

The role of moisture conditions in the formation of yield and responsiveness of *Lens culinaris* (L.) to phosphate fertilizers

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Abstract

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The main obstacles in obtaining consistently high and high-quality crops of *Lens culinaris* (L.) in Kazakhstan are the lack of moisture, low richness of soils with available elements of nutrients. The use of mineral fertilizers for *Lens culinaris* (L.) in the conditions of Northern Kazakhstan has not been studied yet. In our studies, the yield of different varieties of *Lens culinaris* (L.) in the dry-steppe zone has been estimated with different provision of soils with elements of nutrients for two years. Small-seeded varieties of Krapinka and Viceroy *Lens culinaris* (L.) were compared under various vegetation conditions, their responsiveness to growing conditions, the use of phosphorus fertilizers, yield and quality indicators. The results of the study showed that the lack of moisture during the vegetation period in 2019 negatively affected the yield of *Lens culinaris* (L.) and the effectiveness of the use of phosphate fertilizers, reduced the yield of both varieties by 6-8 times compared to 2018, up to 2-4 dt/ha. From the use of phosphorus fertilizers in doses of P₁₂₀₋₁₅₀ with the content of available phosphorus 11-15 mg/kg under control, the yield of *Lens culinaris* (L.) of both varieties and the quality of products increased. It is noted that the variety of Viceroy *Lens culinaris* (L.) produced a higher yield than the variety of Krapinka *Lens culinaris* (L.). This is a biological feature of the variety and is confirmed by a large number of beans and seeds on natural and fertilized backgrounds. The trend of increasing yields and improving the quality indicators of products on fertilized backgrounds was in a favorable year and preserved in the dry season, which indicates the positive effect of improving the background of phosphorus nutrition. The studies have shown that *Lens culinaris* (L.) are very sensitive to moisture conditions. A favorable moisture-related year of receiving Krapinka – 5.6 dt/ha and Viceroy – 9.8 dt/ha brought in a good increase in the yield as a result of the use of phosphate fertilizers. During the research years, the optimal levels of provision of soil with available phosphorus for these varieties were in the range 25-30 mg/kg of soil.

Keywords: moisture conditions; phosphorus nutrition; *Lens culinaris* (L.); phosphate fertilizers; yield

Introduction

Artificial agrocenosis is inherently unstable and is supported only by human intervention. (Gureev, 2020). However, we have been dealing with the predominance of monoculture crops of wheat for many years, which negatively affects the biodiversity of the area and leads to a decrease in soil fertility.

From the moment when Kazakhstan gained independence in 1991, in the structure of sown areas, the share of legumes, fodder, cereals, oilseeds was reduced, which led to the monopoly of wheat in the structure of sown areas, the share of legumes, fodder, cereals, oilseeds was reduced, which led to the monopoly of wheat. This required an urgent restructuring of cropland, reducing the share of wheat and increasing the share of other crops in demand. In this term, “Agribusiness-2020” program was launched in 2013 aimed at diversifying grain production in Kazakhstan (Adilet, 2013). The continuation of this idea is reflected in the new concept of development of the Agro-Industrial Complex in the Republic of Kazakhstan for 2021-30 (Legalacts, 2021).

However, the share of wheat in the structure of crops in Northern Kazakhstan is still high – 10.6 mln ha or 85%, at the same time, the area of cultivation of legumes does not exceed 400 thousand ha, *Lens culinaris* (L.) – 61 thousand ha (Statgov, 2021).

One of the alternatives for the diversification of grain production is *Lens culinaris* (L.).

1. *Lens culinaris* (L.) is a high protein crop (21-31%) (Adsule et al., 1989).

2. It provides with high income (the purchase price in autumn 2021 was 380 thousand tenge/t or 870 USA dollar/t) (Eldala, 2021).

3. *Lens culinaris* (L.) enter into a symbiotic relationship with nodule bacteria that capture atmospheric nitrogen and fix it in the soil (Humphrey et al., 2001).

4. Due to its property not to accumulate harmful substances (nitrates, radionuclides, etc.), *Lens culinaris* (L.) grows anywhere in the world and an organic food (Khalvaloyes, 2016).

5. The need to provide the country’s food security in harsh climatic conditions and more efficient use of cropland requires the introduction of new cost-effective crops and technologies in agricultural production, diversification of the existing structure of cropland which makes *Lens culinaris* (L.) a very popular crop.

Provision of a constant and high export potential requires obtaining high and high-quality crops. However, the problem of increasing the yield of *Lens culinaris* (L.) cannot be solved without the use of mineral, namely phosphate fertilizers.

In conditions of a widespread decrease in soil fertility, the use of mineral fertilizers is of crucial importance. Taking into account the fact that the vast majority of soils in Kazakhstan had (Rylushkin et al., 1977) and still has low and very low availability of mobile phosphorus and nitrogen (Eldala, 2020), the significance of research data for Kazakhstan and regions with similar soil and climatic conditions is immense.

In a number of studies conducted in different geographical conditions, the use of mineral fertilizers on the yield and quality of *Lens culinaris* (L.) resulted in positive effects. The positive effect of phosphate fertilizers is particularly discerned. In relation to that, the research by Kuznetsov I. S. conducted on leached chernozems in determining the dependence of the yield and quality of *Lens culinaris* (L.) on the background of mineral nutrition showed a positive effect of phosphorus fertilizers of P₆₀ and P₆₀K₆₀ doses. Against these backgrounds, the best yield for 3 years was (2001-2003) 24.9 and 25.1 dt/ha and quality 25% of protein (Kuznetsov, 2006). Similar research results were obtained in Canada (Ali-Khan & Kiehn, 1989), Pakistan (Zafar et al., 2003), Egypt (Zeidan, 2007), on leached chernozems in Penza (Karpova, 2010) and foothill zone of the Kabardino-Balkaria Republic (Kononenko et al., 2013).

Along with mineral nutrition, the main factor limiting the yield of *Lens culinaris* (L.) is the lack of moisture. Lack of moisture and high temperatures cause accelerated development of plants (Shrestha et al., 2006). This leads to a reduction of the vegetation period and the yield of *Lens culinaris* (L.) (Shrestha et al., 2009).

Unfortunately, in the abovementioned studies, the characteristics of the experimental sites differ, and the results vary, which indicate a large number of factors affecting the effect of fertilizers and the formation of *Lens culinaris* (L.) yields. This circumstance does not allow to fully apply the results of these studies in the dry-steppe conditions of Northern Kazakhstan.

Agrotechnical factors in the formation of *Lens culinaris* (L.) yields, such as standards, terms (Musynov et al., 2017), sowing depth and cultivation technology (Grintets, 2018) have been studied in Kazakhstan.

However, the issues of mineral nutrition of *Lens culinaris* (L.) and responsiveness to phosphorus fertilizers on dark chestnut soils of the dry steppe zone of Northern Kazakhstan have not been studied yet. In this regard, the aims were defined as follows: (1) to determine the effectiveness of the use of phosphorous fertilizers on the formation of yields and the quality of seed products of *Lens culinaris* (L.), depending on the moisture conditions; (2) to identify the differences in the requirement for phosphorus nutrition of *Lens culinaris* (L.) varieties, ensuring the formation of maximum yield.

Materials and Methods

The Design of the Experiment

The research was conducted in 2018 – 2019 in Tselinograd, Akmola Region, JSC “Organic Farm Aktyk”, located in the dry steppe zone of Northern Kazakhstan 30 km southwest of Nur-Sultan city, the laboratory analyzes were carried out in the agrochemical laboratory of the Soil Science and Agrochemistry Department of S.Seifullin Kazakh Agrotechnical University, Nur-Sultan, Kazakhstan. The agroclimatic zone for the research is slightly humid, moderately dry with $\sum t_{10^{\circ}}=2200-2500^{\circ}\text{C}$ (Baysholanov, 2018).

The soil of the place for conducting the experiment is dark chestnut calcareous, light clayey with humus content 2.9-2.95%, gross nitrogen 0.17%, phosphorus 0.15%, Ca+Mg 22-25 mg equal/100 g of soil, pH slightly alkaline (8.08-8.12).

The experiment was conducted in 3-fold repetition, the size of one plot 2.5 m x 21 m or 52.5 m². Scheme of the experience:

- (without fertilizers);
- P₆₀;
- P₉₀;
- P₁₂₀;
- P₁₅₀.

Brief Description of Varieties

Two varieties of *Lens culinaris* (L.) were studied: Krapinka and Viceroy.

Krapinka. Subvariety *microsperma* Bar. Subtype *var. Atrogrisea*. The weight of 1000 seeds ranges from 39 up to 43 g, the content of protein varies from 26.11 up to 29.52%. It is a variety of early ripening type. The duration of the period from sprouting to ripening varies from 70 up to 110 days. The damage by pests is insignificant. The susceptibility to ascochytosis and fusarium wilt is average. The variety was received in A. I. Barayev Research and Production Center of Grain Farming, Kazakhstan (RPCGF, 2015).

Viceroy. The weight of 1000 seeds is 25-35 g. The variety is considered mid-season, the seeds ripen within 76-80 days, after ripening the seeds become smooth, the green color is preserved. *Lens culinaris* (L.) of this variety are distinguished by high trade and culinary qualities. Plants are resistant to diseases, lodging, drought and shedding. The variety was received in Canada (CFIA).

Agrotechnics of the conducted experiment

Predecessor – wheat II and III crop after fallow. Before fertilization, after harvesting deep tillage was carried out to a depth of 22-25 cm in autumn (mid-October) (ИПГ-3-5 (Russia)),

the plot was harrowed (Pallada 3300 (Ukraine)), only after that fertilized backgrounds were created with the use of ammophos Grade B (11% N, 46% P₂O₅, Kazakhstan) with a seeder C3C-2.1 (Russia) to a depth of 12-15 cm. Sowing was carried out at the rate of 2.2 million germinating seeds/ha in the second half of May with seeder C3C-2.1 (Russia) to a depth of 5-7 cm. Plant protection products were not used before sowing and during the vegetation period. Harvest accounting was carried out from the beginning to the middle of August by collecting sheaves from 1m² in 6-fold repetitions, followed by threshing in thresher Wintersteiger LD 180 (Austria). The applied agrotechnical measures were adopted for the arid steppe zone.

Studies of Soil

Soil samples were taken to study the agrochemical properties of the soil and the effect of fertilizers on them SS (State Standard 17.4.4.02-84) to a depth of 40 cm on control and fertilized variants. To determine the dynamics of changes in soil moisture in the main phases of growth – shoots, branching, flowering, soil samples were taken from the control variant to a depth of 1 m. Soil sampling was carried out with a soil drill with a core diameter of 5 cm. Soil samples were crushed to pass through a 1 mm sieve, and for analysis to determine organic matter to 0.25 mm.

In soil samples, soil moisture was determined by the weight method SS (State Standard 28268-89). The soil was dried at 105°C up to a constant weight, and the percentage and weight difference was determined.

Nitrate-nitrogen in the soil was determined in the 0-40 cm layer. The 0-40 cm layer is diagnostic for nitrogen in our zone (Chernenok, 1997). The determination of the content of nitrate nitrogen was carried out on a nitrate analyzer 150.1 MI (Microprocessor Ion meter) (Russia) SS (State Standard 26951-86) by ion-selective method.

Mobile phosphorus was identified by Machigin's method SS (State Standard 26205-91). This method is similar to Olsen's method. A number of scientists note that the main difference in extracting solutions and interpretation of the obtained results, since data obtained on the same soil vary greatly when determined by two different methods, but the class of provision remains the same. 1% (NH₄)₂CO₃ with pH 9.0 is used by Machigin's method, NH₄F+HCl with pH 8.5 by Olsen's method (Christenco & Ivanova, 2011; Byryukova et al., 2014).

Mobile forms of potassium were determined from one soil extract for phosphorus, received by Machigin's method SS (State Standard 26205-91), on a flaming photometer (MBW-PX (Great Britain) when burned in a propane-air gas mixture.

Humus (organic matter) was determined by modified method of Tyurin Central Institute of Agrochemistry Service SS (State Standard 26213-91), and the sum of absorbed bases Ca+Mg by trilonometric method SS (State Standard 46-52-76), pH from water-salt (KCl) extract SS (State Standard 26483-85).

The Studies of Seeds

The analysis of the chemical composition of *Lens culinaris* (L.) seeds was carried out according to the accelerated method for determining nitrogen, phosphorus and potassium from one sample by Pinevich (Mudrykh & Aleshyn, 2011). It is based on wet incineration of the seed sample by adding concentrated sulfuric acid and 30% hydrogen peroxide and determination in an already diluted and precipitated suspension of nitrogen, phosphorus, potassium. Nitrogen in the seeds was determined by measuring the optical density of the suspension with a yellow light filter $\lambda = 440$ nm on device CPhPh-3-01 (Concentration photoelectric photometer (Russia) by adding Nessler's reagent. Phosphorus was determined by measuring the optical density of the suspension with a blue light filter $\lambda = 710$ nm on device CPhPh-3-01 (Concentration photoelectric photometer (Russia) with the addition of coloring reagents 2.5% ammonium molybdate and 1% 2-aqueous stannous chloride. Potassium was determined on a flame photometer (MBW-PX (Great Britain)) when burned in a propane-air gas mixture. The obtained values of nitrogen, phosphorus, potassium on the basis of the calibration curve were converted into %.

Statistical analysis

Mathematical data processing was carried out according to the method by Dospekhov B. A. in Excel Programme 2013, using functions of data analysis. Typical deviations were determined, correlation graphs of dependence of the yield of *Lens culinaris* (L.) and the presence of phosphorus in the soil were drawn, and the $LSD_{0,95}$ of the yield was measured (Dospekhov, 1985).

Results and Discussion

Climatic conditions

Hydrothermal conditions during the years of study were different. In terms of amount of precipitation, 2018 was favorable, 2019 was hyperarid. The total amount of precipitation was 330.1 mm in 2018, 209.2 mm in 2019, for comparison, the average multiyear norm is 326.0 mm.

Precipitation in the autumn-winter-spring period (September-March) was higher than the multiyear norm in 2018 – 156 mm (+15 mm), 2019 – 145.3 mm (+4.3 mm), which

made it possible to form a good supply of productive moisture in the soil by the beginning of spring field work.

The distribution of precipitation during the vegetation period was uneven. So in 2018, the precipitation in the warm period was within and above the norm, except July, when half of the norm of precipitation fell (-25.9 mm). Vegetation period of 2019 was characterized by extremely low amount of precipitation (26% of the norm). It was also noted that a significant part of the precipitation of the summer period fell on June (Figure 1).

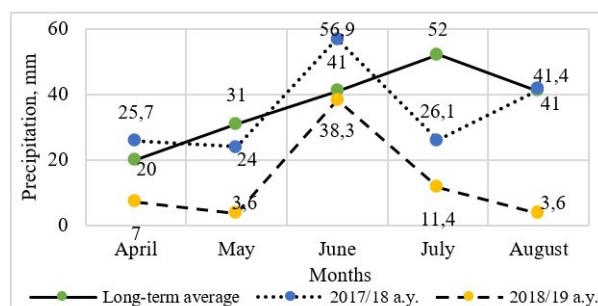


Fig. 1. The distribution of precipitation during the vegetation period of 2018 and 2019 agricultural years

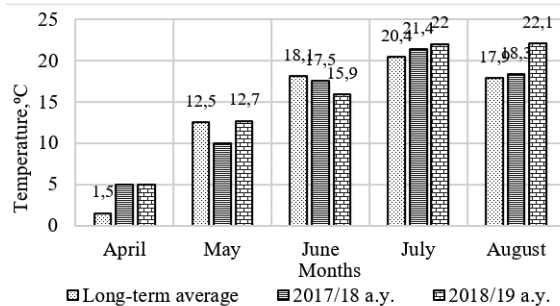


Fig. 2. Average monthly temperature background of the vegetation period of 2018 and 2019 agricultural years

The uneven distribution of precipitation during the warm period was accompanied by an increased temperature background (Figure 2).

In April 2018 and 2019, the average air temperature was above normal by 3.5°C. Low average temperature in May – 10.0°C was recorded in 2018, it was at level of multiyear annual average temperature in 2019. The temperature in June was below normal. In other summer months, the temperature was higher than the multiyear norm, by 1.0°C in July and 1.6°C, by 0.4°C and 4.2°C in August, correspondingly.

Productive Moisture Reserve

The established hydrothermal conditions during the years of research influenced the accumulation and dynamics of productive moisture (Table 1).

Good moisture reserves (according to the gradation by Vadyunina (1986) before sowing *Lens culinaris* (L.) were formed due to the precipitation in the autumn-winter-spring period: in 2018 – 155.2 mm, in 2019 – 148.3 mm in a meter layer of soil. The subsequent decrease in moisture reserves in the upper horizons was due to the consumption by plants and evaporation.

2019 was hyperarid. A sharp increase in temperature from the second decade of June and the complete absence of precipitation led to a rapid consumption of moisture and reduced its reserve to 4.9 mm in the layer 0-40 cm and 55.7 mm in a layer of 0-100 cm to the flowering phase, which is unsatisfactory (Vadyunina, 1986). These moisture reserves were insufficient for the further development of plants.

Agrochemical properties of soils

Significant differences in the content of mineral forms of nutrients were observed in the soil. Nitrate-nitrogen was the main source of nitrogen nutrition. Its content, depending on the year of the study before sowing, varied from 7.6 up to 9.3 mg/kg of soil, which is in the range of average provision (Chernenok, 1997) (Table 2).

Due to the presence of ammonium nitrogen Grade B in amophos (10-11% NH₃, 46% P₂O₅) and the nitrification process, which contributed to the conversion of NH₃ to NO₃ (Mineev, 2006), the content of nitrate-nitrogen rose from 7.6 up to 12.8 mg/kg, thus, an average (8-12 mg/kg) and increased (12-15 mg/kg) backgrounds of nitrogen provision was created (Chernenok, 1997).

The lack of available phosphorus in the soil after the lack of moisture is the main factor limiting the yield of *Lens culinaris* (L.) in the conditions of the dry steppe (dark chestnut soil) zone of North Kazakhstan. The provision of soils with a natural background, phosphorus, was at a very low level. (10.3-12.8 mg/kg). Using 5 different doses of phosphorus fertilizers, backgrounds of provision with phosphorus were created as follows: low (15-25 mg/kg), average (25-35 mg/kg) and increased (over 35 mg/kg P₂O₅) (Chernenok, 2009).

The use of phosphorus fertilizers did not affect the potassium content in the soil. The content of K₂O was over 800 mg/kg in 2018 and over 900 mg/kg in 2019, which is considered of a very high provision by Machigin's gradation (Yakimenko, 2003).

Levels of provision were reflected in the yield of *Lens culinaris* (L.).

Yield of *Lens culinaris* (L.)

Yield is a result of cooperation between plant and envi-

Table 1. The content and dynamics of productive moisture during the vegetation period of 2018 and 2019 agricultural years

Soil layer, cm	2018 year			2019 year		
	before sowing	branching	bloom	before sowing	branching	bloom
0-20	29.5±1.8	11.8±0.1	11.4±0.5	28.4±1.1	17.7±0.4	1.2±0.02
20-40	35.1±0.4	19.8±0.6	19.5±1.2	34.8±0.9	24.7±1.3	3.7±0.07
40-60	32.7±1.0	26.6±1.2	23.9±0.8	32.4±1.4	30.0±2.2	15.1±0.2
60-80	31.2±1.8	36.6±2.2	35.1±1.2	27.0±1.6	29.7±0.9	20.3±1.3
80-100	26.7±1.2	25.1±0.2	29.9±1.3	25.7±1.6	28.8±0.8	15.6±0.8
0-100	155.2±6.7	109.4±5.2	115.1±6.5	148.3±7.6	130.9±8.9	55.7±3.6

Table 2. The effect of phosphate fertilizers on the presence of nitrate-nitrogen of in the soil in 0-40 cm layer, mobile phosphorus and potassium in layer 0-20 cm before sowing *Lens culinaris* (L.), mg/kg of soil

Applied, kg a.i./ha	Krapinka						Viceroy					
	N-NO ₃		P ₂ O ₅		K ₂ O		N-NO ₃		P ₂ O ₅		K ₂ O	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
O (without fertilizer)	9.3	8.5	11.1	12.8	840	957	7.6	9.2	10.3	11.8	829	971
P ₆₀	8.8	9.0	16.3	16.9	826	964	8.8	8.4	17.5	16.7	823	965
P ₉₀	9.8	9.3	24.9	19.8	829	969	9.4	10.8	20.5	20.7	880	990
P ₁₂₀	12.1	10.0	27.4	24.8	843	930	9.6	11.9	27.6	23.0	883	963
P ₁₅₀	12.5	10.0	31.3	28.1	822	919	8.4	12.8	35.4	26.8	859	960

Table 3. Yield of *Lens culinaris* (L.) varieties “Krapinka” and «Viceroy» depending on the level of provision of soils with mobile phosphorus in 2018-2019, dt/ha (Tselinograd, Akmola Region)

Applied, kg a.i./ha	Krapinka						Viceroy					
	2018 year			2019 year			2018 year			2019 year		
	productivity, dt/ha	increase in “O”		productivity, dt/ha	increase in “O”		productivity, dt/ha	increase in “O”		productivity, c/ha	increase in “O”	
		dt/ha	%		dt/ha	%		dt/ha	%		dt/ha	%
O (without fertilizer)	11.5±1.1	-	100	1.8±0.1	-	100	15.6±0.6	-	100	2.7±0.1	-	100
P ₆₀	15.1±1.2	3.5	131	2.1±0.1	0.3	117	20.5±0.8	4.9	131	2.9±0.1	0.2	107
P ₉₀	15.2±0.8	3.6	132	2.4±0.1	0.6	130	22.3±0.9	6.7	142	3.4±0.1	0.7	126
P ₁₂₀	17.1±1.3	5.6	148	2.6±0.1	0.8	144	25.4±1.4	9.8	162	3.7±0.1	1.0	137
P ₁₅₀	16.0±1.6	4.5	139	2.5±0.1	0.7	139	25.1±1.7	9.5	160	4.1±0.1	1.4	152
the average	15.0	4.3		2.3	0.6		21.8	7.7		3.4	0.8	
LSD _{0.95}		1.25			0.23			1.73			0.2	
m, %		3.54			3.32			4.91			0.1	

ronmental factors (Pivovarov et al., 2003). Different conditions of moisture, with close indicators of fertility, were crucial in the formation of *Lens culinaris* (L.) yield. The yield of Krapinka *Lens culinaris* (L.) was 6.0-6.5 times higher in favorable moisture-related year of 2018 than hyperarid 2019 (Table 3).

Phosphorus plays an important part in grain formation. It is noted that the increase in the yield of *Lens culinaris* (L.) is linked with a balanced supply of phosphorus and any change in its dose may lead to changes in its yield (Balyan & Singh, 2005).

So, on fertilized backgrounds, the high yield of the Krapinka variety provided by the increase formed from an increase in the content of available phosphorus in the soil. It was obtained against backgrounds with different content of mobile phosphorus in the soil. Against the background P₁₂₀ – 17.1 dt/ha, the yield increase comprised 5.6 dt/ha in 2018 and 2.6 dt/ha in 2019 (+0.8 dt/ha of increase). The content of mobile phosphorus on these backgrounds is 27.4 mg/kg, 24.8 mg/kg.

In a favorable and hyperarid year, Viceroy variety showed a higher responsiveness to phosphorus fertilizers. The highest yield and increase was formed on the backgrounds P₁₂₀, P₁₅₀ with the presence of mobile phosphorus 27.0 mg/kg and 26.8 mg/kg, Table 3.

Research (Yessaulco & Galda, 2016) showed the positive effect of mineral fertilizers on the phosphorus content in the soil and the yield of *Lens culinaris* (L.). By the use of doses P₄₀K₃₀ and N₂₅P₄₅K₁₈ the content of mobile phosphorus increased rose from 26.5 up to 30.0 mg/kg of soil. In addition, Vekhovskaya Zelenaya variety showed the best yield at 30 mg/kg – 20.5 dt/ha and Canadian Red – 17 dt/ha.

In our studies, the maximum yield of *Lens culinaris* (L.) was formed on backgrounds with high doses of phosphorus fertilizers P₁₂₀ and P₁₅₀ with the content of mobile phospho-

rus 25-27 mg/kg. Similar results were achieved in the research (Abid Ali et al., 2017), conducted in Pakistan, where the maximum yield of *Lens culinaris* (L.) was formed on fertilized backgrounds P₁₀₀, P₁₂₀. This is due to the difference in the effectiveness of the use of phosphorus fertilizers, depending on the moisture conditions.

A number of scientists mentioned a high yield on lower backgrounds of P₂₀₋₈₀ (Zeidan, 2007; Datta et al., 2013; Togay & Parsak, 2014; Yumnam et al., 2018; Chaubey et al., 2019; Dona et al., 2019).

It can be concluded from the received results that the moisture factor was the determining factor in the formation of yield. According to the results of 2019, in drought conditions, the availability of nutrients was less significant in the formation of yields. And according to the results of a favorable year of 2018, it was noted that the presence of moisture, on the contrary, allowed plants to take advantage of the nutrients available in the soil and realize their inherent genetic potential.

The Structural Analysis of the Yield

It is noted that the parameters of the subcomponents of seed productivity (the structure of the yield) have a significant impact on the formation of yields in leguminous crops: number of beans per plant, number of seeds per bean, the weight of seeds from one plant and weight of 1000 seeds (Zotikov, 2016).

The varieties have a multidirectional reaction to environmental conditions. The sensitivity of the variety Viceroy to the lack of moisture during the formation of seeds was reflected in the performance of the seeds. Unlike 2018, the decrease in the weight of 1000 seeds of this Viceroy variety comprised 12.9% in the hyperarid year of 2019, and on the contrary, in 2019, an increase by 10% in the weight of 1000 seeds of the Krapinka variety was noted in 2019 against 2018 (Figure 3).

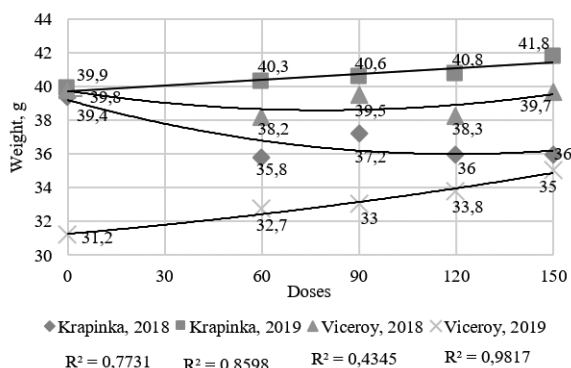


Fig. 3. Influence of moisture conditions and phosphate fertilizers on the weight of 1000 lentil (*Lens culinaris* (L.)) seeds

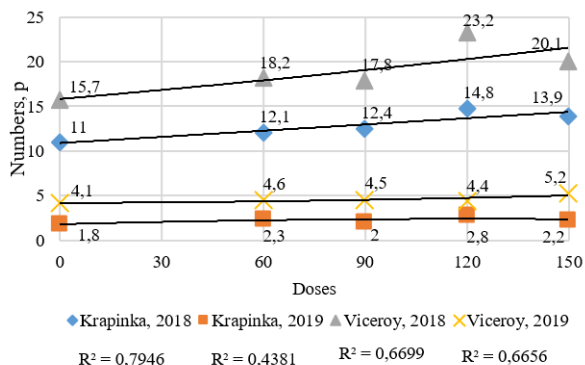


Fig. 4. Influence of moisture conditions and phosphate fertilizers on the number of beans from one lentil (*Lens culinaris* (L.)) plant

Against the background of the use of phosphorus fertilizers, the weight of 1000 *Lens culinaris* (L.) seeds changed less than other structural indicators. Similar conclusions were made in 2013 (Datta et al., 2013), then, against the background of use of fertilizer, an increase in all structural indicators was noticed, except the weight of 1000 seeds.

In 2018, as the content of the available phosphorus in the soil increases for both varieties, the weight of 1000 seeds changed slightly, which may be due to a lack of nutrients (assimilants) for additionally formed seeds. In arid 2019, the weight of 1000 seeds accompanied with the improvement of phosphorous nutrition. It was mentioned (Maqsood et al., 2000), that the apparent effect in increasing the weight of 1000 seeds is linked with the effect of phosphorus on cell division in *Lens culinaris* (L.) seeds and the formation of fats and albumins. A similar effect of phosphorous fertilizers in

increasing the weight of 1000 *Lens culinaris* (L.) seeds was mentioned in the works by Rasheed et al. (2010) and Dogan et al. (2014).

The number of legumes is one of the defining structural indicators of the yield of *Lens culinaris* (L.) (Togay et al., 2008). In our studies, their number varied in accordance with varieties and backgrounds (Figure 4).

Phosphorous fertilizers affect the establishing and formation of more legumes (Maqsood et al., 2000), which was confirmed in our research. Against the background of improved phosphorus nutrition, there was an increase in the number of legumes for both varieties up to 34-45%. Similar results were obtained (Abid Ali et al., 2017; Yunnam et al., 2018).

Viceroy variety was distinguished by a large number of legumes in a favorable year of 2018 with average 19.0 pieces per plant, Krapinka variety – 12.8 pieces. In hyperarid 2019, the number of legumes decreased 5-6 times, but the pattern of their number on fertilized backgrounds was kept and became more noticeable. The number of legumes in Viceroy variety was 2 times more than in Krapinka variety.

With a smaller weight of 1000 seeds, due to the larger number of legumes and seeds, Viceroy variety formed a higher yield than Krapinka variety. The number of seeds from one plant of Viceroy variety was higher by 63% in 2018, by 53% in 2019 Krapinka variety (Figure 5).

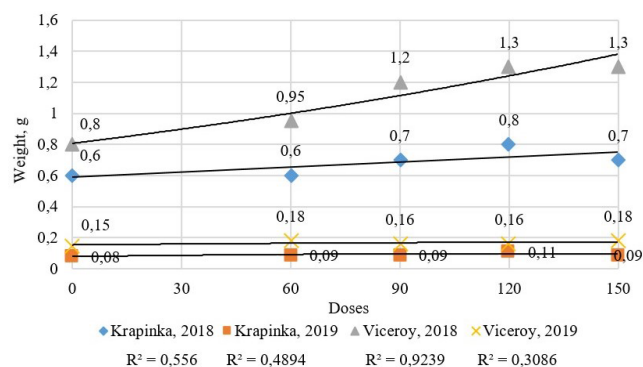


Fig. 5. Influence of moisture conditions and phosphorous fertilizers on the number of seeds from one *Lens culinaris* (L.) plant

In addition, the weight of seeds from one plant differed by 5-10 times for both varieties, depending on the moisture conditions and the background of phosphorus nutrition, which predetermined the formed yield. In the research (by Marakaeva, 2019), revealed a strong positive relationship between yield and seed weight per plant was mentioned ($r=0.80\pm 0.04$) and with the number of legumes from one plant ($r=0.80\pm 0.04$), which is confirmed by our research.

Table 4. The impact of fertilizers on the chemical composition and quality of *Lens culinaris* (L.) seeds, %

Applied, kg a.i./ha	Structural indicators					
	Weight of 1000 seeds, g		Number of beans per plant, pieces		Weight of grains per plant, g	
	2018	2019	2018	2019	2018	2019
Krapinka						
O (without fertilizer)	39.4±0.01	39.9±0.01	11.0±0.5	1.8±0,05	0.6±0.01	0.08±0.001
P ₆₀	35.8±0.01	40.3±0.01	12.1±0.6	2.3±0,06	0.6±0.02	0.09±0,001
P ₉₀	37.2±0.1	40.6±0.01	12.4±0.6	2.0±0,05	0.7±0.02	0.09±0.001
P ₁₂₀	36.0±0.06	40.8±0.01	14.8±0.7	2.8±0,07	0.8±0.03	0.11±0.001
P ₁₅₀	36.0±0.01	41.8±0.01	13.9±0.6	2.2±0,05	0.7±0.01	0.09±0.001
the average	36.9±1.5	40.7±0.7	12.8±0.5	2.2±0,37	0.7±0.08	0.09±0.01
Viceroy						
O (without fertilizer)	39.8±0.09	31.2±0.01	15.7±0.5	4.1±0.01	0.8±0.03	0.15±0.01
P ₆₀	38.2±0.01	32.7±0.01	18.2±1.0	4.6±0.01	0.95±0.04	0.18±0.01
P ₉₀	39.5±0.05	33.0±0.01	17.8±0.9	4.5±0.01	1.2±0.01	0.16±0.01
P ₁₂₀	38.3±0.01	33.8±0.01	23.2±1.2	4.4±0.01	1.3±0.07	0.16±0.01
P ₁₅₀	39.7±0.16	35.0±0.01	20.1±1.1	5.2±0.01	1.3±0.05	0.18±0.01
the average	39.1±0.8	33.1±1.4	19.0±2.8	4.6±0.4	1.1±0.2	0.17±0.01

It can be concluded from the abovementioned that the main structural indicators affected the yield, the number of legumes per plant and the number of grains per plant, changed depending on the moisture conditions and the level of phosphorus nutrition.

The Quality of Seeds

Moisture conditions and soil conditions affected the quality of products. Chemical analysis of *Lens culinaris* (L.) seeds showed that the highest content of nutrients in the seeds was in an hyperarid year. Similar conclusions were made by other scientists (Galda & Yessaulco, 2017). In their studies, they say that climatic conditions had a significant impact on the nitrogen content in plants, and in a dry year, its content was the highest, regardless of the background of nutrition, which is confirmed by our studies.

In a favorable year of 2019, on the contrary, a decrease in the content of nutrients in seeds was noticed.

While studying the *Lens culinaris* (L.) genotypes in Washington and Idaho States, the USA, the research showed that the content of elements in *Lens culinaris* (L.) seeds varies depending on the variety (genotype) and conditions of the area (Vandemark et al., 2018). In our research, the difference in the content of nutrients also has a varietal character, which can be seen in (Table 4).

Viceroy variety differed by a high content of nitrogen and protein in *Lens culinaris* (L.) seeds. The content of nitrogen and protein is less in the seeds of Krapinka variety. The improvement of the nutrient background increased the nitrogen content in the seeds up to 0.4, protein by 1.6%.

In this research, the content of phosphorus in seeds is inversely proportional to moisture conditions. The use of phosphorus fertilizers increased the content of phosphorus by 0.2-0.4%, which agrees with the results of studies by other scientists (Galda & Yessaulco, 2017). The content of phosphorus and potassium in *Lens culinaris* (L.) seeds was slightly higher in Krapinka variety – 1.7% and 2.5%, Viceroy variety – 1.6% and 2.4%.

Against the background of the use of phosphorus fertilizers, the potassium content did not change.

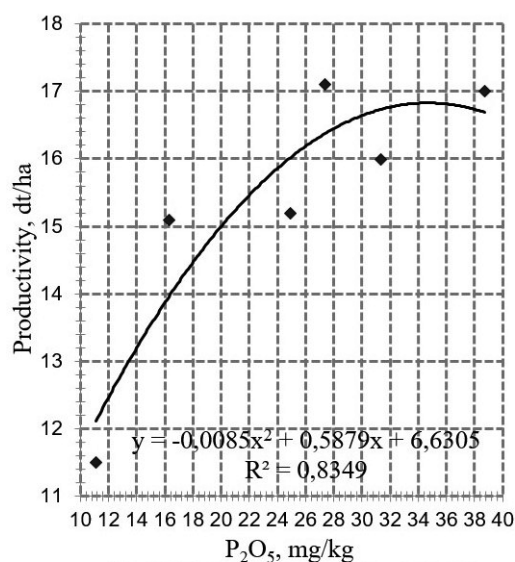


Fig. 6. Relationship between the yield of the lentil variety "Krapinka" and P₂O₅ in the soil, 2018 y., R = 0.91

Correlation analysis

We have established a high correlation between the yield of *Lens culinaris* (L.) and the content of mobile phosphorus in the soil (Figures 6, 7, 8 & 9).

Correlation and regression analysis showed that the optimal levels of mobile phosphorus in the soil for the studied

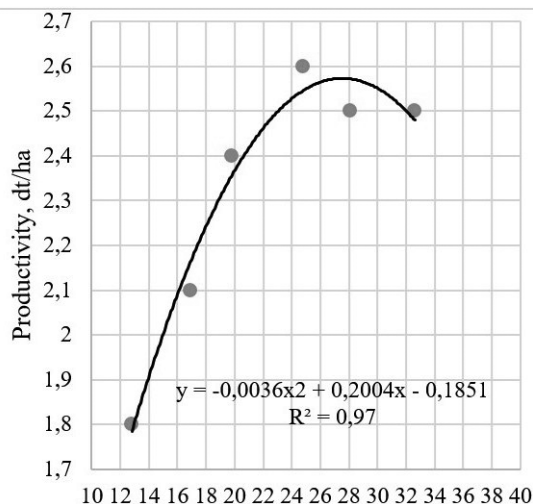


Fig. 7. Relationship between the yield of the lentil variety "Krapinka" and P₂O₅ in the soil, 2019 y., R = 0.98

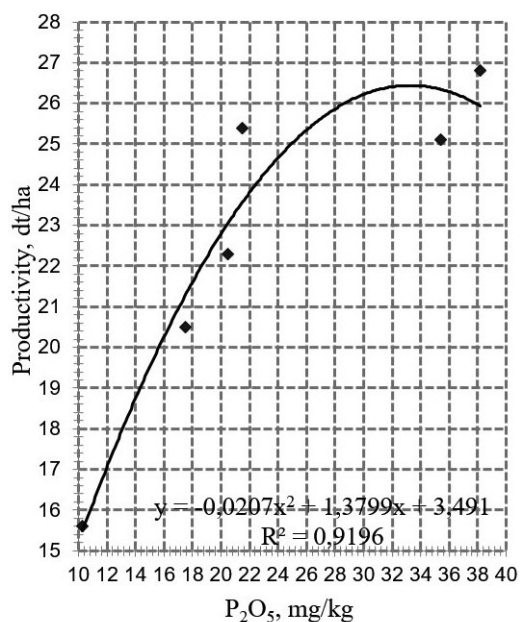


Fig. 8. Relationship between the yield of the lentil variety "Viceroy" and P₂O₅ in the soil, 2018 y., R = 0.96

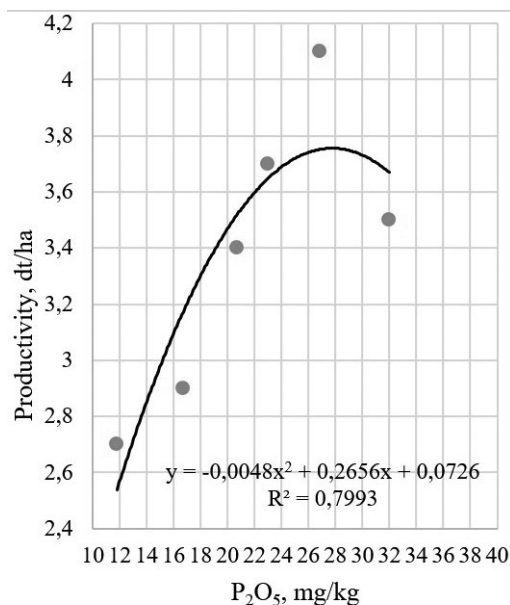


Fig. 9. Relationship between the yield of the lentil variety "Viceroy" and P₂O₅ in the soil, 2019 y., R = 0.89

varieties of *Lens culinaris* (L.) were at the level from 25-30 mg/kg in 0-20 cm layer.

In a hyperarid year, the correlation between the yield of *Lens culinaris* (L.) and the content of phosphorus was at low levels of provision (Figures 7, 9). This is due to the low need for phosphorus in *Lens culinaris* (L.) in conditions of lack of moisture. The high correlation between *Lens culinaris* (L.) yield and low phosphorus levels shows that phosphorus becomes less demanded in a hyperarid year.

In a favorable year, unlike Krapinka variety, Viceroy variety formed a yield against a higher background, which indicates a greater intensity of this variety.

Conclusion

It has been concluded that these varieties of *Lens culinaris* (L.) respond well to the use of phosphorus fertilizers and the improvement of phosphorus nutrition. Against the background of an increase in the applied doses of phosphorus fertilizers and available phosphorus, there was an increase in the yield of *Lens culinaris* (L.) and an improvement in product quality.

The optimal levels of mobile phosphorus can be considered for *Lens culinaris* (L.) varieties Krapinka – 25-27 mg/kg and Viceroy – 28-30 mg/kg.

The research has shown that the dry steppe zone with dark chestnut soils, under favorable moisture conditions, allows you to get a high yield of *Lens culinaris* (L.).

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