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Formation dynamics of biomass of lentil crops depending on the plant density in the steppe zone of Kazakhstan

Nurlan Serekpayev[1], Nurbolat Mukhanov[2], Almas Kurbanbayev[2], Balzhan Akhylbekova[2*]

1. S. Seifullin Kazakh Agro-Technical Research University (KATRU), 62 Zhenis Ave., Astana, Kazakhstan
2. A.I. Baraev Research and Production Center for Grain Farming, 15 Barayev Str., Shortandy District, Akmola Region, Kazakhstan

** Corresponding author's Email: bakhylbekova@mail.ru*

ABSTRACT
The right planting density and the optimal number of seeds introduced during sowing play a crucial role in ensuring the efficient production of lentils. This factor significantly affects the process of culture rooting, the ability of plants to absorb solar radiation, the development of vegetation cover, as well as the level of infection with harmful insects, pests, and diseases. The purpose of this study was to investigate the influence of seeding rates on the formation of plant biomass and yield at different sowing dates. The object of the study was an early-ripening variety of lentils, i.e., Shyraily. One-Way ANOVA was used to study the impact of sowing dates (May 10, May 20, May 30) and seeding rates (1.0 million, 1.3 million, 1.6 million germinating seeds per ha) of lentils on plant biomass and yield. According to the results of two-year studies, the maximum yield of lentil grain was formed when sowing on May 30 and at a seeding rate of 1.3 million germinating seeds per ha – 11.5 c/ha. It was found that the greater the density of the plants, the higher the yield of lentil grain.

Keywords: Lentils, Agrotechnical techniques, Sowing dates, Seeding rate, Sowing methods, Grain yield.
Article type: Research Article.

INTRODUCTION
The lentil, *Lens culinaris* Medik is a legume crop of multiple spheres of use (food, feed, and technical). Agro-climatic, socio-economic, and agrotechnical factors influence the success and acclimatization of the culture (Saikenova *et al.* 2021; Shaimerdenova *et al.* 2022). Lentils are usually grown in the northern regions of Kazakhstan. According to the Bureau of National Statistics, in 2022 the sown area of lentils in the country was 144.3 thousand ha, while in the Akmola region, 26.4 thousand ha. The yield in this region averaged 10 kg/ha. For comparison, in Canada, which is a world producer of lentils, the average yield is 19 c/ha; it falls short of 10 c/ha in Russia. Global climate change, which includes an increase in temperature, a reduction in water resources, a decrease in precipitation, and the expansion of arid zones and deserts, is one of the main environmental problems (Bekezhanov *et al.* 2021). It is an alarming factor that stimulates the search and identification of crops that are highly resistant to drought and heat, as well as the improvement of cultivation technology for regions affected by climate change (Baiseitova *et al.* 2021). Optimal plant standing density and seeding rate are crucial for the cost-effective production of lentils, as they affect the acclimatization rate, radiation absorption, vegetation development, insect, pest, and disease infestation, lodging, and ease of harvesting (Siddique *et al.* 1998a). To create a crop with an optimal density of standing plants means to make those main factors that determine it work for the harvest. As the stem thickens, the total area of the leaves increases, and they absorb more solar energy and use it better in the process of photosynthesis (Nokusheva *et al.* 2023). However, the effectiveness of increasing crop density is not unlimited. There is always a productivity threshold above which an increase in crop density

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ceases to improve the rooting in the long term (Burton *et al.* 2006). Along with the positive effect of thickening, negative phenomena also arise as a result of the growing competition of plants for light, nutrients, and water (Batayneh *et al.* 2022). This can lead to problems such as shading, limited growth, reduced yields, or even competition for limited water and nutrient resources (Baloch *et al.* 2002; Grime 2006). Ultimately, the greatest yield is obtained at such a density when the product of the indicator of the number of plants per unit area of 1 m^2 by the indicator expressing the average weight of one plant is the maximum. This density is optimal. The purpose of this study was to investigate the influence of seeding rates on the formation of plant biomass and yield at different sowing dates.

MATERIAL AND METHODS

Experimental design

Location: southern carbonate chernozems of the Akmola region, located in the station of the Research and Production Center for Grain Farming named after A.I. Baraev, Shortandy (51°38'03.2" N, 71°01'55.0" E). The experiments were conducted in 2021-2022.

Object: an early-ripening variety of lentils, i.e., Shyraily, recommended for cultivation in this region. The plant is medium-sized, the blooms are large and white, a vane with purple veins, and 1-2 flowered peduncles. The beans are cylindrical, medium-sized with a pointed tip, mainly two-seed. The resistance to cracking of beans is average. Experiments on the study of the timing of sowing and the seeding rate of lentil seeds were conducted in three-fold repetition. The area of one experimental plot was 100 m^2, with an accounting area of 100 m^2. The placement of variants in the experiments was systematic with a consistent arrangement in repetition by timing and by seeding rates (Table 1).

Table 1. Experimental design

Sowing period	Seeding rate, mln. of germinating seeds/ha (seeds/m^2)
May 10	1.0 (100)
	1.3 (130)
	1.6 (160)
May 20	1.0 (100)
	1.3 (130)
	1.6 (160)
May 30	1.0 (100)
	1.3 (130)
	1.6 (160)

Agrotechnics

Lentils were sown using pure mechanical ley. Pure ley was prepared according to the recommended technology for the steppe zone of Northern Kazakhstan. Four treatments with plane-cutting tools were carried out during the frost-free period. The first, second, and third treatments were carried out with the MTZ-82 + KPSh-3 unit to a depth of 6-8 cm (June), 8-10 cm (July), and 10-12 cm (August). The fourth treatment (cold treatment) was carried out with the K-700 + PG-3.5 unit to a depth of 25-27 cm in September. In spring, with the onset of physical ripeness of the soil, pre-sowing treatment was carried out in one step with the John Deere tractor 8 series + spring harrows Kama-15 to a depth of 5-6 cm. Seed etching was carried out with a PS-10 etching machine while using a single-component fungicidal Olymp etcher with a flow rate of 0.6 L/sec. Sowing of lentil seeds was carried out with MTZ-82 + DMC-4000 units (anchor working body) on May 10, May 20, and May 30 with seed sowing rates of 1.0 million (100 seeds/m^2), 1.3 million (130 seeds/m^2), and 1.6 million (160 seeds/m^2) germinating seeds per 1 ha. Lentils ripen unevenly; therefore, harvesting was carried out separately: mowing to the dump when the lower beans ripen by 60-70% and the seeds harden in them followed by selection with grain moisture up to 18%.

Records and observations

An assessment of the conditions of humidification of the vegetation period in areas without irrigation was carried out by calculating the hydrothermal coefficient (HC) according to the method of G.T. Selyaninov once during the vegetation period:

$$HC = r / 0,1 \sum t \quad \textbf{(1)}$$

The following scale was used to assess the HC indicators: >1.6: excessively wet; 1.6-1.3: wet; 1.3-1.0: slightly arid; 1.0-0.7: arid; 0.7-0.4: very arid; and <0.4: dry.
The determination of productive moisture reserves in the soil was carried out using the thermostatic-weight method on 10-cm soil layers to a depth of 1 m in the main phases of lentil growth, i.e., shoots, branching, and flowering. Soil sampling was carried out with a special needle drill, plunging it into the soil to a predetermined depth. The drill was removed by turning 1-2 times clockwise, and the soil in its cavity was placed in a pre-weighed cup, which was quickly closed with a lid and weighed. Then the lids were opened in the laboratory, the cups with soil were placed in a drying cabinet and dried to a constant mass at a temperature of 105 °C. For the first time, the soil was weighed after 6 h of drying, for which the cups with soil were removed from the drying cabinet with tongs, closed with lids, and placed in a desiccator with $CaC1_2$ for cooling. When the cups cooled to room temperature, they were weighed, and then the lids were opened and placed in a drying cabinet for control drying. They were again removed from the cabinet after 1-2 h and were weighed after cooling. The differences in weight after repeated drying should not exceed 0.05 g. When a constant mass was established, weighing was stopped, and the cups were freed from the soil. Soil moisture was determined using the following formula:

$$W = \frac{(m_1 - m_2) \times 100}{(m_2 - m_0)}, \% \quad \textbf{(2)}$$

where W is the soil moisture in % of the mass of absolutely dry soil; m_0 is the mass of the aluminum cup (g); m1 is the mass of the cup with soil before drying (g); m_2 is the mass of the cup with dry soil after drying (g). Reserves of productive moisture (RPM per mm), were calculated according to the formula:

$$W = 0.1\, qh\, (u - k) \quad \textbf{(3)}$$

where W is RPM (in mm of water layer), q is the volume mass of the soil (g cm^{-3}), h is the soil layer (cm) in which RPM is determined, u is the humidity of absolutely dry soil (in %), k is the humidity of stable wilting (in %), and 0.1 is the coefficient for converting rpm into mm of the water layer. RPM is determined in each 10-cm layer of soil and the uppermost – and at a depth of 5 cm. The calculation was performed in layers, and then the data were summarized to estimate reserves in a layer of 100 cm or more capacity. The following scale was used when assessing the RPM in the meter layer of soil: for the arable layer: 0-20 cm, the degree of moisture is good: 40 mm or more; satisfactory: 20-40 mm; unsatisfactory: 20 mm or less; for the layer 0-100 cm, the degree of moisture is high: 160 mm or more; good: 160-130 mm; satisfactory: 130-90 mm; bad: 90-60 mm; and very bad: 60 and below mm. Phenological observations and records of the phases of plant development were carried out according to generally accepted methods of state variety testing of crops. In crops, the beginning of the onset of the phase was marked, when it was observed in 10% and the full phase, i.e., in 75% of the total number of plants. According to the growth phases, plants were selected for biometric measurements, namely the height of plants, for which 50 plants were selected for each variant, in three repetitions (Skokbaeva 2002). The structure of the crop was determined before harvesting according to the methods of state variety testing of crops. An average sample of 1 kg of grain/seeds was taken from each plot of an experiment to determine the contamination, the mass of 1,000 grains/ seeds, humidity, and oil content. The harvest from the plots was recalculated to standard humidity and purity (Kumakova *et al.* 2000; Ivanikov 2002).

Statistical analysis

One-Way ANOVA was used to study the impact of sowing dates (May 10, May 20 and May 30) and seeding rates (1.0 million, 1.3 million and 1.6 million germinating seeds per ha) of lentils on plant biomass and yield. To do this, the distributions were first checked for sampling normality using Shapiro-Wilk's test, and the uniformity of variance was determined using Levene's test. The Duncan criterion was used for multiple comparisons. The SPSS 23.0 program was used for the analysis.

RESULTS

Calculations of the hydrothermal coefficient were carried out based on the prevailing temperature regime and the amount of precipitation during the vegetation period was characterized the meteorological conditions of 2021 as dry [HC = 0.4, BP (bioclimatic potential) = 0.54]. The hydrothermal coefficient was 0.5 in 2022 and corresponded to the "very arid" scale, BP = 0.59. The actual temperature in 2021 at the beginning of the lentil branching phase was higher than the average annual indicators, and precipitation fell lower. The temperature was lower in the flowering phase, and precipitation was at the level of long-term indicators. Precipitation fell by 5.8, 1.4, and 4.9 mm lower than mean annual precipitation in the summer months of June, July, and August, respectively. According to the decadal calculation, the maximum amount of precipitation fell in the 3rd decade of July, which exceeded the average annual figures by 24.3 mm.

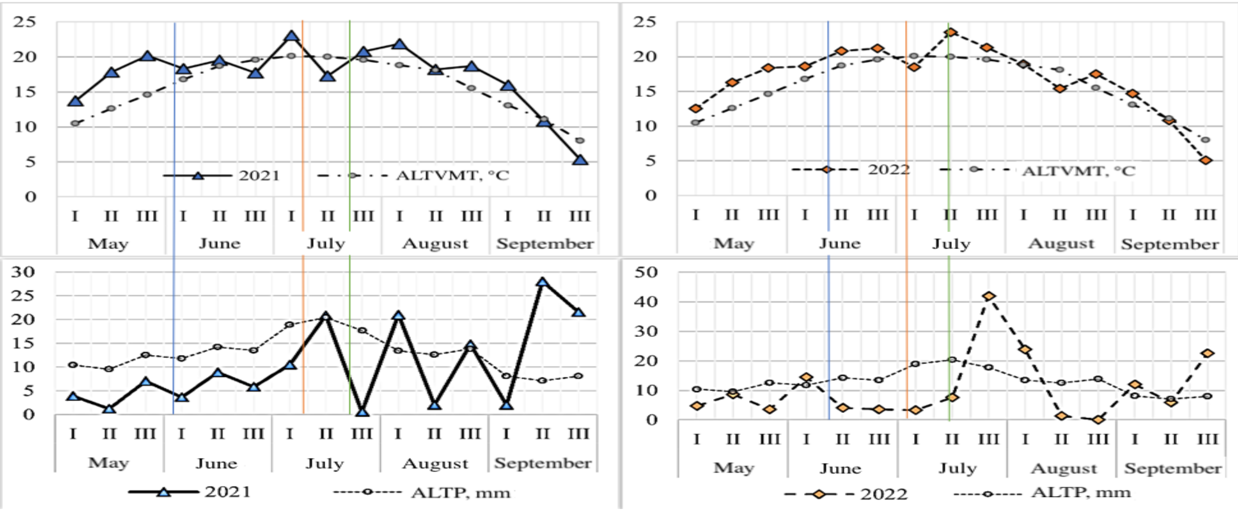

Fig. 1. Weather conditions of 2021 and 2022: a) graphs from above: temperature in comparison with the average long-term values of mean temperatures (ALTVMT); b) graphs from below: the amount of precipitation in comparison with the average long-term precipitation (ALTP). Vertical lines show the range of onset phases of lentil development: blue line: branching, orange: flowering and green: bean formation.

Precipitation was lower compared to the previous year of the study in 2022, in the phase of branching and flowering of lentils (Fig. 1). In 2021, the productive moisture in the layer of soil before sowing lentils at the first (May 10), second (May 20) and third (May 10) sowing periods were 138.3, 159.5 and 149.1 mm. During 2022, it was 125, 130.4 and 101 mm, respectively.

Biomass

The biomass of plants at different seeding rates, depending on the timing of sowing and climatic conditions of the year of the study, ranged from 6.19 to 114.4 g in 2021, while from 3.55 to 102.16 g in 2022. In 2021, on average, the largest biomass was formed at a seeding rate of 100 seeds/m^2 for all periods. In 2022, and also in 2021, when sowing lentils on May 10 and May 20, the largest biomass was observed at a rate of 100 seeds/m^2. However, when sowing on May 30, the maximum biomass was shown by plants with a norm of 160 seeds/m^2 per ha (Table 2). In studies, an increase in the seeding rate led to a drop in plant biomass and also in the safety of plants for harvesting.

Table 2. Indicators of growth, development, and yield of lentils depending on agrotechnical measures.

Experimental options		Field germination		Biomass per phase (g)			Establishment for harvesting plants		Grain yield (c/ha)
Sowing period	Seeding rate (seeds/m^2)	Seeds/m^2	%	Branching	Flowering	Bean formation	Seeds/m^2	%	
				2021					
May 10	100.0	93	92.7	68.0	504.8	792.8	80	86.0	9.7
	130.0	112	86.0	69.3	411.3	769.0	90	80.4	9.7
	160.0	136	85.3	59.1	391.1	702.5	101	74.3	9.8
May 20	100.0	77	77.3	78.5	461.9	1,124.0	55	71.4	5.6
	130.0	119	91.9	62.1	356.4	825.4	81	68.1	6.7
	160.0	149	93.1	54.2	225.2	701.5	102	68.5	7.3
May 30	100.0	64	63.9	112.0	564.7	1,124.5	59	92.2	9.8
	130.0	112	86.0	131.7	510.9	928.4	95	84.8	12.5
	160.0	131	81.6	66.6	282.0	601.6	110	84.0	11.7
				2022					
May 10	100.0	72	72.1	50.7	405.4	1,012.5	60	83.6	6.4

	130.0	108	83.2	54.9	368.9	815.2	82	75.7	7.1
	160.0	137	85.7	37.2	342.4	729.0	95	69.5	7.6
May 20	100.0	82	82.3	59.7	347.0	1,005.0	66	80.5	9.5
	130.0	115	88.5	51.5	309.4	987.5	71	62.1	10.5
	160.0	118	74.0	42.2	254.2	854.2	95	80.5	12.0
May 30	100.0	82	51.5	38.7	260.4	986.5	64	78.4	10.2
	130.0	83	40.1	29.5	238.1	821.5	60	72.5	10.5
	160.0	93	39.2	46.2	244.0	789.5	65	69.8	12.5
Average for 2021-2022									
May 10	100	83	82.4	59.3	455.1	902.7	70	84.8	8.1
	130	110	84.6	62.1	390.1	792.1	86	78.0	8.4
	160	137	85.5	48.1	366.7	715.8	98	71.9	8.7
May 20	100	80	79.8	69.1	404.5	1,064.5	61	76.0	7.6
	130	117	90.2	56.8	332.9	906.5	76	65.1	8.6
	160	134	83.6	48.2	239.7	777.9	98	74.5	9.7
May 30	100	73	57.7	75.3	412.6	1,055.5	62	85.3	10.0
	130	98	63.1	80.6	374.5	875.0	78	78.7	11.5
	160	112	60.4	56.4	263.0	695.6	87	76.9	12.1

On average, during the two years of the study, when sowing lentils on May 10 with a sowing density of 100 seeds per m^2, the establishment of plants for harvesting was 84.8%. It was also 78.0% at 130 seeds/m^{2,} and 71.9% at 160 seeds/m^2. At the time of sowing on May 20, the records were 76.0%, 65.1% and 74.5% at the rates of 100, 130 and 160 seeds/m^2 respectively. The biomass of plants with a seeding rate of 100 seeds/m^2 in the branching, flowering and bean formation phases were 66.1 g, 424.0 g and 1,007.6 g respectively. Plant biomass was higher at a seeding rate of 130 seeds/m^2 compared to the previous seeding rate, by 5.4 g in the branching phase, 70.0 g lower in the flowering phase, and 149.7 g in the bean formation phase. At the maximum seeding rate of 160 seeds/m^2, the biomass of plants was even lower, amounting to 50.9 g, 289.8 g and 729.7 g in the branching, flowering and bean formation phases respectively.

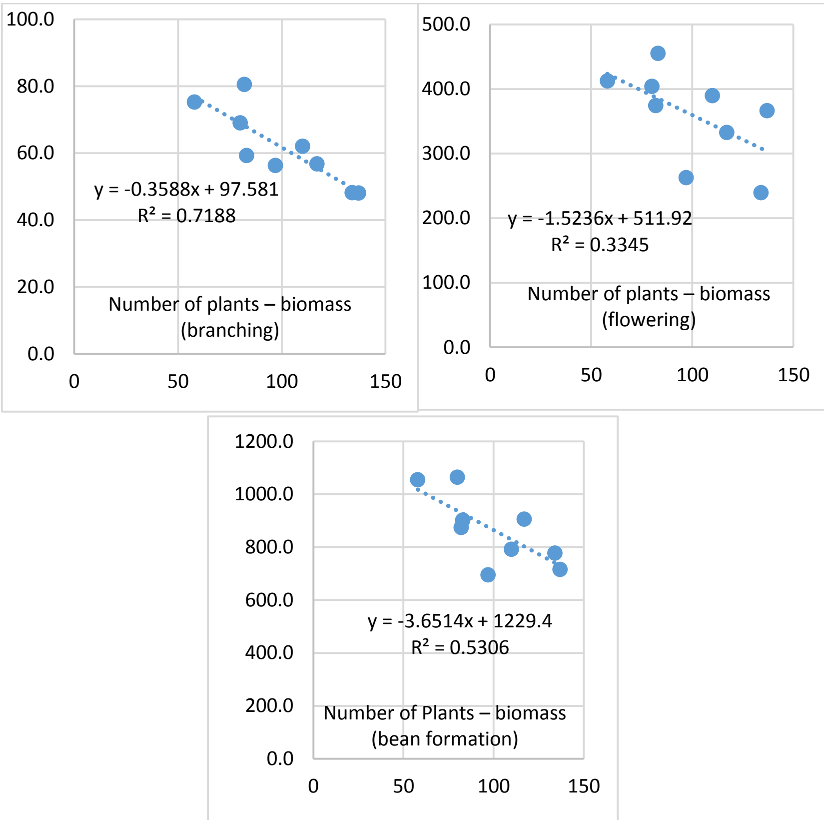

Fig. 2. Correlative relationship between crop density and plant biomass.

Plant biomass decreased by elevating crop density, by a correlation coefficient of -0.85, -0.58 and -0.73 in the branching, flowering and bean formation phases respectively.

Yield and statistics

The productivity of lentils, depending on the timing of sowing and the seeding rate, varied from 6.41 to 12.64 c/ha in the research year (Table 3). Depending on the seeding rate of lentil seeds, the maximum yield was obtained at a seeding rate of 1.6 million seeds/ha. According to the terms of sowing lentils, the largest harvest was obtained on average during sowing on May 30. It may be due to the fact that precipitation that fell in the 3rd decade of July (42.0 mm) and the 1st decade of August (23.9 mm) coincided with the phase of legume formation of lentils sown on May 30. The exception was when sowing on May 20 at the rate of 1.6 million in 2022.

Table 3. Yield by sowing time.

	Sowing dates	Yield 2021 (± standard deviation)	Yield 2022 (± standard deviation)
1.0 million	May 10	9.733 ± 0.493^{c}	6.413 ± 0.716^{b}
	May 20	5.633 ± 0.351^{b}	$9.440 \pm 0/562^{a}$
	May 30	9.800 ± 0.264^{a}	10.180 ± 2.107^{a}
Sig.(p), ANOVA		**<0.005**	**0.029**
1.3 million	May 10	9.767 ± 0.651^{c}	7.063 ± 0.431^{b}
	May 20	6.733 ± 0.513^{b}	10.457 ± 0.988^{a}
	May 30	$12.533 \pm 0/289^{a}$	10.527 ± 1.548^{a}
Sig.(p), ANOVA		**<0.005**	**0.013**
1.6 million	May 10	9.867 ± 1.530^{a}	7.627 ± 0.753^{b}
	May 20	7.300 ± 0.200^{b}	12.000 ± 1.176^{a}
	May 30	11.700 ± 1.353^{a}	12.643 ± 0.741^{a}
Sig.(p), ANOVA		**0.011**	**0.003**

Note: *a, b: different letters in the same column show a statistical difference (P<0.05).

The conducted normality Shapiro-Wilk's test showed that the distribution was normal p > 0, and the variables obeyed the law of normality (p = 0.122 and p = 0.751). Levene's test showed uniformity of variances (p = 0.938 and p = 0.187; Table 4). The results of statistical analysis (ANOVA test, p < 0.05, Duncan) showed that the timing of sowing significantly affected the yield of lentils.

Table 4. Normal distribution criteria.

	Shapiro-Wilk's test		
Year of research	Statistics	stl	Significance
2021	0.940	27	0.122
2022	0.976	27	0.751
Criterion of uniformity of variances (Levene's test)			
2021	0.064	24	0.938
2022	1.802	24	0.187

Note: *This is the lower bound of true significance; a. Lilliefors significance correction

When conducting a statistical analysis on the effect of the seeding rate on yield, a significant effect was revealed for certain sowing dates: May 20 and May 30 (Table 5). When sowing lentils on May 10, the yield indicators did not differ significantly in terms of seeding rates (seeding density; p > 0.05). So, it can be assumed that an elevation in the standing density (seeding rate and sowing density) of lentils provides an upraise in yield when sowing at the right time: In the present study, it was found in May 20 and May 30.

Table 5. Results of statistical analysis on seeding rates.

Seeding rates	Sowing dates	Yield 2021 (± standard deviation)	Yield 2022 (± standard deviation)
1.0 million		9.733 ± 0.493	6.413 ± 0.716
1.3 million	May 10	9.767 ± 0.650	7.063 ± 0.431
1.6 million		9.867 ± 1.530	7.627 ± 0.753
Sig.(p), ANOVA		**0.986**	**0.189**
1.0 million		$5.633 \pm 0,351^{b}$	9.440 ± 0.562^{b}
1.3 million	May 20	6.733 ± 0.513^{a}	10.124 ± 0.988^{ab}
1.6 million		7.300 ± 0.200^{a}	12.000 ± 1.176^{a}
Sig.(p), ANOVA		**0.05**	**0.043**
1.0 million		9.800 ± 0.265	10.180 ± 2.107
1.3 million	May 30	12.533 ± 0.289	10.527 ± 1.548
1.6 million		11.700 ± 1.353	12.643 ± 0.741
Sig.(p), ANOVA		**0.042**	**0.048**

Note: *a, b: different letters in the same column show a statistical difference (P<0.05).

DISCUSSION

We found that different soil and climatic conditions of the research year significantly affect the relationship between biomass and yield. In studies conducted in South Australia, the relationship between crop density and crop yield was found only in favorable conditions (Sadras *et al.* 2013), in agreement with that in the present study. According to the terms of sowing lentils, the largest harvest was obtained on average during sowing on May 30. This may be due to the fact that precipitation that fell in the 3rd decade of July (42.0 mm) and the 1st decade of August (23.9 mm) coincided with the phase of legume formation of lentils sown on May 30. Minimum temperatures and lack of precipitation during critical growth periods can have a negative impact on plant development and, ultimately, on yield (Yessimbek *et al.* 2022; Nasiyev & Dukeyeva 2023). Investigators noted that lentils form sufficiently high yields on highly aerated soils, average in fertility. It is categorically impossible to sow on brackish, heavily compacted soils. In this case, even compliance with all the recommendations for cultivation is not able to allow an acceptable yield to be formed (Nasiyev 2013). Therefore, one of the main factors affecting yield, in addition to soil moisture availability, is the presence of a sufficient supply of nutrients (Kunanbayev 2022), which suggests further study of this aspect.

CONCLUSION

The maximum yield of lentil grain was obtained in 2021 in the third sowing period, i.e., May 30, while at the seeding rate of 130 seeds/m^2 it was 12.52 kg ha^{-1}. In 2022, in the second sowing period, i.e., May 20 and at the seeding rate of 160 seeds/m^2 it was 12.0 kg ha^{-1}. According to the results of two-year studies, we found that in the steppe zone of Northern Kazakhstan, to obtain a high grain yield, the most acceptable seeding rate and the sowing period of lentils is seeding with a norm of 1.3 million seeds of germinating seeds per 1 ha and later sowing dates –11.5 c/ha.

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REFERENCES

Baiseitova, G, Moraru, G, Sarsenbayev, B, Kirshibayev, E & Kenenbayev, S 2021, Biological characteristics and productivity of sweet sorghum varieties in the arid conditions of Southeastern Kazakhstan. *OnLine Journal of Biological Sciences*, 21: 245-252, https://doi.org/10.3844/ojbsci.2021.245.252.

Baloch, AW, Soomro, AM, Javed, MA, Ahmed, M, Bughio, HR, Bughio, MS, & Mastoi, NN 2002, Optimum plant density for high yield in rice (*Oryza sativa* L.). *Asian Journal of Plant Sciences,* 1: 25-27.

Batayneh, KA, Abdel Razzaq, MG, Ghazuan, T, Sabah Jabr, HM, Hameed, NS, Zabibah, R, Obaid, FN, Obaid, AJ, Attia Thijail, H, Ahjel, S, Safaa, G & Ghaleb Maabreh, H 2022, Effects of water shortage on food legume crops. *Caspian Journal of Environmental Sciences*, 20: 839-844, DOI: 10.22124/ cjes.2022.5776

Bekezhanov, D *et al.* 2021, Environmental and legal regulation of digitalization of environmental protection. *Journal of Environmental Management and Tourism*, 7(55): 1942 - 1951. DOI: 10.14505/jemt.v12.7(55) .19.

Burton, CM, Burton, PJ, Hebda, R, & Turner, NJ 2006, Determining the optimal sowing density for a mixture of native plants used to revegetate degraded ecosystems. *Restoration Ecology,* 14: 379-390.

Grime, J P 2006, Plant strategies, vegetation processes, and ecosystem properties. John Wiley & Sons

Ivanikov AV, Tomilov VP 2002, Workshop on biometrics. Tutorial. Astana, 112 p., [In Kazakh].

Kumakova VA 2000, Some techniques and methods of physiological study of varieties of grain crops in the field. Saratov: RASKhN, NIISKh Yu.-V. [In Kazakh].

Kunanbayev, K, Churkina, G, Filonov, V, Utebayev, M & Rukavitsina, I 2022, Influence of cultivation technology on the productivity of spring wheat and the humus state of southern carbonate soils of Northern Kazakhstan. *Journal of Ecological Engineering,* 23: 49-58

Nasiyev, B & Dukeyeva, A 2023, Influence of mineral fertilizers and methods of basic tillage on the yield and oil content of sunflower. *OnLine Journal of Biological Sciences*, 23: 296-306. https://doi.org/10.3844/ojbsci.2023.296.306

Nasiyev, BN 2013, The role of organic fertilizers in increasing the fertility of West Kazakhstan soils. *Polish Journal of Soil Science*, 46: 115-146.

Nokusheva, ZA, Kantarbayeva, EY, Ormanbetov, MB, Yermagambet, BT, Kassenova, ZM & Kazankapova, MK 2023, Development and implementation of effective schemes for the use of mineral fertilizers in the forest-steppe zone of the North Kazakhstan region. *OnLine Journal of Biological Sciences*, 23: 313-322. https://doi.org/10.3844/ojbsci.2023.313.322.

Sadras, VO, Lake, L, Leonforte, A, McMurray, LS, Paull, JG, 2013, Screening field pea for adaptation to water and heat stress: associations between yield, crop growth rate, and seed abortion. *Field Crops Research*, 150: 63-73, https://doi.org/10.1016/j.fcr.2013.05.023.

Saikenova, AZ, Kudaibergenov, MS, Nurgassenov, TN, Saikenov, BR & Didorenko, SV 2021, Crop Yield and Quality of Lentil Varieties in the Conditions of the Southeast of Kazakhstan. *OnLine Journal of Biological Sciences*, 21: 33-40, https://doi.org/10.3844/ojbsci.2021.33.40.

Shaimerdenova DA, Chakanova ZhM, Iskakova DM, Sarbassova GT, Bekbolatova MB, Yesmambetov AA 2022, Storage of extruded cereal and legume grain bases in ion-ozone medium. *SABRAO Journal of Breeding and Genetics*, 54: 165-174, http://doi.org/10.54910/sabrao2022.54.1.15.

Siddique, K H M, Loss S P, Pritchard D L, Regan K L, Tennant D, Jettner R L Wilkinson D 1998, Adaptation of lentil (*Lens culinaris* Medik.) to Mediterranean-type environments: Effect of time of sowing on growth, yield, and water use. *Crop and Pasture Science*, 49: 613-626, https://doi.org/10.1071/A97128.

Skokbaeva, SO 2002, Methodology for state variety testing of agricultural crops. Almaty, 2002, Kazakhstan.

Yessimbek, B, Mambetov, B, Akhmetov, R, Dosmanbetov, D, Abayeva, K, Kozhabekova, A, Oraikhanova, A & Baibatshanov, M 2022, Prevention of desertification and land degradation using black saxaul in arid conditions. *Online Journal of Biological Sciences*, 22: 484-491.

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