International Journal of Agriculture and Biosciences 2024 xx(x): xx-xx.
https://doi.org/10.47278/journal.ijab/2024.207

RESEARCH ARTICLE
eISSN: 2306-3599; pISSN: 2305-6622

Influence of Seed Protectants on Fungal Pathogens of Lentil Seeds (Lens Culinaris) Against Different Cultivation Technologies in North Kazakhstan

Abdumamat Kochorov*, Yerlan Utelbayev, Alena Kharitonova, Berik Bazarbayev, Vera Davydova and Tatyana Nelis

A.I. Barayev Scientific and Production Center of Grain Farming, Kazakhstan
*Corresponding author: a.s.kochorov@gmail.com

ABSTRACT

The study aims to investigate the influence of biological (Seedspor S) and chemical seed protectants (Piligrim, s.c.) on seed pathogens under different lentil cultivation technologies. The research gives evidence of the high efficiency of a comprehensive application of seed protectants, with the degree of seed infestation decreased by two or three times compared to the control variant. The integrated treatment demonstrates the lowest degree of seed infestation and the highest laboratory germination rate, vigor and field germination rate. In inhibiting and suppressing the spread and development of Fusarium ssp. root rot, the biological seed protectant Seedspor S is less effective than the chemical seed protectant Piligrim, s.c. The no-till cultivation technology provides greater intensiveness of inhibition and suppression, while the traditional technology shows lower intensiveness. Over the years of cultivation, the highest yield was obtained with the comprehensive application of the seed protectants (Piligrim, s.c. + Seedspor S).

Keywords: Lentils, Lentil diseases, Seed protectants, Crop yield

Article History
Article # 24-932
Received: 27-Oct-24
Revised: 19-Nov-24
Accepted: 08-Dec-24
Online First: 18-Dec-24

INTRODUCTION

Lentil is one of the world's most valuable food legume crops (Madenova et al., 2019). The major lentil-producing countries include Canada, India, the USA, Turkey, Australia, Kazakhstan, Nepal, Russia, Bangladesh, China and Ethiopia, accounting for more than 93% of global production (FAO, 2023). Lentil is grown mainly for grain, being one of the world's leading leguminous crops in grain protein content (20-36%) and being valued for its high nutritional content (Mussynov et al., 2017). Lentil contains several important nutrient compounds, including carbohydrates, prebiotics, fiber, vitamins, amino acids, and antioxidants. Due to its high nutrient content, lentil has become an excellent crop for bio-enrichment with micronutrients in the human diet (Thavarajah et al., 2011). Kazakhstan has been annually expanding lentil sowing areas, especially in the northern regions of the country – Akmola, North Kazakhstan, and Kostanay (Atabayeva et al., 2018). Lentil production is becoming profitable because its price is several times higher than that of monocrop wheat, which occupies about 80% of the cultivated area in these grain-producing regions (Gridneva & Kaliakparova, 2018). Annual statistics suggest that lentil acreage was growing from 2014 to 2018 and from 2021 to 2024, although 2019 and 2020 were marked by a reduction in the area sown with this crop. Lentil yield shows dramatic drops and surges over the years (Fig. 1 and 2). This demonstrates the instability of lentil production and indicates problems, which require solutions in the cultivation technology and improvement of the phytosanitary condition. A factor hindering the production of high and quality yields of leguminous crops is the wide spread of diseases (Chen & Sharma, 2011). Research findings suggest that the most common and harmful diseases are fusarium, caused by fungus Fusarium oxysporum f. sp. Lentis; anthracnose, caused by the imperfect fungus Colletotrichum spp.; peronosporosis, caused by the imperfect fungus Peronospora lentis Gaum; askochitosis, caused by the imperfect fungus Ascochyta fabae f. sp. lentis; rust, caused by the basidial fungus Uromyces fabae D. B. f. Lentis; root rot or wilt, caused by the bacteria Pseudomonas radiciperda (Javoronkova) Savulescu; root rot caused by the fungi Fusarium spp. and Rhisoctonia solani (Ahmed & Ahmed, 2000; Utelbayev et al., 2021).

Cite this Article as: Kochorov A, Utelbayev Y, Kharitonova A, Bazarbayev B, Davydova V and Nelis T, 2024. Influence of seed protectants on fungal pathogens of lentil seeds (Lens Culinaris) against different cultivation technologies in north Kazakhstan. International Journal of Agriculture and Biosciences xx(x): xx-xx. https://doi.org/10.47278/journal.ijab/2024.207

A Publication of Unique Scientific Publishers

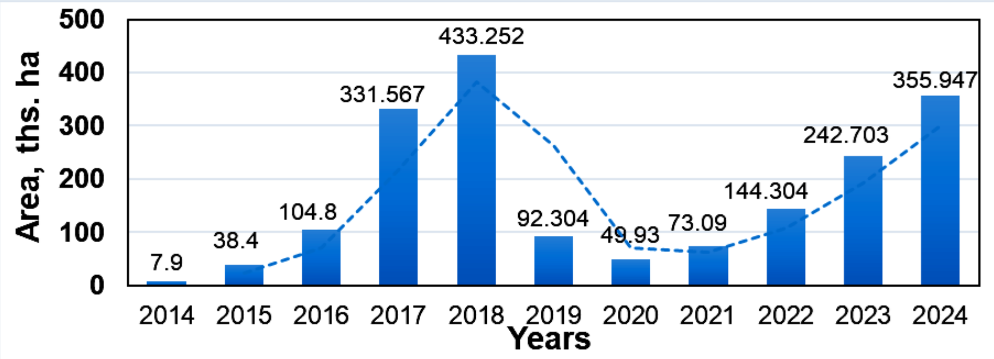

Fig. 1: The dynamics of the area sown with lentils in Kazakhstan in 2014-2024, ths. ha (Bureau of National Statistics).

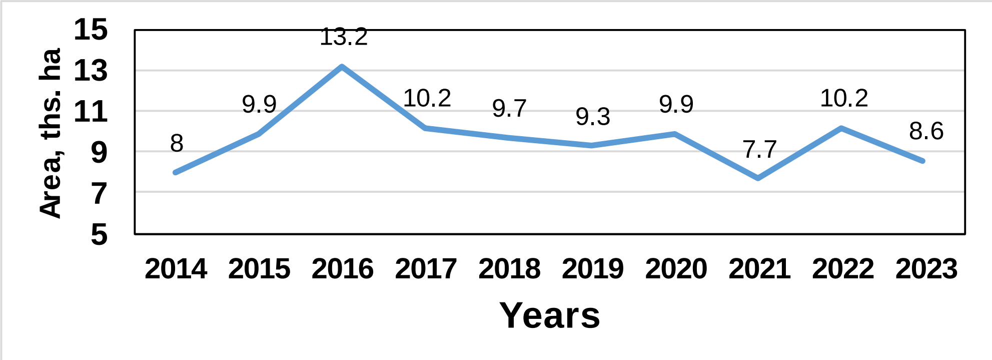

Fig. 2: The dynamics of average lentil yield in Kazakhstan in 2014-2024,c/ha (Bureau of National Statistics).

Various methods of protecting lentil from diseases are accepted in modern plant protection. Researchers recommend seed treatment with protectants (biological and chemical preparations) and fungicidal treatment during the growing season to eliminate lentil pathogens (Handelsman & Stabb, 1996; De & Chaudhary, 1999; Amangeldi et al., 2016). There is little research into the biological features of the species composition of lentil pathogens. The insufficient assortment of fungicides registered in Kazakhstan is also a pressing issue. Thus, studying the species composition and the system of protection against a complex of diseases under traditional and energy and water-saving cultivation technologies in the dry-steppe zone of North Kazakhstan is an urgent objective that will allow to increase the quantity and quality of lentil yields.

Our research aims to determine the species composition of lentil seed infection pathogens and to explore the impact of chemical and biological seed protectants in laboratory and field conditions against different lentil cultivation technologies in North Kazakhstan. The research objectives are to determine: (1) determining the species composition of pathogens associated with lentil seed infections, (2) assessing the spread and development of lentil diseases under varying cultivation technologies, and (3) to identify the most effective protectants for seed-borne infectious diseases.

MATERIALS & METHODS

The studies were conducted in 2023-2024 on an experimental field of A.I. Barayev Research and Production Centre for Grain Farming located in the Shortandy district, Akmola region, Kazakhstan (51.675382, 71.016108). Laboratory tests and all related analyses were conducted in the Plant Protection Laboratory. The scheme of the field experiment was developed following Dospekhov's field experiment methodology (Dospekhov, 1985). The dimensions of the plot were 100m in length and 4.2m in width, the total area equaling 420m^2. The experiment was repeated three times. The seeding rate was 80-100kg/ha. The seeding was performed at the optimal time for the zone – May 18-20. The sowing technique employed was row sowing. Traditional and minimal cultivation technologies used the SZS-2.1 seeder (tine colters) and the no-till technology – the Amazone seeder (DMC, anchor colters), with the seeding depth equaling 4-5cm. The predecessor in fruit-replacing crop rotation was soft wheat. The effectiveness of pre-sowing seed treatments during sowing and the growing season under different crop cultivation technologies was studied according to Table 1.

Experiment Variants

Cultivation Technology

The steps taken under the traditional cultivation technology after harvesting the predecessor included:

- deep tillage of the soil in fall at 24-27cm;
- snow retention in the 1st and 3rd decades of December;
- closing moisture at physical soil ripening in spring;
- pre-sowing surface tillage at 12-14cm.

Under the minimal cultivation technology, in spring, 2-3 weeks before sowing, the fields were treated with a persistent herbicide (glyphosate) Tornado 540, whose active ingredient is glyphosate potassium salt, 540g/L, at a rate of 2.5L/ha against annual and perennial dicotyledonous and grass weeds. The soil was subjected to physical impact only during sowing with the SZS-2.1 seeder (tine colters). Under the no-tillage technology, in the spring, 2-3 weeks before sowing, the fields were treated with Tornado 540 at a rate of 2.5L/ha against annual and perennial dicotyledonous and grass weeds. In this case, the soil was not subjected to any mechanical impact.

Table 1: Pre-sowing seed treatment with different lentil cultivation technologies

Experiment variants		Repetitions		
Cultivation technology	Pre-sowing seed treatment	I	II	III
Traditional	Control	1	13	25
	Piligrim, s.c. (0.4L/t)	2	14	26
	Seedspor S (2.0L/t)	3	15	27
	Piligrim, s.c. (0.4L/t) + Seedspor S (2.0L/t)	4	16	28
Minimal	Control	5	17	29
	Piligrim, s.c. (0.4L/t)	6	18	30
	Seedspor S (2.0L/t)	7	19	31
	Piligrim, s.c. (0.4L/t) + Seedspor S (2.0L/t)	8	20	32
No-till	Control	9	21	33
	Piligrim, s.c. (0.4L/t)	10	22	34
	Seedspor S (2.0L/t)	11	23	35
	Piligrim, s.c. (0.4L/t) + Seedspor S (2.0L/t)	12	24	36

Pre-sowing Treatment

Piligrim, s.c. – active ingredient – thiamethoxam, 350g/L + flutriafol, 87g/L + metalaxyl, 43g/L. This is an innovative three-component systemic preparation with fungicidal and insecticidal properties intended for treating the seeds of cereal and leguminous crops against a complex of seed-borne, soil-borne, and aerogenic infections and sucking and gnawing crop pests. *Seedspor* S is an innovative biological preparation by HANSE PLANT consisting of living organisms, including Mycorriza propagules, 10 colonies/mL, *Trichoderma*, >1*10^7 spores/mL, *Bacillus subtillis* and *Bacillus megaterium* bacteria, >2*10^7 spores/mL, and microelements – Fe (2%), Zn (0.5%), KO_2, P_2O_5, MgO, and CaO. It is a fertilizer containing nitrogen, phosphorus, potassium, and microelements iron and zinc and is a 100% natural microbiological product for pre-sowing seed treatment. The product is designed to maximize yield after a single application even under unfavorable weather, environmental, and phytosanitary conditions. It is effective against seed and soil phytopathogens.

General Background of Experimental Field Treatment against Harmful Organisms during the Growing Season

The general background of the experiment included herbicidal and insecticidal treatment during the growing season. These treatments are not reflected in the scheme of the experiment because they were applied in all variants of the experiment except for the control:

1. Herbicide treatment was conducted in phase 4-6 of true leaves of lentils, with Kadim 240 herbicide, e.c., 0.3L/ha against annual and perennial cereal weeds. *Kadim 240, e.c.* – the active ingredient – clethodim, 240g/L. A selective herbicide. Suppresses annual cereal weeds, including self-sown cereals, and perennial cereals, including couch grass and others. Effective against a wide range of cereal weeds.

(2). Insecticide treatment was conducted in the early phases of lentil growth against fleas and aphids with Engio 247 insecticide, s.c. – 0.2L/ha. *Engio 247, s.c.* – the active ingredient – thiamethoxam, 141g/L + lambda-cyhalothrin, 106g/L. A combined contact and systemic insecticide against a wide range of pests, from larva to imago. Highly effective against pests in a wide variety of cultures.

According to the research objectives, we conducted the following surveys, observations, and analyses:

(1) Phytopathological analysis of lentil seeds was conducted in a moist chamber and by sowing seeds on nutrient media. Four samples of 50 seeds each were taken. The seeds germinated for 7 days at 25°C. The seeds were not disinfected before planting. Three layers of filter paper were used. Screening was conducted on days 7 and 14, each germinated seed (cotyledons, root) and all ungerminated seeds were examined. Total seed infestation with lentil diseases was calculated using the common phytopathology method (GOST, 1995). (2) The sowing qualities of seeds were determined according to the Methodology of the State Variety Testing Network (Metodika gosudarstvennogo sortoispytaniia, 1983). The indicators of laboratory germination rate and vigor were determined according to GOST 12038-84 (1986). The seeds were germinated on two layers of moistened filter paper in Petri dishes. Four samples of 100 seeds each were taken from weighed portions. Laboratory germination rate, i.e., the percentage of normally germinated seeds in the analyzed sample, was determined on day 7, while vigor, an indicator of germination simultaneity, was determined on day 3 (Mozhaev & Arinov, 2014). (3) The identification and accounting of lentil diseases were conducted according to the methods of the All-Union Research Institute of Plant Protection and were performed over the entire growing season of lentil plants (from the sprouting period to full maturity). (4) The spread and development of diseases in lentil crops were determined according to the method of Chumakova et al. (1974). Disease spread was calculated using the formula:

$$P = \frac{n}{N} x100$$

where: *P* is the spread of the disease;

n is the number of plants or organs affected;

N is the total number of plants or organs analyzed.

The percentage of the development or the degree of plant infestation was determined using the formula:

$$R = \frac{\sum(ab)}{N \cdot K} x100$$

where: *R* is the percentage or degree of disease development;

N is the number of plants, leaves, fruits, tubers, or other organs counted;

K is the highest score on the assessment scale.

The degree of disease development was assessed on a universal four-point scale for lentil diseases (Sagitov & Kambulin, 2016). (6) Yields were measured with a Wintersteiger selection combined with conversion to 100% purity and 12% moisture content (Arinov et al., 2016). (7) Mathematical data processing was conducted in SNEDECOR software (SNEDECOR, 2004).

RESULTS & DISCUSSION

The results of this study, which highlights the effectiveness of biological and chemical seed protectants on lentil pathogens (Fusarium ssp., Colletotrichum ssp, etc.,) are consistent with findings in recent literature that study their efficiency and the advantages of a biological and chemical combination for seed protectants. (Bugingo, 2022; Chekaev et al., 2022). The agrometeorological conditions were generally characterized by a significant precipitation deficit during the growing season, more severe in 2023. In 2023, the plants were developing under very arid and dry conditions – the hydrothermal coefficient (HTC) ranged from 0.3 to 0.6, which negatively affected the growth and development of cultivated plants and weeds. The precipitation during the growing season (from May to August) was 38.1mm, 130.6mm below the multi-year average. In May and June, total precipitation amounted to 15.7mm, 56.2mm below the multi-year average. The remainder of the growing season was characterized by very dry conditions. The precipitation deficit for July-August amounted to -74.4mm, while the temperature regime in July and August was 2.3-4.5°C above the multi-year average. In contrast to 2023, the amount of precipitation in 2024 was sufficient, exceeding the multi-year average by 44.5mm in May, 22.8mm in June, 6.3mm in July, and 66.8mm in August. By moisture content, 2024 is characterized as favorable for plant growth and development and the formation of the vegetative mass of lentils, but also for the intensive development and spread of fungal lentil diseases (Fig. 3).

In 2023, low precipitation was accompanied by elevated temperatures. The average daily air temperature for May-August was 2.8-4.5°C above the multi-year average. Strong changes in night air temperatures and frosts were not recorded, the minimum temperature was +4.6-5.7°C in the 2nd decade of June. The maximum temperature was recorded in the 2nd decade of July and reached +37.5-38.7°C. Compared to 2023, the 2024 temperature regime during the growing season of lentils aligned with the multi-year average with an insignificant decrease in May by 1.3°C and an insignificant increase in June and July by 1.8-4.3°C. During the lentil seed ripening period in August, the temperature was at the level of the multi-year average. The analysis of meteorological conditions shows that the parameters of the temperature regime during the growing season of lentils over the studied years were generally favorable for the growth and development of the lentil yield (Fig. 4). Laboratory studies to determine the infestation of lentil seeds sown in the studied area with infectious diseases were conducted to organize the field experiment with seed protectants against soil and seed diseases. Phytopathological laboratory analysis was conducted before the sowing of lentil seeds. The laboratory analysis was conducted using the rolling method and microscopy. The method was used to determine contamination by seed infections, particularly the presence of spores, conidia, and conidiophores of fungi, etc. As a result of the laboratory analysis, fungi from the genera Fusarium ssp., Alternaria ssp., Colletotrichum ssp., Ascochyta ssp., Aspergillus, and Penicillium were detected on the seeds. Our methodology aligns with recent studies on phytopathology and agrees with the works of (Martinez et al., 2021; Doolotkeldieva & Bobusheva, 2022), who applied rolling and microscopy to determine infestation.

The 2024 seeds of lentil varieties were more severely affected by diseases compared to 2023, because the crop yielded in 2023 was of poor seed quality. High efficiency was found in the variant with the combined application of Piligrim, s.c. + Seedspor S. Similar results were obtained in 2024. This finding aligns with the works of Mishra et al. (2023) and Kochorov et al. (2023). In their study, Kochorov et al. (2023) obtained similar high-efficiency results after combining chemical and biological protectants of oilseed flax against fungal disease pathogens. This phenomenon leaves a gap for more research on the mechanism behind the increased efficiency when combining two or more seed protectants of different natures and the types of seeds to which these methods can be applied.

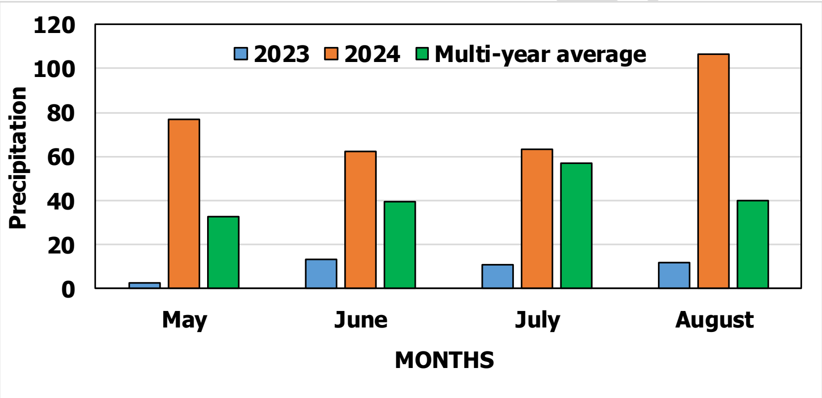

Fig. 3: Precipitation (mm) during the growing season.

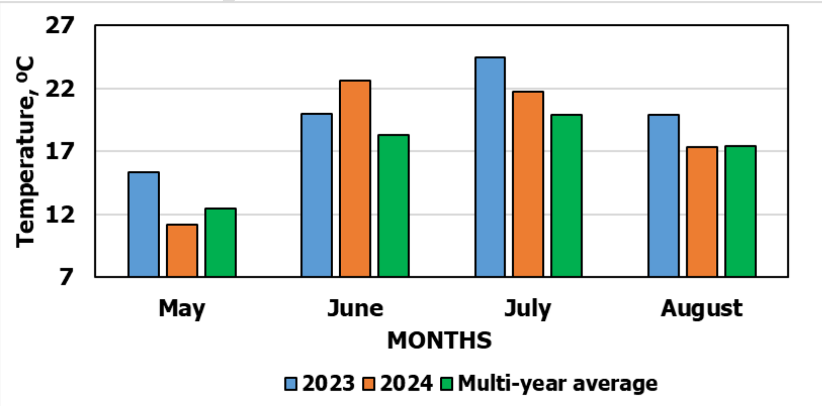

Fig. 4: Average monthly air temperatures (°C) during the growing season.

The difference between the variants with seed protectants and control is significant, as it exceeds the least significant difference (LSD05), ranging from 1.06 to 1.73 in 2023 and from 1.12 to 1.98 in 2024 (Table 2). The treatment of lentil seeds with protectants showed different results by the sowing qualities of seeds determined in laboratory conditions. Considering the influence of chemical and biological seed protectants on the germination of lentil seeds, vigor across the experiment variants ranged from 83.0 to 90.0% in 2023 and 80.0 to 88.0% in 2024. This suggests that the pre-sowing treatment of lentil seeds regardless of the type has a positive impact on vigor. This finding agrees with the work of (Amulya et al., 2021), who highlighted the effectiveness of pre-sowing seed treatment of lentils with bioinoculants and micronutrients. According to our results, adding seed protectants will also produce positive results, but more research is needed to determine the specific compositions during pre-sowing treatment with other compounds.

Laboratory assessment of the germination rate by the type of protectant demonstrated that this parameter ranged from 87.0 to 97.0% in 2023 and from 84.0 to 93.0% in 2024. The lentil seeds treated with a complex of protectants demonstrated a high laboratory germination rate. The biological protector Seedspor S outperformed the chemical protectant Piligrim, s.c. in influence on the germination rate by 1-2%. The difference between the variants with seed protectants and control is significant, exceeding the LSD05, ranging from 2.82 to 3.64 (Table 3). This also aligns with the study of Kochorov et al. (2023), who observed a high laboratory germination rate where a complex of protectants were applied. The performance of biological protectants is also supported by various studies (Campanella & Miceli, 2021; Baah et al., 2024), who not only highlighted their sustainability and ecological advantages but also obtained high germination rates, vigor index and, in some cases, slightly lower effectiveness when compared to chemical protectants.

Field experiments showed that the influence of the chemical and biological protectants separately and in combination improved the field germination rate of lentil seeds regardless of the cultivation technology. The minimal cultivation technology provided an insignificant increase in the field germination rate compared to the traditional and no-till technologies – by 0.4-4.2% in 2023 and 1.0-5.2% in 2024. On average across the two years, a high field germination rate was ensured by the comprehensive application of Piligrim, s.c. + Seedspor S. – 83.2-86.8%. The LSD05 amounted to 0.48 for the traditional technology, 1.08 for the minimal technology, and 0.57 for no-till. The results thus confirm the high significance of the variants (Table 4). We determined the infestation of plant roots by root rot caused by fungi of the genus Fusarium ssp., etc., can cause partial or even complete loss of lentil seedlings. In the experiments with seed protectants, the infestation of lentils with root rot depended on cultivation technology. Under the no-till technology, the disease spread and development were greater compared to the traditional and minimal technologies. This aligns with findings by Zitnick-Anderson et al. (2021), who reported *Fusarium* root rot in 83% of samples from no-till systems. Our study, however, disagrees with (Suproniené et al., 2023), who concluded that traditional tillage had more advantage in controlling Fusarium infection when compared to medium tillage and no-tillage.

Researchers argue that the accumulation of crop remains and weeds under no-till serves as a repository and overwintering place for pests and fungal pathogens (Pandey et al., 2023). The spread and severity of root rot in 2023 were not as high as in 2024, which owes to weather conditions (little precipitation during the growing season of lentils) (Fig. 3). The role of temperature in the spread of root rot is supported by the work of (Yan & Nelson, 2022), who observed a negative correlation between temperature and the spread of Fusarium. A decrease in temperature and an increase in soil moisture content promotes the spread of soil infection. In terms of the inhibition and

Table 2: Phytopathological analysis of lentil seed infestation by diseases

Experiment variants	Fungal disease pathogens											
	Fusarium ssp.		Alternaria ssp.		Colletotrichum ssp.		Ascochyta ssp.		Penicillium		Aspergillus	
	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%
2023												
Control	3.0	6.0	5.0	10.0	4.0	8.0	3.0	6.0	5.0	10.0	4.0	8.0
Piligrim, s.c.	0.7	1.5	1.0	2.0	1.2	2.3	0.5	1.0	0.7	1.5	1.0	2.0
Seedspor S	1.3	2.5	1.3	2.5	1.5	3.0	1.2	2.3	1.0	2.0	1.5	3.0
Piligrim, s.c. + Seedspor S	0.2	0.3	0.5	0.9	0.3	0.6	0.3	0.6	0.7	1.4	0.5	1.0
LSD_{05}	1.10		1.73		1.38		1.06		1.12		1.18	
2024												
Control	4.0	8.0	5.0	10.0	4.0	8.0	3.0	6.0	6.0	12.0	5.0	10.0
Piligrim, s.c.	1.0	2.0	1.5	3.0	1.0	2.0	1.0	2.0	1.5	3.0	1.7	3.4
Seedspor S	1.5	3.0	2.0	4.0	1.7	3.4	1.7	3.4	2.0	4.0	2.0	4.0
Piligrim, s.c. + Seedspor S	0.2	0.3	0.2	0.3	0.5	1.0	0.5	1.0	0.3	0.5	0.3	0.5
LSD_{05}	1.12		1.74		1.14		1.13		1.22		1.98	

Table 3: The influence of seed treatment with protectants on the laboratory germination rate of lentil seeds

Experiment variant	2023		2024	
	Vigor, %	Laboratory germination rate, %	Vigor, %	Laboratory germination rate, %
Control	80.0	83.0	78.0	80.0
Piligrim, s.c.	86.0	94.0	83.0	90.0
Seedspor S	87.0	95.0	85.0	92.0
Piligrim, s.c. + Seedspor S	90.0	97.0	88.0	94.0
LSD_{05}	2.30	2.82	3.26	3.64

suppression of the spread and development of root rot, the biological protectant Seedspor S was inferior to the chemical protectant Piligrim, s.c. The greatest effectiveness against soil-borne diseases across the three cultivation technologies was demonstrated by Piligrim, s.c. (0.4L/t) in a tank mix with Seedspor S (2.0L/t) (Table 5). Due to the ecological effects of chemical protectants, recent research is focused on more effective yet eco-friendly approaches like the application of nanotechnology (Dutta et al., 2023) or complex mixtures as shown in our study.

Table 4: The influence of seed treatment on the lentil field germination rate under different cultivation technologies

Experiment variants		Plant stand density by sprouts				
Cultivation technology	Pre-sowing seed treatment	2023		2024		Mean,
		pcs/m²	%	pcs/m²	%	%
Traditional	Control	136.0	68.0	143.0	71.5	69.8
	Piligrim, s.c.	154.0	77.0	165.0	82.5	79.8
	Seedspor S	159.5	79.8	169.0	84.5	82.2
	Piligrim, s.c. + Seedspor S	167.0	83.5	174.5	87.3	85.4
	LSD_{05}					0.48
Minimal	Control	135.0	67.5	145.0	72.5	70.0
	Piligrim, s.c.	158.0	79.0	167.0	83.5	81.3
	Seedspor S	160.5	80.2	172.3	86.2	83.2
	Piligrim, s.c. + Seedspor S	169.0	84.5	178.0	89.0	86.8
	LSD_{05}					*1.08*
No-till	Control	130.0	65.0	140.0	70.0	67.5
	Piligrim, s.c.	150.3	75.2	158.0	79.0	77.1
	Seedspor S	152.0	76.0	160.0	80.0	78.0
	Piligrim, s.c. + Seedspor S	163.0	81.5	169.5	84.8	83.2
	LSD_{05}					0.57

Table 5: Effectiveness of seed treatments against lentil root rot diseases depending on the cultivation technology

Experiment variants	Cultivation technology					
	Traditional		Minimal		No-till	
	P	R	P	R	P	R
	2023					
Control	31.0	3.9	29.0	2.8	38.0	5.8
Piligrim, s.c.	16.5	1.4	15.3	1.0	20.0	2.3
Seedspor S	23.1	2.2	21.5	1.5	25.0	3.4
Piligrim, s.c. + Seedspor S	14.0	1.1	13.0	0.8	17.3	2.1
LSD_{05}		0.35		0.29		0.32
	2024					
Control	37.2	4.0	33.1	3.5	43.2	6.0
Piligrim, s.c.	18.0	1.5	17.0	1.3	22.0	2.5
Seedspor S	25.4	2.3	24.5	1.7	27.0	3.4
Piligrim, s.c. + Seedspor S	16.0	1.3	15.2	1.0	19.5	2.2
LSD_{05}		0.29		0.43		0.28

Note: P – the spread of root rot, % R – the development of root rot, %

As demonstrated in Table 5, the lowest LSD05 ranges from 0.29 to 1.98 in 2023 experiments and from 0.28 to 2.93 in 2024, which proves the high significance of the variants. The results indicate that depending on the cultivation technology, the pre-sowing seed treatment variant, and weather conditions, lentil yields fluctuated on average from 9.0 to 12.7c/ha. In 2023, given the severe drought and low seed yields, relatively high results were obtained in variants with minimal cultivation technology. Compared to no-till, it provides a 0.3-0.9c/ha greater lentil yield, although no significant difference was observed when compared with the traditional technology – 0.1-0.3c/ha. With the treatment of lentil seeds with protectants, there is an upward trend in seed yields. The maximum yield increase compared to control was observed in the variant with the combined application of seed protectants, amounting to 2.0-3.4c/ha (Table 6). Table 6 showed that the lowest LSD05 for the traditional technology amounts to 0.73, for the minimal technology – 0.46 and for no-till – 0.65. These results give evidence of the high significance of the variants in terms of the yield.

Table 6: The influence of seed treatment on the lentil yield under different cultivation technologies

Experiment variants		Yield,c/ha			Yield increase	
Cultivation technology	Pre-sowing seed treatment	2023	2024	Mean	c/ha	%
Traditional	Control	7.0	11.4	9.2	-	-
	Piligrim, s.c.	8.6	14.4	11.5	2.3	20.0
	Seedspor S	9.5	13.3	11.4	2.2	19.3
	Piligrim, s.c. + Seedspor S	10.3	14.9	12.6	3.4	27.0
	LSD_{05}			0.73		
Minimal	Control	7.2	11.4	9.3	-	-
	Piligrim, s.c.	8.7	14.7	11.7	2.4	20.5
	Seedspor S	9.6	13.6	11.6	2.3	19.8
	Piligrim, s.c. + Seedspor S	10.4	15.0	12.7	3.4	26.7
	LSD_{05}			0.46		
No-till	Control	6.9	11.1	9.0	-	-
	Piligrim, s.c.	7.8	14.8	11.3	2.3	20.3
	Seedspor S	8.9	13.1	11.0	2.0	18.1
	Piligrim, s.c. + Seedspor S	9.7	14.3	12.0	3.0	25.0
	LSD_{05}			0.65		

As suggested by Kaskarbaev et al. (2023), proper soil preparation for sowing is crucial to obtaining high and stable lentil yields in North Kazakhstan. Given that lentil plants are short and the lower bean attachment point is usually 7-8 cm above ground, the fields selected for this crop need to be either perfectly flat or harrowed before and after sowing. Lentils requires favorable conditions from germination to flowering due to low competitiveness with the windfall of the preceding culture and weeds and susceptibility to fungal diseases, especially in humid years (Kaskarbaev et al., 2023). Experimental findings from North Kazakhstan indicate that soil treatment strategies should account for variability in soil and landscape conditions, precluding a one-size-fits-all approach. Therefore, to reduce the intensity of tillage in the dry-steppe zone with dark chestnut soils, it is most important to know its exact impact on the soil and the plant (Suleimenov et al., 2013).

In recent years, in the cultivation of leguminous crops in North Kazakhstan, preference has been given to energy and water-saving technology: minimal tillage and no-till. However, in the cultivation of leguminous crops, especially those as short and vulnerable as lentils, the adoption of energy and water-saving technology results in the aggravation of the phytosanitary situation (Islam et al., 2023). There is an increase in the number of phytophages, the crops suffer from increasing contamination with annual and perennial root-propagating weeds, and fungal pathogens accumulate in plant debris and the soil. The detrimental impact of harmful organisms reduces lentil yields and seed quality. For this reason, when cultivating leguminous crops using minimal and no-till technologies, it is important to use protective measures, such as pre-sowing seed treatment and crop treatment against a complex of harmful organisms (Amangeldikyzy et al., 2018; Kochorov et al., 2023). In our studies, the variants applying the biological seed protectant Seedspor S demonstrated high effectiveness and environmental safety. We recommend this preparation for industrial application in cultivating lentils in North Kazakhstan and further research. The advantage of biologized systems lies in their improved environmental safety due to reduced chemical load on plants, lower costs due to the replacement of expensive chemical products with biological ones, and decreased stress phytotoxicity (Das et al., 2019). Our recommendations include the support and adoption of green agriculture to reduce the prevalent health risks and food contamination caused by overexposure and the constant use of chemicals for agriculture in Kazakhstan (Kenenbayev, 2024). We also suggest including tailoring seed treatment combinations based on the anticipated seasonal climate.

Our study established that high germination rates and yield prove the effectiveness of combining chemical and biological treatments under specific cultivation methods. These findings highlight the need for further research to optimize these interventions, especially under the dynamic weather patterns expected with climate change. Such adaptive strategies could form the basis for broader guidelines in lentil cultivation, with implications for leguminous crop management across different climates and soil types (Nisa et al., 2021). We also observed that minimal tillage is the most optimal and cost-effective technology to protect lentil crops from diseases compared to traditional and no-till cultivation technologies. (Atencio, 2021). It is found that minimal tillage is the most optimal and cost-effective technology to protect lentil crops from diseases compared to the traditional and no-till cultivation technologies. We argue for the expediency of the minimal cultivation technology because it involves surface tillage, which breaks down and shreds plant debris and destroys harmful organisms inside the soil and on its surface, particularly soil-borne diseases.

Conclusion

This study detected the fungal pathogens Fusarium ssp., Alternaria ssp., Colletotrichum ssp., Ascochyta ssp., Aspergillus, and Penicillium on the lentil seeds. Chemical and biological seed protectants hindered the spread and development of the diseases, contributing to the formation of healthy crop seedlings. Piligrim, s.c. in a tank mix with Seedspor S under the minimal cultivation technology showed high effectiveness against fusarium root rots with a marked decrease in plant infestation – 0.8-2.5% and provided high lentil yields – 12.0-12.7c/ha.

Acknowledgment: The study was conducted within the framework of the scientific and technical program "Development of sustainable farming system in changing climate conditions for various soil and climatic zones of Kazakhstan" BR22885719.

Author's Contribution: Abdumamat Kochorov*, Yerlan Utelbayev designed the research and conducted the data analysis. Alena Kharitonova, Berik Bazarbayev carried out field trials and seed treatment procedures. Vera Davydova and Tatyana Nelis reviewed and interpreted the results. All authors contributed to manuscript preparation and final review, approved the final manuscript for submission.

REFERENCES

Ahmed, S., & Ahmed, S. (2000). Efficacy of pesticides on population dynamics of F. oxysporum f. sp. lentis. *Annals of Agricultural Research*, 21, 527-529.

Amangeldi, N., Amirkulova, A.Z., Agibaev, A.Z., Dababat, A.A., & Kochorov, A.S. (2016). Effectiveness of biologics application against root rot of grain crops. *Biosciences Biotechnology Research Asia*, 13(4), 1997–2001.

Amangeldikyzy, Z., Kochorov, A.S., Karakaya, A., Morgunov, A.I., Karbozova, R.D., & Gabdulov, M.A. (2018). Immune-phytopathological assessment of resistance of wheats to stem rust in conditions of the Southeast of Kazakhstan. *Ecology, Environment and Conservation*, 24(4), 1604–1610.

Amulya, M., Dayal, A., & Rai, P.K. (2021). Pre-Sowing Seed Treatment with Bio Inoculants and Micronutrients on Growth, Yield and Yield Attributing Traits of Lentil. *International Journal of Environment and Climate Change*, *11*(11), 92-99. https://doi.org/10.9734/ijecc/2021/v11i1130518

Atabayeva, S., Nurmahanova, A., Yernazarova, G., Asrandina, S., Alybayeva, R., Ablaikhanova, N., Turasheva, S., Tynybekov, B., & Fei, L.U.I. (2018). Effect of cadmium on mineral composition of rice grain. *Research on Crops*, 19(4), 569–575.

Atencio, S.C. (2021). Role of crop fertility and seed treatments in managing fusarium root rot of lentil (Lens culinaris Medikus) in the northern Great Plains. Montana State University, Bozeman, MT, USA. https://scholarworks.montana.edu/handle/1/16343

Baah, P., Nyaku, S.T., Agamah, S., & Tongoona, P.B. (2024). Evaluation of Preplant Seed Protectants for the Management of Root-Knot Nematode of Okra in Ghana. *International Journal of Agronomy*, *2024*(1), 1–11. https://doi.org/10.1155/2024/4025844

Bugingo, C. (2022). *Characterization and assessing fungicide sensitivity of Fusarium spp. causing root rot and wilt in lentils in the northern Great Plains*. Ph.D. Dissertation, Plant Sciences and Plant Pathology, Montana State University. https://scholarworks.montana.edu/xmlui/handle/1/18261

Campanella, V., & Miceli, C. (2021). Biological control of Fusarium wilt of Ustica landrace lentil. *Crop Protection*, *145*, 105635. https://doi.org/10.1016/j.cropro.2021.105635

Chekaev, N.P., Blinokhvatova, Y.V., Nushtaeva, A.V., & Nogaev, V.O. (2022). The Effect of Microbiological Fertilizers and Chemical Protectants on the Sowing Qualities of Agricultural Seeds. *Volga Region Farmland*, 2(1), 1003-1005. https://doi.org/10.36461/vrf.2022.12.1.009

Chen, W., & Sharma, H.C., (2011). In Crop protection compendium for chickpea and lentil diseases and pests. The American Phytopathological Society, St Paul, MN, p. 166.

Das, A., Dutta, S., Jash, S., Barman, A.R., Das, R., Kumar, S., & Gupta, S. (2019). Current Knowledge on Pathogenicity and Management of Stemphylium botryosum in Lentils (Lens culinaris ssp. culinaris Medik). *Pathogens*, *8*(4), 225.

De, R.K., & Chaudhary, R.G. (1999). Biological and chemical seed treatment against lentil wilt. *Lens Newsletter*, 26(1), 28-31.

Doolotkeldieva, T., & Bobusheva, S. (2022). Microbial communities of vegetable seeds and biocontrol microbes for seed treatment. *Seed Science and Technology*, 50(1), 77–102. https://doi.org/10.15258/sst.2022.50.1.08

Dutta, P., Kumari, A., Mahanta, M., Upamanya, G.K., Heisnam, P., Borua, S. & Vijayreddy, D. (2023). Nanotechnological approaches for management of soil-borne plant pathogens. *Frontiers in Plant Science*, *14*, 1136233. https://doi.org/10.3389/fpls.2023.1136233

FAO, 2023. Food and Agriculture Organization Corporate Statistical Database. Available online at: http://faostat.fao.org/

GOST 12038-84, (1986). Agricultural seeds. Methods for determination of germination. Moscow: Gosstandart Rossii: Izdatelstvo standartov.

GOST 12044-93, (1995). Agricultural seeds. Methods for determination of disease infestation. Gosstandart Rossii, Izdatelstvo standartov, Moscow, Russia.

Gridneva, E.E., & Kaliakparova, G.S. (2018). Prospects for the development of the niche crops market in the Republic of Kazakhstan. *Ekonomika i Statistika*, 2, 59-56.

Handelsman, J., & Stabb, E.V. (1996). Biocontrol of soilborne plant pathogens. *The Plant Cell*, *8*(10), 1855.

Islam, M.A., Sarkar, D., Alam, M.R., Jahangir, M.M.R., Ali, M.O., Sarker, D., Hossain, M.F., Sarker, A., Gaber, A., Maitra, S., & Hossain, A. (2023). Legumes in conservation agriculture: A sustainable approach in rice-based ecology of the Eastern Indo-Gangetic Plain of South Asia – an overview. *Technology in Agronomy*, *3*(1), 1–17. https://doi.org/10.48130/tia-2023-0003

Kenenbayev, S. (2024). Green Agriculture with Negation of Chemicals in Kazakhstan. *SABRAO Journal of Breeding and Genetics*, *56*(4), 1534–1542. https://doi.org/10.54910/sabrao2024.56.4.19

Kochorov, A.S., Utelbayev, Y.A., Tuleeva, A.K., Kharitonova, A.S., Bazarbayev, B.B., Davydova, V.N., & Aldabergenov, A.S. (2023). Effect of seed protectants on fungal disease pathogens when using different technologies of oilseed flax, Linum usitatissimum cultivation. *Caspian Journal of Environmental Sciences*, *21*(4), 827-839. https://doi.org/10.22124/cjes.2023.7132

Madenova, A.K., Atishova, M.N., Kokhmetova, A.M., Galymbek, K., & Yernazarova, G.I. (2019). Identification of carriers of resistance to common bunt (Tilletia caries) of winter wheat. *Research on Crops*, 20(4), 782–790.

Martinez, S.I., Wegner, A., Bohnert, S., Schaffrath, U., & Perelló, A. (2021). Tracing seed to seedling transmission of the wheat blast pathogenMagnaporthe oryzaepathotypeTriticum. *Plant Pathology*, 70(7), 1562–1571. https://doi.org/10.1111/ppa.13400

Mishra, S.N., Singh, S., Para, P.K., Sharma, L., & Bhandari, V.V.S. (2023). A Review: Combination of Fungicide, Polymer Coating and Packaging Materials on Improve Germination Rate and Improve Uniformity of Seedling Emergence of Different Seeds during Storage. *International Journal of Environment and Climate Change*, *13*(8), 2142–2157. https://doi.org/10.9734/ijecc/2023/v13i82173

Mussynov, K.M., Kipshakbaeva, A.A., Arinov, B.K., Utelbayev, Y.A., & Bazarbayev, B.B. (2017). Productivity and cooking advantages of lentil grades grown under conditions found in North Kazakhstan. *Pakistan Journal of Nutrition*, 16(11), 843-849.

Nisa, R.T., Bhat, K.A., Basu, U., Rashid, R., Wang, X., Jan, S.K., & EL Sabagh, A. (2021). Identification and characterization of triple action bioagents (TAB) and their potency against Fusarium wilt of lentil. *Horticulturae*, *7*(12), 587. https://doi.org/10.3390/horticulturae7120587

Pandey, A.K., Kumar, A., Mbeyagala, E.K., Barbetti, M.J., Basandrai, A., Basandrai, D., & Lamichhane, J.R. (2023). Anthracnose resistance in legumes for cropping system diversification. *Critical Reviews in Plant Sciences*, *42*(4), 177-216. http://dx.doi.org/10.1080/07352689.2023.2228122

SNEDECOR applied statistics package software: One-way ANOVA, (2004). Version 4.7.

Supronienė, S., Kadžienė, G., Shamshitov, A., Veršulienė, A., Šneideris, D., Ivanauskas, A., & Žvirdauskienė, R. (2023). Soil Fungistasis against Fusarium Graminearum under Different tillage Systems. *Plants*, *12*(4), 966. https://doi.org/10.3390/plants12040966

Thavarajah, D., Thavarajah, P., Wejesuriya, A., Rutzke, M., Glahn, R.P., Combs, G.F., & Vandenberg, A. (2011). The potential of lentil (Lens culinaris L.) as a whole food for increased selenium, iron, and zinc intake: Preliminary results from a three-year study. *Euphytica*, 180, 123–128. https://doi.org/10.1007/ s10681-011-0365-6

Utelbayev, Y.A., Abysheva, G.T., Bazarbayev, B.B., Mussynov, K.M., & Tahsin, N.T. (2021). Development and spread of diseases in spring camelina (Camelina sativa (l.) grantz) when using various treatments. *OnLine Journal of Biological Sciences*, *21*(4), 288-298. https://doi.org/10.3844/ojbsci.2021.288.298

Yan, H., & Nelson, B. (2022). Effects of Soil Type, Temperature, and Moisture on Development of Fusarium Root Rot of Soybean by Fusarium solani (FSSC 11) and Fusarium tricinctum. *Plant Disease*, *106*(11), 2974–2983. https://doi.org/10.1094/pdis-12-21-2738-re

Zitnick-Anderson, K., Jbir, T.G., Carlson, A., Postovit, S., Pasche, J., & Kalil, A. (2021). Fusarium Species Associated with Root Rot of Lentil (Lens culinaris) in North Dakota. *Plant Health Progress*, *22*(4), 524–528. https://doi.org/10.1094/php-03-21-0063-rs

Dospekhov B.A. (1985). Methodology of field experience. Moscow: Agropromizdat.

Metodika gosudarstvennogo sortoispytaniia. (1983). Moscow: State Commission for Variety Testing of Agricultural Crops under the USSR Ministry of Agriculture. Retrieved from: https://gossortrf.ru/upload/2019/08/metodica_3.pdf

Mozhaev, N.I., Arinov, K.K., Shestakova, N.A. (2014). Workshop on plant growing: textbook. Astana: KazATU.

Chumakov, A.E., Minkevich, I.I., Vlasov, Yu.I. (1974). Basic methods of phytopathological research. Moscow: Kolos.

Sagitov, A.O., Kambulin, V.E. (2016). Methodological guidelines for recording and identifying harmful and especially dangerous harmful organisms. Astana: Kazakh Agrotechnical University.

Arinov K.K., Musynov K.M., Shestakova N.A. (2016). Plant growing. Astana: Kazakh Agrotechnical University.

Kaskarbaev, J., Pokhorukov, Y., Kitdralina, A., Sasykov, A., Werner, A. (2023). Technology of Cultivation of Oilseeds in the North of Kazakhstan. A.I. Baraev Research and Production Center for Grain Farming. 2023. Available online: https://baraev.kz/statya/427-tehnologiya-vozdelyvaniya-maslichnyh-kultur-na-severe-kazahstana.html?ysclid=lepbd5nao0680069173y

Suleimenov B., Saparov A., Tanirbergenov S. (2013). Status and Prospects of Use of Irrigated Seriozems Of Southern Kazakhstan. Soil Science and Agrochemistry, 1, 19-27. Retrieved from: https://journal.soil.kz/jour/article/view/336/328