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Research Article
Productivity and Cooking Advantages of Lentil Grades Grown Under Conditions Found in North Kazakhstan

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Abstract
Objective: This study was conducted to identify the impact of various soil preparation technologies and seed application rates on crop yield and dietary value of lentil grown in the dry steppe zone of North Kazakhstan. Characteristics of crop and grain quality of different lentil grades as a function of seed application rates and various soil preparation technologies were studied. **Materials and Methods:** Three lentil grades, Vekhovskaya, Canadian Red and Wice Road, were sown at an application rate of 2.0, 2.2 or 2.5 million viable seeds ha^{-1}. Field and laboratory experiments were conducted in accordance with the "methods of the state strain testing of crops". **Results:** The productivity level of the different lentil grades varied depending on varietal features and lentil seed application rates that ranged from 11.6-18.9 dt ha^{-1}. All lentil grades in this study had excellent cooking qualities that scored between 4.1 and 4.8 out of 5. In terms of the economic efficiency, the highest efficiency was seen with low seed application rates. **Conclusion:** The best technology for lentil cultivation in North Kazakhstan involves minimal soil preparations and low rates of seed application.

Key words: Lentil, grade, seed application rate, productivity, protein, cooking advantages

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Protein is a vital component of human diets and animal feed. Protein-poor diets can compromise normal bodily functions and have adverse consequences on health. Elimination of dietary and feed protein shortages is a strategic objective for maintaining human health and productivity of livestock. Therefore, study of the dietary and feeding advantages of high-protein vegetable raw materials, as well as processing approaches, are needed.

In recent years, increased attention has been given to an important legume-lentil, which is a valuable source of vegetable protein[1]. Lentil (*Lens culinaris Medik*) belongs to a group of high-protein food crops and lentil grains that are frequently used for cooking due to their ease of preparation and good digestibility[2-4]. Lentils are highly nutritious and have a higher protein content than wheat, peas and kidney beans. Indeed, lentils have the highest nutritional values compared to all legumes. A 100 g portion of lentils has 310 calories and consists of 24-35% protein, 48-53% carbohydrate, 0.6-2% fat and 2.3-4.4% minerals[2]. Most of the protein content (80%) in lentils is found in the water-soluble fraction[5]. Moreover, lentils have a high content of essential amino acids and are a good source of bioactive essential minerals, including the major nutrients (K, P, Ca, Mg, Na) and trace elements (Fe, Zn, Cu, Mn)[6]. Lentils do not accumulate nitrates, toxic elements or radio nuclides to a significant degree and thus can be considered as an ecologically pure product[2]. In contrast to many other foods, lentils lose few nutrients following heating during cooking.

Several studies suggested that lentil-based dishes could have beneficial effects on several diseases, including nervous disorders, cardiovascular diseases, diabetes, ulcers and colitis. Lentils may strengthen the immune system and have anti-cancer effects. Lentils also have a good nutrient source for pregnant women[3].

Lentils are cultivated in many regions worldwide, including South and West Asia, North Africa, Canada, Australia and the USA[5]. According to FAOSTAT data, in 2010 lentils were grown in 52 countries. On average, lentils yield 4.2 million t ha^{-1} and have a gross yield totaling 4.6 million t ha^{-1}. Lentils are the fourth most-commonly harvested grain legume after soybeans, kidney beans and peas[7-8]. Canada harvests the most lentils (1.34 million ha, gross yield 1.9 million t), followed by India (1.3 million ha, 1.1 million t) and Turkey (234 thousand ha, 345 thousand t)[5].

In Russia, the main areas of lentil cultivation are in the Middle Volga regions of Penza, Saratov, Samara and Ulyanovsk as well as in the Tatarstan region in the Central Black Earth zone that includes Belgorod, Voronezh and Kursk. However, lentils are not a major crop in Russia where yields do not exceed 20-25 thousand ha and the seed yield is low and unstable.

Penza Agricultural Research Institute findings revealed that an increase in lentil seed application rates from 2.0-3.0 million viable seeds ha^{-1} reduces crop production/1 ha, especially in drought years. Under field trials, a seed application rate of 2.4 million ha^{-1} of viable seeds produced the highest yield (2.44 t ha^{-1}), which exceeded the yield of the smallest seed application rate (2.0 million ha^{-1}) by 0.37 t ha^{-1} (17.8%). Meanwhile, the treatment with the highest seed application rate (2.4 million seeds/1 ha) had the highest number of surviving plants /unit of crop and in turn high productivity. However, in drought years, sowing 2.0 or 2.2 million seeds ha^{-1} produced the largest yield of lentil grains[9].

Lentils have significant export potential for Kazakhstan where the planted acreage of lentils was 2,884 ha in 2012. In subsequent years, the planted acreage of this crop has been increasing, as reflected by the Kostanay region of Kazakhstan that planted 3,910 ha of lentils in 2013[2,10].

The A.I. Baraev Research and Development Centre for grain crops in Kazakhstan found that high lentil yields require proper bedding given the low plant height (35-45 cm) of lentils and, in contrast to bean plants that can be trellised at a height of 7-8 cm, lentils require nearly flat fields or pre and post-seeding harrowing. In the period from germination to flowering, lentil plants require special attention and favorable conditions because of the low competitiveness of this plant. Thus, lentil seeds require reliable protection from windfalls of the previous crop and weeds. Processing of soil with phosphorous followed by sowing in weed-cleared fields is a factor in generating a competitive lentil yield[11].

In a study by Kireyev[12], lentil seed application rates are dependent on seed size and cultivation region. For lentils grades with small and large seed sizes, the optimal application rates range between 80 and 100 kg ha^{-1} and between 100 and 120 kg ha^{-1}, respectively[12]. At the Karabalyk agricultural experiment station in the Kostanay region the typical seed application rate is 1.5 million viable seeds ha^{-2}.

Based on experimental data for North Kazakhstan, Suleimenov[13] noted that no definite conclusions about soil treatment for various soil and landscape conditions can be made in terms of optimal soil treatments. Thus, to reduce the intensity of soil treatment in dry steppe zones, that have dark chestnut-colored soil, it is necessary to know the impact of such reductions on soil and the plants grown in that soil[12].

However, compared to other grain crops, lentil acreage in Kazakhstan is insignificant and the increasing interest in lentil crop is constrained by the low yield and underdeveloped cultivation technology. Due to this, it becomes necessary to study new lentil grades that meet the requirements of modern cultivation technologies, as well as improvements in cultivation methods and grain processing technology that are tailored to Kazakhstan. So this study was conducted to identify the impact of various soil preparation technologies and seed application rates on crop yield and dietary value of lentil grown in the dry steppe zone of North Kazakhstan.

MATERIALS AND METHODS

This field experiment was implemented on an experimental plot at "Farmer 2002" LLP in the Astrakhan district of the Akmola region in Kazakhstan that have dark chestnut soil. The tests were conducted in a dry steppe zone of North Kazakhstan according to the methods of state strain testing of crops and the methods of field experience[14,15].

Cooking properties and protein content of lentil sample was determined according to the "methodology of state strain testing of crops, technological evaluation of grains, cereals and legumes" developed in the Biochemistry Laboratory of the A.I. Baraev Research and Development Center for Grain Crops[16].

Hydrothermal factor (HTF) was calculated according to the methodology described by Selyaninov[17]. To assess the vegetative period of plants using the HTF, the following scale was used: HTF$\leq$0.5 is arid, 0.5-0.7 is severe drought, 0.7-1.0 is mild drought, 1.0-1.5 is slight drought and 1.5-2.0 is wet[18].

Three lentil grades used in this study were: Vekhovskaya, Canadian Red and Wice Road. The plot size was 4.2 m$\times$30 m, 126 m^2 and the number of replications was 4. The total area of the experimental field was 1.36 ha. The lentil seed application rate was 2.0, 2.2 or 2.5 million viable seeds ha^{-1}. A SZS-2.1 seeder was used for seed application with arow spacing of 23 cm.

The following three soil preparation technologies were used:

- **Zonal soil treatment technology:** In autumn, the soil underwent deep loosening to a depth of 16-18 cm, snow retention in winter was allowed. The soil was mulched and the plants were sowed and harvested by plots as the lentil grains matured[19]
- **Minimal soil treatment technology:** In autumn, a surface treatment was undertaken; snow retention in winter was allowed. The soil was mulched and treated twice (before seeding and during the germination phase) with herbicides. Seeds were sowed and plants were harvested by plots as the lentil grains matured
- **Minimal-zero soil treatment technology:** Snow retention in winter was allowed. The soil was mulched and treated twice (before seeding and germination phase) with herbicide. Seeds were sowed and harvested by plots as the lentil grains matured[1]

RESULTS AND DISCUSSION

According to the Zhaltyr meteorological center in the Akmola region of Kazakhstan, 226 mm of precipitation fell during the growth and development of lentil plants in this region in 2015, this amount was 72 mm higher than average rainfall rates. In Kazakhstan, May is typically wet with an average of 54 mm rainfall. In 2015, 69 mm of rain fell during May, Meanwhile, in June and July-2016, 53 and 74 mm of rain, respectively, fell, which was higher than the average annual rainfall of 11.0 and 25.0 mm, respectively. These wet conditions indicated that during the study period of 2015-2016, lentil plants would have experienced conditions with sufficient moisture (Fig. 1).

The average monthly air temperatures in May and June, 2015 were +2.6 and +2.2°C higher than average and in July and August were lower than the average annual value by 2.2 and 1.5°C. Nonetheless, the sum of active temperatures between May-August during the study period (2015-2016) was within the range of long-term indicators and thus would be predicted to have no significant impact on lentil grain yield, although a decline in the average daily temperature during the vegetative season would contribute to a lengthening of the vegetative period for plants (Fig. 2).

The HTF, calculated for the vegetative period in this study was 0.8, consistent with mild drought. Meanwhile, the HTF for lentils during the sprouting-budding period was 1.0,

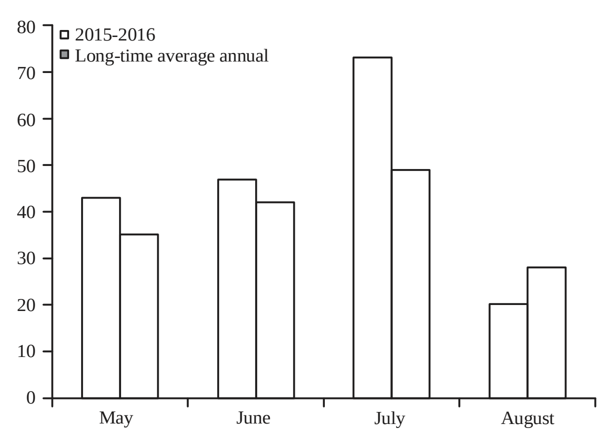

Fig. 1: Average monthly precipitation in 2015-2016 compared with the long-time average annual rain, mm (data from the Zhaltyr weather station)

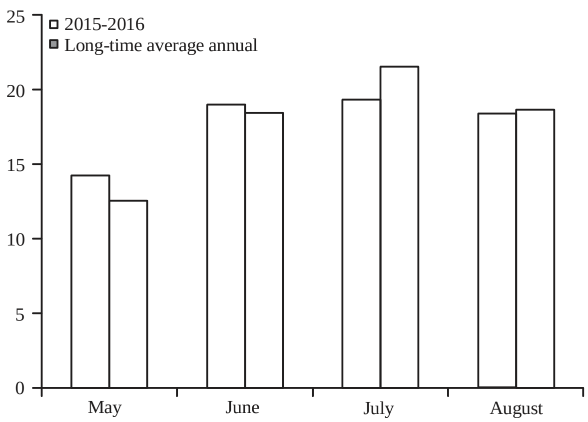

Fig. 2: Average monthly air temperature in 2015-2016 compared with average annual temperatures (°C, data from the Zhaltyr weather station)

consistent with mild or slight drought. The HTF for lentils during the budding-seeds maturing phase was 0.7, which is consistent with mild or severe drought and indicates that plants which are provided with sufficient moisture and temperatures during this period can form high-quality grains.

Conditions during the vegetative period can also significantly impact the duration of different inter phase periods of lentil grades. In the 2015-2016 study period, the sprouting phase in the tested lentil grades occurred after 7-8 days. The "branching-budding" period lasted 10-14 days, whereas the interphase "budding-flowering" period was 12 days. The entire vegetative period of various lentil grades lasted between 90 and 98 days, which was due to the large amount of precipitation and low temperatures, relative to seasonal averages, seen during the initial periods of lentil growth and development.

The field germination of lentil grades in the present study averaged between 76 and 85%, whereas the survivability of the lentil plants before harvesting ranged from 87.0-92.7%.

For zonal soil preparation technology, the yield of the lentil grades was between 12.0 and 17.8 dt ha^{-1}, whereas with minimal technology the yield was between 12.6 and 18.9 dt ha^{-1} and for minimal-zero technology the yield was11.6-18.1 dt ha^{-1}.

Only the Vekhovskaya grade with minimal soil treatment technology and increased seed application rate from 2.2-2.5 million viable seeds ha^{-1} showed a significant increase in grain yield compared with the control (0.4-0.8 dt ha^{-1}). No similar trend was seen for the other grades and treatment methods (Table 1).

The largest yield among the grades was seen for minimal soil preparation technology. For example, the yield of Vekhovskaya grade lentil with this method was 1.0-1.1 and 0.7-0.8 dt ha^{-1} and was higher than that for zonal technology and minimal-zero technology, respectively. The yield ranges for Canadian Red and Wice Road grown with these two methods were 0.5-0.6, 1.0, 0.8-1.1 and 0.6-0.9 dt ha^{-1}, respectively. The least significant difference was seen for zonal technology, which had a yield of up to 1.1 followed by minimum and minimum zero technology at 0.8 and 1.0, respectively.

In a study carried out in the mountainous area of the Kabardino-Balkar Republic, the yield of lentil grades decreased with a decrease in the seed application rate from 2.8-2.0 million germinated seeds (with an interval of 0.2 million germinated seeds/1 ha)[20].

In the steppe zone of the Kemerovo region of the Russian Federation, when lentils with different seed application rate were sown (2.5, 3.0, 3.5 and 4.0 million germinated seeds), the highest yield was 10.5 dt ha^{-1} with the seed application rate 2.5 million germinated seeds, while the lowest yield was 6.8 dt ha^{-1} with the seed application rate 4.0 million germinated seeds[21].

Lentils are rich in vegetable protein, including the essential amino acids, isoleucine and lysine. In the present study, it is observed that for the various lentil grades, weather conditions as well as the economic and biological features of the lentil grade were key factors that influenced the accumulation of protein in lentil grains (Table 2).

Among the grades, the protein content was higher for Canadian Red lentils (27.46-28.61%) than the other two grades. An increased seed application rate was associated with decreased protein content for all lentil grades, regardless of the soil treatment method used (Table 2).

According to a previous study conducted by Storozhnik[22], in the Voronezh region, the grain yield at different sowing times produced 15.4-16.9 dt ha^{-1}, while the protein content in grain ranged between 20.1 and 26.1%.

Lentils are a popular food product for four main reasons: good taste, high digestibility, easy to prepare in a short time period (65-75 vs. 140-160 min for kidney beans) and favorable dietary and pharmacological properties.

For assessment of cereals, taste and cooking properties are important indicators. Cooking advantages are determined by taste, color, texture, cooking time and cooking properties such as the ratio of the volume of the cooked to raw product. For cereals used for porridge, taste, smell color and consistency must be appropriate. A high protein content improves porridge consistency, whereas fibers, pentosans and water-soluble substances decrease consistency.

The lentil grades tested here had different cooking properties that were assessed using five parameters. Canadian Red and Wice Road grades at all seed rate applications cooked

Table 1: Lentil yield (dt ha^{-1}) in 2015-2016 as a function of agricultural practices

Grade	Seed application rate (million viable seeds ha^{-1})	Grain yield (dt ha^{-1})	Deviation from control
Zonal technology			
Vekhovskaya	2.0	16.6	-0.7
	2.2	17.3	-
	2.5	17.8	-0.6
Canadian Red	2.0	12.0	-5.3
	2.2	13.1	-4.2
	2.5	14.1	-3.2
Wice Road	2.0	12.3	-5.0
	2.2	12.6	-4.7
	2.5	13.1	-4.2
LSD_{05}		1.1	
Minimal technology			
Vekhovskaya	2.0	17.6	-0.5
	2.2	18.5	+0.4
	2.5	18.9	+0.8
Canadian Red	2.0	12.6	-4.7
	2.2	13.8	-3.5
	2.5	14.6	-2.7
Wice Road	2.0	13.1	-4.2
	2.2	13.6	-3.7
	2.5	14.2	-3.1
LSD_{05}		0.8	
Minimal-zero technology			
Vekhovskaya	2.0	16.8	-0.5
	2.2	17.6	-0.7
	2.5	18.1	-0.2
Canadian Red	2.0	11.6	-5.7
	2.2	12.8	-4.5
	2.5	13.6	-3.7
Wice Road	2.0	12.2	-5.1
	2.2	13.0	-4.3
	2.5	13.6	-3.7
LSD_{05}		1.0	

LSD_{05} is the least significant difference

Table 2: Protein content in lentil seeds collected between 2015 and 2016

Grade	Seed application rate (million viable seeds ha^{-1})	Protein (%)
Vekhovskaya	2.0	27.45
	2.2	26.38
	2.5	25.99
Canadian Red	2.0	28.61
	2.2	28.22
	2.5	27.46
Wice Road	2.0	25.93
	2.2	25.37
	2.5	25.20

uniformly, whereas for the Vekhovskaya grade only the 2.5 million viable seeds ha^{-1} rate had uniform cooking. The cooking time varied among the grades, with the Vekhovskaya grade having longer cooking times compared to the Canadian Red and Wice Road lentils (Table 3). Meanwhile, organoleptic characteristics such as color, smell and taste of the lentils corresponded to established norms.

In terms of yield, the most efficient soil treatment technology was the minimal technology that produced a maximum yield (11.6 and 18.9 dt ha^{-1}). Thus, the economic effectiveness of cultivation of lentil grades for seed depended on the seed application rate and the soil treatment technology. The efficiency of lentil grades as a function of seed application rate and soil treatment technology showed values

Table 3: Cooking parameters of lentil samples collected between 2015 and 2016

Samples	Seed application rate (million viable seeds ha^{-1})	Coefficient of cooking (score)	Uniformity of cooking	Cooked seeds (score)			Cooking time (min)	Total cooking (score)
				Color	Smell	Taste		
Vekhovskaya	2.0	5.0	non-uniform	green-brown	3.0	5.0	40	4.3
	2.2	5.0	non-uniform	green-brown	3.0	5.0	40	4.3
	2.5	5.0	uniform	green-brown	3.0	5.0	40	4.3
Canadian Red	2.0	5.0	uniform	brown	4.5	5.0	35	4.8
	2.2	5.0	uniform	brown	4.5	5.0	30	4.8
	2.5	5.0	uniform	brown	4.5	5.0	31	4.8
Wice Road	2.0	5.0	uniform	green	2.5	4.8	32	4.1
	2.2	5.0	uniform	green	2.5	4.8	32	4.1
	2.5	5.0	uniform	green	2.5	4.8	33	4.1

between 26 and 31%. The Vekhovskaya grade applied at 2.0 million viable seeds ha^{-1} with minimal soil preparation technology had the highest efficiency. An increase in seed application rate both increased costs leads and decreased efficiency for all soil preparation technologies.

CONCLUSION

This study established that the most efficient soil treatment technology is the minimal technology.

Yield level is dependent on lentil grade and seed application rate that varied between 11.6-18.9 dt ha^{-1}. The yield of the different grades was significantly influenced by indicators of plant preservation at harvest.

All lentil grades tested showed favorable cooking properties in terms of appropriate color, smell and taste of cooked lentils. The overall cooking evaluation of all lentil grades was between 4.1 and 4.8 points.

For economic efficiency of lentil grades, the best technology for lentil cultivation was minimal soil treatment.

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