhogaleva and Strel’cova, 2021).

Research findings indicated the seeding rate of peas plays a significant role in shaping the crop structure. By increasing the seeding rate, a considerable decline was evident in the number of pods and seeds per pod. Variants with lower seeding rates tend to have more seeds per pod due to better moisture conditions, resulting from sparser plant density. There, the plant population is crucial in determining overall pea yield. Another key productivity measure was the number of pods per plant, as influenced by the genetic makeup of the cultivars under examination. The said trait is also relative and effective for comparisons within samples with similar seed sizes. Past findings revealed the number of pods per plant affects the yield, with weather conditions, particularly drought, during the reproductive stage compared with the vegetative stage, playing a significant role (Amelin *et al*., 2013).

As a result of this research, in cultivar Aksari, the largest number of beans developed using a seed rate of 600,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 80 kg ha^{-1}. For the cultivar Zhasylai, more beans occurred with a seed rate of 800,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 60 kg ha^{-1}. However, fewer beans were evident in the cultivar Aksari with a seed rate of 600,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 30 kg ha^{-1}. Meanwhile, in the cultivar Zhasylai, it was with 700,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 30 kg ha^{-1} (Table 2). The fewer beans per plant emerged with insufficient nutritional area and the highest plant’s competitive ability. According to past research of Strigun (2016), the number of beans per plant in the Parade variety (9.4 = 1.2 pcs.) was greater than the Duet variety (5.6 = 1.3 pcs.). Their average value was 7.4 pcs. (Table 1). The studied trait in the parent varieties had a high level of variability – 42.6% and 48.4%, respectively. According to the number of beans per plant (Table 1), the population F6 (9.5 ± 0.8 pcs.) surpassed both parents. In relation to the average parent, the advantage was 28.4%. At the same time, it was at the level of the best parent (the increase in the number of beans per plant in the population was only 1.3%). The variability of the trait was very high, the coefficient of variation reached 55.6%, which indicates a significant heterogeneity of the initial population (Strigun, 2016).

The beans per plant vary depending on the feeding area. As noted above, the number of seeds per plant increased with an increasing feeding area. In each option with a larger feeding area, a slight decrease in seed productivity occurs. However, when comparing the two studied pea cultivars, the best indicators for the said trait resulted in the cultivar Zhasylai, and this may refer to the genetic makeup of the genotype (Table 3). The regression analysis showed the influence of the three factors on the number of beans. The coefficient of determination (Multiple R-squared) was 0.2775, which means these factors managed approximately 27.75% of the variability in the number of beans. The Adjusted R-squared was 0.2344, given the number of predictors in the model. The F-statistic was 6.435 on the 4 and 67 d.f. with a p-value of 0.0001918 (Table 4). The pea grain yield, as influenced by seeding rate in the steppe zone of the Orenburg Urals, demonstrated the highest number of beans per plant, seeds per bean, and seed mass per plant, observed in 2017 (Voskobulova *et al.,* 2019). This was due to prevailing cool weather throughout the growing season. During the bean formation period, the Samarius variety produced 2.2 to 3.1 beans per plant and 4.1 to 5.1 seeds per bean, with weights ranging from 2.0 to 3.4 g. The Flagship 12 variety yielded 2.0 to 4.1 beans per plant and 3.9 to 4.8 seeds per bean, weighing 1.51 to 4.33 g, respectively.

Furthermore, increasing the seeding rate of peas to 1.2 to 1.4 million germinating seeds per hectare resulted in a reduction in the number of beans per plant, seeds per bean, and grain weight per plant. However, the grain yield per hectare did not exhibit significant variation across the studied years, irrespective of the seeding rate (Voskobulova *et al.,* 2019).

Significance of the coefficients

Regression analysis showed the reliability of the influence of factors on the cultivar Aksari, but not on the Zhasylai. The fertilizer levels have a positive effect ($P < 0.001$) on the number of beans. As the fertilizer dose increases by 1 unit, the amount increases by 0.076656 units. Seeding density and row spacing do not have a significant ($P > 0.05$) effect on the number of beans.

This analysis considered the average seeding rates and row spacing values. Therefore, the regression analysis showed the ineffectiveness of the influence of these factors on the number of beans in pea cultivars. From a separate study for the influence of different seeding rates, this study obtained different results, and with a row spacing of 15 cm, the low seeding rates influenced said trait. Meanwhile, at row spacing of 30 cm, the number of beans per plant showed the best response due to an increased seeding rate. Previous studies reported in F1 hybrid, the leafy morphotype was a dominant trait, and the inheritance of traits plant height and the number of beans per plant was according to the type of over dominance. The number of seeds in a bean and 1000-grain weight had intermediate values between the parental cultivars (Sukhenko *et al*., 2021). For instance, on the number of beans per plant, the genotypes significantly differed, and the cultivar Chishminsky-95 produced 5.3 beans per plant, and cultivar Aksai Usatiy-55 produced 4.7 beans per plant (As = 1.72) (Sukhenko *et al*., 2021).

Seed weight per plant

The seed weight per plant holds a significant value as it directly affected the overall yield of the cultivars. Structural examination of the pea plants revealed the seeding rate remarkably influenced the formation of seed mass per plant, and the number of seeds decreases in

Table 3. The influence of agrotechnological methods on the beans per plant in peas.

Cultivars	Mineral fertilizers	Seeding rate	Beans per plant (pcs.)	
			2022	2023
Row spacing of 15 cm				
Aksari	30	600	19.9	17
		700	19.8	17
		800	24	19
Aksari	60	600	23.8	20
		700	18.3	17
		800	17.1	17
Aksari	80	600	25.9	25.2
		700	21.5	19.7
		800	24.2	20.1
Zhasylai	30	600	16.1	14.3
		700	15.1	13.2
		800	22.5	17
Zhasylai	60	600	18.2	17
		700	19.1	19
		800	29.9	20
Zhasylai	80	600	30.3	17
		700	18.1	17
		800	20.6	28.2
Row spacing of 30 cm				
Aksari	30	600	19	18
		700	17.8	16
		800	20	18
Aksari	60	600	21.2	19
		700	19	16
		800	16.1	16.8
Aksari	80	600	29.9	25.4
		700	22.5	19.5
		800	24.2	22.3
Zhasylai	30	600	15.1	13.5
		700	12.1	13.1
		800	20.5	16
Zhasylai	60	600	16.2	15
		700	18.1	18
		800	27.9	19.6
Zhasylai	80	600	18.3	16.5
		700	19.1	16.7
		800	21.6	19.6

Table 4. Regression analysis of the factors affecting beans per plant in peas.

Factors	Estimate	Std. Error	t value	Pr (>|t|)
Cultivar Aksari	13.520066	3.842143	3.519	0.000784 ***
Cultivar Zhasylai	-1.158333	0.800684	-1.447	0.152649
Fertilizers	0.076656	0.019483	3.934	0.000201 ***
Seeding rate	0.006958	0.004903	1.419	0.160491
Row spacing	-0.132407	0.053379	-2.481	0.015638 *
Signif. codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			
Residual standard error	3.397 on 67 degrees of freedom			
Multiple R-squared	0.2775 Adjusted R-squared: 0.2344			
Adjusted R-squared	0.2344			

denser crop and increases in crop with a lower seeding rate. Environmental factors exert the strongest influence on this trait. The seed weight per plant's inheritance polygenically indicated the involvement of multiple genes in shaping the said trait. Studies conducted on the structure of pea grain yield depending on the seeding rate in the steppe zone of the Orenburg Urals revealed the weight of seeds per plant. As the crops thickened, it also decreased from 2.23 g with a seeding rate of 0.6 million germinating seeds per 1 ha to 1.27 g with a seeding rate of 1.4 million germinating seeds per 1 ha for the Samarius variety, and from 2.28 to 1.34 g for the Flagship 12 variety (Voskobulova *et al.,* 2019).

In the presented study, the maximum seed weight per plant resulted in the cultivar Aksari with a seed rate of 700,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 80 kg ha^{-1}. For the cultivar Zhasylai, it was with 800,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 80 kg ha^{-1}. The minimum seed weight per plant came from the cultivar Aksari with 800,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 60 kg ha^{-1}, and for the cultivar Zhasylai, 700,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 60 kg ha^{-1} (Table 5). The importance of economically valuable traits increases with a rising nutrition feeding area at the reduced seeding rate. Past findings showed the influence of row spacing and reduced seeding rate; mineral fertilizers' application is also crucial, with a positive effect on the studied trait (Dzedaev and Yuldashev*,* 1993). By comparing the pea genotypes, cultivar Zhasylai has more influence on this trait.

The regression analysis exhibited the influence of genotypes, fertilizer doses, sowing density, and row spacing on seed weight per plant. The coefficient of determination (Multiple R-squared) was 0.3426, which means approximately 34.26% of the variation in bean count had these factors' control. The Adjusted R-squared was 0.3033, given the number of predictors in the model. The F-statistic was 8.727 on 4 and 67 d.f., with p-value of 9.872e-06 (Table 6).

Significance of the coefficients

Regression analysis data disclosed the reliability of the influence of factors on the cultivar Aksari, however, not for cultivar Zhasylai. The fertilizer levels have a significant ($P < 0.001$) positive impact on seed weight per plant. As the fertilizer dose increases by 1 unit, the amount increases by 0.007039 units. Seeding density and row spacing do not have a substantial ($P > 0.05$) effect on seed weight per plant. The row spacing negatively affects the seed weight per plant ($P < 0.001$). The row spacing increases by 1 unit, the quantity decreases by 0.038333 units.

The presented analysis comprised average seeding rates and row spacing values. Therefore, the regression analysis displayed the ineffectiveness of the influence of these factors on the seed weight per plant in pea cultivars. In a separate study with the influence of different seeding rates, the results revealed with row spacing of 15 cm the said trait bore influences from low seed sowing rates. With a row spacing of 30 cm, an increased seeding rate has a positive effect on the seed weight per plant. The analysis incorporated average seeding rates and row spacing values. Regression analysis signified these factors had minimal impact on seed weight in pea varieties. In another study focusing on different seeding rates, their findings indicated with 15 cm row spacing, seed weight incurred negative effects from lower seeding rates (Koshelyaev *et al.,* 2018). Conversely, with a 30 cm row spacing, higher seeding rates positively affected seed weight on the plant.

Regression analysis in peas is a statistical method used to explore relationships between various factors that may affect pea yields. Essentially, it allows for identifying which factors, such as, weather conditions, soil type, or fertilizer levels, significantly influence pea yield. The process involves gathering data on independent variables (such as those mentioned) and dependent variables (pea yield), constructing a mathematical model to

Table 5. The influence of agrotechnological methods on the seed weight per plant in peas.

Cultivars	Mineral fertilizers	Seeding rate	Seed weight per plant (g)	
			2022	2023
Row spacing of 15 cm				
Aksari	30	600	3.3	3.6
		700	3.2	3.4
		800	3.7	3.9
Aksari	60	600	3.6	3.7
		700	4.9	4.6
		800	2.5	2.6
Aksari	80	600	4.5	4.7
		700	7.6	8.6
		800	3.5	3.9
Zhasylai	30	600	6.8	7.4
		700	6.5	6.9
		800	6.3	6.8
Zhasylai	60	600	5.9	6.1
		700	4.3	4.6
		800	7.4	8.1
Zhasylai	80	600	6.7	7.8
		700	4.1	4.2
		800	4.8	5.3
Row spacing of 30 cm				
Aksari	30	600	3.9	4.2
		700	4.1	3.9
		800	4.9	5.1
Aksari	60	600	4	4.3
		700	5.1	5.9
		800	2.8	3.3
Aksari	80	600	4.9	4.9
		700	7.9	9.7
		800	4.2	5.3
Zhasylai	30	600	7.2	7.8
		700	6.8	7.1
		800	6.9	7.3
Zhasylai	60	600	6.1	6.9
		700	4.7	5.8
		800	7.8	8.9
Zhasylai	80	600	6.9	8.2
		700	4.8	5.3
		800	5.7	5.9

Table 6. Regression analysis of the factors affecting seed weight per plant in peas.

Residuals	
Min 1Q Median 3Q Max -2.1684 -0.8415 -0.2230 0.6522 4.7149	
Coefficients	
(Intercept)	4.438596 1.612462 2.753 0.0076 **
Cultivar Zhasylai	1.858333 0.336029 5.530 5.7e-07 ***
Fertilizers	0.007039 0.008177 0.861 0.3924
Seeding rate	-0.001667 0.002058 -0.810 0.4208
Row spacing	0.038333 0.022402 1.711 0.0917
Signif. codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Residual standard error	1.426 on 67 degrees of freedom

describe their relationship, and evaluating the extent of each factor's impact on yield. Pea regression analysis can be a useful tool for agricultural research, helping to optimize growing conditions and manage agronomic practices to maximize pea yields (Koshelyaev *et al.,* 2018).

1000-seed weight

The 1000-seed weight is the most essential quantitative trait, vital in genotype yield management. The large-seeded genotypes are most valuable, with a 1000-seed weight exceeding 200 g. The 1000-seed weight also determines the grain size, and a key trait in the production of canned green peas. With increased grain size, the marketability of products decreases, the consumption of seeds for sowing increases, and the reproduction coefficient significantly decreases, causing higher prices for the products. Therefore, cultivars with the 1000-seed weight of 200–220 g are mainly superior for freezing. The "mass of 1000 seeds" attribute determines the grain size and is key in producing canned "green peas." With an increase in grain size, the marketability of products decreases, the consumption of seeds for sowing increases, the reproduction coefficient notably declines, raising the cost of products. Therefore, varieties with a mass of 1000 seeds of 200–220 g excelled mainly for freezing. The canning industry currently uses varieties characterized by average grain sizes (7–10 mm) and a mass of 1000 seeds less than 200 g, and varieties with a mass of 100–140 g are promising (Kotlyar *et al.,* 2018).

For producing canned green peas, the industry currently uses cultivars characterized by the average grain size (7–10 mm) and a 1000-seed weight of less than 200 g; the pea cultivars with a 1000-seed weight of 100–140 g are promising. Grain size is critical in determining the overall productivity of the plant. The 1000-seed weight also depended upon the varietal characteristics and environmental factors. Past studies enunciated 1000-seed weight of pea cultivars varied over the years of research due to weather conditions and by using mineral fertilizers (Amelin *et al*., 2013).

The result of this research obtained the cultivar Aksari with the highest 1000-seed weight (200 g) at a seeding rate of 700,000 seeds ha^{-1}, row spacing of 30 cm, and NPK at 60 kg ha^{-1}. Likewise, the same occurred for cultivar Zhasylai with a seed rate of 600,000 seeds ha^{-1}, row spacing of 30 cm, and NPK 60 at kg ha^{-1}. The lowest 1000-seed weight (150 g and below) resulted in the cultivar Aksari with integration of 600,000 seeds ha^{-1}, row spacing of 15 cm, and NPK at 30 kg ha^{-1}, and similar integrations in cultivar Zhasylai, except NPK at 60 kg ha^{-1}. However, the negative value was evident for 1000-seed weight due to a lack of nutritional area, solar energy, and seeding density (Table 7). In seed crops, the agriculture techniques should help increase the 1000-seed weight. In Kotlyar's studies on seed crop cultivation, the agricultural practices should aim to enhance the weight of 1000 seeds. Based on his research, we found prolonged application of mineral fertilizers increases the content of macronutrients in the main products of peas (Kotlyar *et al.,* 2018).

The regression analysis showed the influence of pea genotypes, fertilizer doses, sowing density, and row spacing on the 1000-seed weight. The coefficient of determination (Multiple R-squared) was 0.2775, which means these factors administered the variability of approximately 27.75% in 1000-seed weight. The Adjusted R-squared was 0.2344, given the number of predictors in the model. The F-statistic was 16.54 on 4 and 67 d. f., with p-value of 1.786e-09 (Table 8). The 1000-seed weight varied over the years of the experiments. The heaviest seeds developed in 2000, when sowing transpired from May 17 to 24, and the 1000-seed weight ranged from 287.1 to 344.9 g. One of the reasons for obtaining larger pea seeds was precipitation that fell during the filling of beans. On average over three years, the 1000-seed weight was the maximum when sowing began on May 17. In the experiment with seeding rates, the variant with a rate of 1.0 million units/ha, sown from May 3 to 17, stood out (Sardana *et al*., 2007; Korepanova *et al*., 2018).

Table 7. The influence of agrotechnological methods on the 1000-seed weight in peas.

Cultivars	Mineral fertilizers	Seeding rate	1000-seed weight (g)	
			2022	2023
Row spacing of 15 cm				
Aksari	30	600	180	183
		700	187	192
		800	192	196
Aksari	60	600	146	156
		700	167	179
		800	171	189
Aksari	80	600	187	189
		700	169	172
		800	172	176
Zhasylai	30	600	189	213
		700	193	215
		800	190	200
Zhasylai	60	600	180	189
		700	185	187
		800	195	198
Zhasylai	80	600	180	199
		700	190	191
		800	197	200
Row spacing of 30 cm				
Aksari	30	600	182	185
		700	189	195
		800	190	194
Aksari	60	600	148	163
		700	173	172
		800	168	181
Aksari	80	600	178	179
		700	165	165
		800	169	166
Zhasylai	30	600	187	200
		700	189	202
		800	188	199
Zhasylai	60	600	185	198
		700	176	189
		800	189	190
Zhasylai	80	600	190	195
		700	193	189
		800	198	190

Table 8. The regression analysis of the factors affecting 1000-seed weight in peas.

Residuals	
Min 1Q Median 3Q Max -29.9189 -6.0362 0.1678 7.6387 18.0680	
Coefficients	
(Intercept)	179.87939 11.22547 16.024 < 2e-16 ***
Cultivar Zhasylai	16.83333 2.33933 7.196 6.75e-10 ***
Fertilizers	-0.19101 0.05692 -3.356 0.00131 **
Seeding rate	0.01750 0.01433 1.222 0.22614
Row spacing	-0.20000 0.15596 -1.282 0.20412
Signif. codes	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Significance of the coefficients

Regression analysis demonstrated the reliability of the influence of factors on the pea cultivar Aksari, but not for Zhasylai. The fertilizer levels have a significant ($P < 0.001$) positive effect on the 1000-seed weight. However, by increasing fertilizer dose by 1 unit, the amount increases by 0.076656 units. Seeding density and row spacing do not have a significant ($P > 0.05$) effect on the 1000-seed weight. The row spacing negatively ($P < 0.001$) affects the 1000-seed weight. Past research revealed distance between the rows negatively ($P < 0.001$) modifies the weight of 1000 seeds. By increasing the distance between rows by 1 unit, the number of seeds decreases by 0.132407 units (Singh *et al*., 2015; Koshelyaev *et al.,* 2018).

CONCLUSIONS

The results based on the influence of agrotechnological methods on economically valuable traits of two pea (*P. sativum* L.) cultivars revealed significantly varied values for plant height, beans, and seeds per plant, and 1000-seed weight under irrigated conditions in the South-East of Kazakhstan.

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