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EFFECT OF ORGANIC FERTILIZER ON YIELD AND OIL QUALITY OF FLAXSEED GROWN IN THE KAZAKH SEMI-ARID STEPPE ZONE

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Abstract

Flaxseed, scientifically known as Linum usitatissimum L., is a globally cultivated crop valued for its oil and fiber production and diverse nutritional, therapeutic, and culinary applications. In scientific periodicals, Kazakh studies of oil flax do not cover the area of research related to local organic fertilizers. The main objective of the project was to study the effect of an organic fertilizer based on bird droppings and highly effective microorganisms on the yield and technological qualities of flax seeds of the oilseed variety Kostanai Yantar in the Kazakh semi-arid steppe zone and based on the results obtained, to recommend to producers the working doses of target fertilizer that increase crop of oil flax seeds. The seed germination index evaluated at concentrations of 0.1; 1.0; 2.5; 5.0, and 10.0% was above 100%, indicating the fertilizer's maturity and stability. One-factor field experiments over two years have shown that the experimental fertilizer dose of 10 t/ha is the most optimal and leads to an increase in yield by an average of 33.7%. All experimental variants increased the protein content by 12% and did not affect the oil content in the 2022 oil crop flax seeds. A dose of 10 t/ha of organic fertilizer tested in the project can be recommended to interested agricultural enterprises to produce oil flax seeds.

Key words: Crop structure; Effective microorganisms; Poultry manure; Seed quality; Yield.

Introduction

Flax or flaxseed (*Linum usitatissimum* L.) is a significant industrial crop cultivated worldwide for its oil and fiber production. Along with oil and fiber, flaxseed offers a diverse range of nutritional and therapeutic benefits as a feed and food source, thanks to its high content of α-linolenic acid (an omega-3 fatty acid), lignans, protein, minerals, and vitamins (Dzuvor *et al*., 2018; Cui *et al*., 2022). However, the unpredictable occurrence of environmental stresses like drought, heat, salinity-alkalinity, and diseases poses a challenge to meeting the increasing market demand for flax. Furthermore, these abiotic and biotic factors have detrimental effects on biodiversity and the quality of oil and fiber (Klein *et al*., 2017; Gao *et al*., 2018; Yadav *et al*., 2022).

Kazakhstan is one of the world's largest oilseeds producers (Stavropoulos *et al*., 2023). In 2018/19 MY, the share of Kazakhstan in the world production of flaxseed was 25% (Anon., 2019). This crop is widely grown in temperate regions (Yan *et al*., 2018). In recent years, there has been a decline in the quality of cultivated land in Kazakhstan, as mentioned by Yerseitova *et al*., (2018). Soil productivity in Kazakhstan is being negatively affected by factors such as the neglect of crop rotation, the environmental impact of chemical fertilizers, and the insufficient availability of organic and mineral fertilizers. These factors lead to a decrease in humus content in the upper layers of the soil, as highlighted by Yerseitova *et al*., (2018).

Researchers have found that chemical factors, particularly the application of mineral fertilizers, impact flax productivity, as Emam (2019) highlighted. Among the nitrogen fertilizers introduced into the soil, such as ammonium nitrate, ammonium sulfate, and urea, the highest yields of flax straw and seeds are obtained when using ammonium nitrate and ammonium sulfate, as opposed to urea (Emam, 2019).

Increasing the nutrient use efficiency of crops is also possible with the help of biofertilizers (Gulshan *et al*., 2022). Small-scale producers of vegetables and fruits in economically developed countries use local organic fertilizers processed from municipal solid waste, manure, and agricultural waste by composting. Organic soil fertilizers meet the nutrient needs of crops, and to preserve soil health, it is necessary to modify the soil's physical, chemical, and biological characteristics (Adekiya *et al*., 2019; Eyhorn *et al*., 2019; Yaldız *et al*., 2019; Khasawneh & Othman, 2020).

However, organic soil fertilizers can add undesirable elements such as greenhouse gas and odor molecule emissions, toxic heavy metals, or salts, hindering crop growth and reducing yields. These destructive processes are inhibited by adding organic, inorganic, or biological additives to the compostable or bio-humus mixture. The latter are highly effective microorganisms (Barthod *et al*., 2018). The quality of compost and its maturity is controlled by biological tests (Luo *et al*., 2018; Kebrom *et al*., 2019).

In scientific periodicals, Kazakh studies of oil flax do not cover the area of research related to local organic fertilizers. The initial objective of the project was to study the effect of an organic fertilizer based on bird droppings and highly effective microorganisms on the yield and technological qualities of flax seeds of the oilseed variety Kostanai Yantar in the Kazakh semi-arid zone of the steppes based on the results obtained, to recommend to producers the working doses of target fertilizer that increase crop of oil flax seeds.

Material and Methods

Composted organic fertilizer based on chicken manure and highly effective microorganisms (hereinafter referred to as the fertilizer) was purchased from the Akmola-Phoenix poultry farm.

Oil flax seeds with the name the variety "Kostanay Yantar" were purchased from the Research and Production Center for Grain Farming named after A.I. Baraev.

Laboratory trails: Evaluation of the phytotoxicity of the fertilizer in relation to oil flax using a biological analysis of seed germination in aqueous extracts of the fertilizer at concentrations of 0.1; 1.0; 2.5; 5.0 and 10.0% was carried out according to generally accepted methods (Luo *et al*., 2018; Kebrom *et al*., 2019) with minor modifications. Healthy seed material was selected for analysis, and underdeveloped, mechanically damaged, diseased, weak seeds were removed. The bottom of Petri dishes (diameter 9 cm) was covered with filter paper moistened with 2 ml of an aqueous fertilizer extract for each fertilizer concentration in triplicate. Twenty flax seeds were placed in each Petri dish. Three filter dishes soaked in sterile distilled water were used as a control.

To measure the length of the shoots, 20 seedlings were selected from each group of test samples and the control variant after six days of germination. It was measured with a caliper from the beginning of the curved arc of the hypocotyl genu to the cotyledon leaves. Then the average shoot length was calculated for each experimental variant and the control group. Similarly, the root length measurement was taken from the root tip to the bend in the hypocotyl curve.

The findings were also represented as the germination index (GI), which is calculated by multiplying the relative germination percentage (% G) and the relative root elongation percentage (% L) and dividing the product by 100, in comparison to the control group treated with distilled water (Barral & Paradelo, 2011).

In the test of relative germination of seeds, Petri dishes were kept for 6 days at a constant temperature (20^{o}C) and high humidity.

On the fourth day, the evaluation of germination energy was conducted by observing and counting the number of typical seedlings under controlled conditions of a constant temperature (20°C) and high humidity, in accordance with the ISTA (International Seed Testing Association) guidelines from 2004 (Anon., 2004). An ideal germination rate is considered to be 95% or higher.

Field trails: A one-factor field experiment was conducted to investigate the efficacy of various doses of organic fertilizer on flax.

A one-factor field experiment was conducted to investigate the efficacy of various doses of organic fertilizer on flax.

Plots of 1 × 1 m in size were used, consisting of five rows at a distance of 20 cm from each other. The experiments included four variants in three replicas: (1) - without the use of fertilizer (control), (2) - with the use of fertilizer 5 t/ha, (3) - with the use of fertilizer 10 t/ha, and (4) - with the use of fertilizer 15 t/ha.

Flax was planted using a narrow-row sowing method on May 24, 2021, and May 20, 2022. The recommended seeding rate of 6.0 million seeds per hectare was followed, and the seeds were manually planted at a depth of 4-5 cm. Throughout the growing season, the standard technology of flax cultivation was used, as well as care measures, which consisted of regular weed and bark mechanical removal, without chemicals. During the growing season, artificial irrigation was not applied. The 2021 crop was harvested on September 10; the 2022 crop was harvested on September 19.

Determination of yield and related parameters: The yield and quality of seeds were analyzed after full maturation when more than 80% of oil flax capsules had reached the yellowing phase. The number of plants per unit area of the selected variants in 3 replicas was counted. The average number of capsules per plant was determined by calculating the average number of capsules in a group of 25 plants across three replicates, and the average value was obtained. Similarly, the average number of seeds per capsule was determined by calculating the average number of seeds in a group of 5 capsules across three replicates. After threshing, the seeds of all plants from the control group and each treatment were dried to a moisture content of 7%, and their weight was determined. The overall weight of 1000 seeds and the specific weight of seeds from one plant was determined using a digital scale in triplicate. The total seed yield obtained from the plot was calculated in units of measurement as cwt/ha.

Chemical analysis of organic fertilizer: Was carried out by employees of the Agroecological Testing Center at the Non-Commercial Joint Stock Company "Kazakh Agrotechnical Research University named after S. Seifullin" (Table 1).

An analysis of the technological qualities of the seeds of the 2022 crop, namely: The content of proteins, oils, and fatty acids, was carried out by employees of the Laboratory of Biochemistry and Quality Technology, LLP "Scientific and Production Center for Grain Farming named after A.I. Baraev (Fig. 2AB, Table 6).

Statistical analysis

The measurements were conducted with three replications, and a one-way analysis of variance (ANOVA) was performed to determine significant differences among the options. Statistical significance was defined as P values ≤ 0.05. The data are presented as mean ± standard deviation (SD). Then the obtained data were subjected to statistical processing using the XLSTAT program.

Result and Discussions

To achieve the goal of the project, the following tasks were solved: (1) - a study of the chemical composition of the target fertilizer and comparison with the literature data, (2) - a study of the phytotoxicity of the target fertilizer, (3) - evaluation of the yield and technological qualities of oil flax seeds of the Kostanay amber variety after processing planting soil with target fertilizer in the conditions of the steppe zone of Kazakhstan, (4) - recommendations for agricultural producers on dosages of target fertilizer to increase the yield of oil flax seeds.

Laboratory trails: Identifying specific chemicals in organic fertilizers that either stimulate or inhibit seed germination can contribute to developing strategies to enhance the effectiveness of recycled organic fertilizers in agriculture.

Therefore, at the project's first stage, a study of the chemical composition of the target fertilizer (Table 1) and a comparison with literature data (Table 2) were carried out.

As seen in Tables 1 and 2, the nitrogen contents in the target fertilizer, both in 2021 and 2022, were within the norm recommended in scientific periodicals (Cui *et al*., 2022) when 5 t/ha of fertilizer was applied to the soil. The other two fertilizer doses are outside the recommended total nitrogen limit. The same can be said about the content of the phosphorus compound (P_2O_5), with a slight excess in 2021 at the level of 10 kg/ha fertilizer applied. A different picture is observed with the potassium compound (K_2O). In the target fertilizer dosage of 5 t/ha, K_2O is almost two times less than the lower limit of the recommended rate, and fertilizer doses of 10 and 15 t/ha reach this rate for the potassium compound (Tables 1 and 2). All three doses of the target fertilizer were field tested to achieve the recommended concentration (in the case of K_2O), assuming that excess (in the case of nitrogen and phosphorus) of chemical compounds may contribute to minor phytotoxicity.

Study of target fertilizer phytotoxicity: The phytotoxicity of a specific fertilizer can be attributed to its impact on seed germination, root growth, or both, as Luo *et al*., (2018) mentioned. It is crucial to comprehend the individual contributions of these factors when devising strategies to mitigate or eliminate the adverse effects of organic fertilizers on seedling establishment. For instance, if the phytotoxic effect primarily affects germination but not subsequent growth, one approach could involve germinating the seeds separately without the application of organic fertilizers and then transplanting the seedlings into fields enriched with soil supplemented with organic fertilizers, as suggested by Kebrom *et al*., (2019).

The results of testing the germination of flax seeds at different concentrations of filtrates of the target fertilizer show that fertilizer concentrations up to 5.0% do not inhibit and, at 2.5%, significantly activate the elongation of the shoot and roots of oil flax (Table 3). All experimental variants positively affect germination and germination energy (Table 3).

The recommended levels of chemical constituents in the fertilizer are presented in the literature as total nitrogen (N) within 75-150 kg/hm^2, P_2O_5 within 35-75 kg/hm^2, and K_2O within 35-52.5 kg/hm^2 (Cui *et al*., 2022). Table 2 shows the amount of chemical inorganic constituents in the composition of the target fertilizer (Table 1) in terms of kg/ha for comparison with their recommended doses (Cui *et al*., 2022).

Table 1. Chemical composition of organic fertilizer based on bird droppings in 2021 and 2022 years.

Year	Total moisture, %	pH	Organic substance, %	The actual content of chemical compounds (g per 100 g fertilizers), %		
				Nitrogen total	P_2O_5	K_2O
2021	39.2	7.61	20.88	1.65	1.7	0.35
2022	32.35	7.55	35.3	2.89	1.29	0.38
Average	35.77	7.58	28.1	2.27	1.5	0.37

Table 2. Calculated doses of chemical constituents in the target fertilizer in 2021 and 2022 years.

Field trials	Fertilizer	The quantity of chemical constituents in the target fertilizer		
Years	t/ ha	Nitrogen total kg/ha	P_2O_5 kg/ha	K_2O kg/ha
2021	5	82.5	85.0	17.5
	10	165.0	170.0	35.0
	15	247.5	255.0	42.5
2022	5	144.5	64.5	19.0
	10	289.0	129.0	38.0
	15	433.5	193.5	57.0
		The recommended amount (Cui *et al*., 2022)		
		75-150	35-75	35-52.5

Table 3. The effect of various concentrations of organic fertilizer on the growth of seedlings of oilseed flax variety Kostanay Yantar.

Concentration,%	Germination energy %	Seed germination, %	Shoot length, cm	difference sample means d	Root length, cm	difference sample means d
Control	86.6	87.3	5.1 ± 0.06		6.1	
0.1	91	90.6	5.4 ± 0.12	0.3	9.8 ± 0.14	3.7
1.0	100	98.6	5.4 ± 0.08	0.3	9.6 ± 0.14	3.5
2.5	94.6	94.6	5.5 ± 0.12	0.4	9.9 ± 0.05	3.9
5.0	97.3	97.3	5.2 ± 0.09	0.1	9.4 ± 0.12	3.3
7.5	98.6	98.6	4.28 ± 0.17	-0.8	8.77 ± 0.23	2.67
10.0	93.3	93.3	4.8 ± 0.09	-0.3	8 ± 0.2	1.9
[a]$LSD_{0.5}$				0.39		0.49

[a] Least significant difference

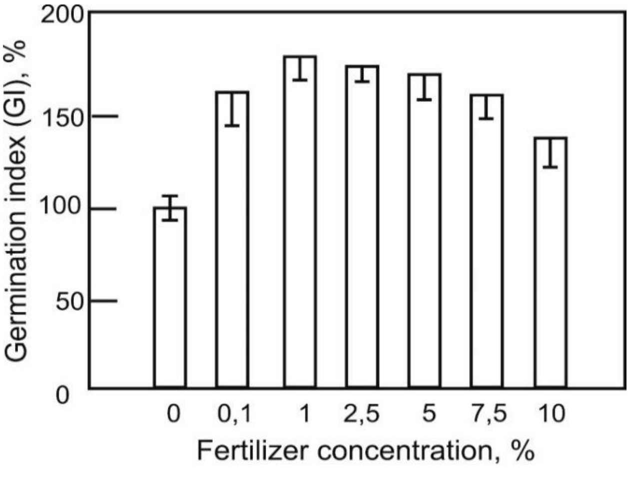

Fig. 1. Germination index of oil flax seeds in a medium with aqueous extracts of the target fertilizer.

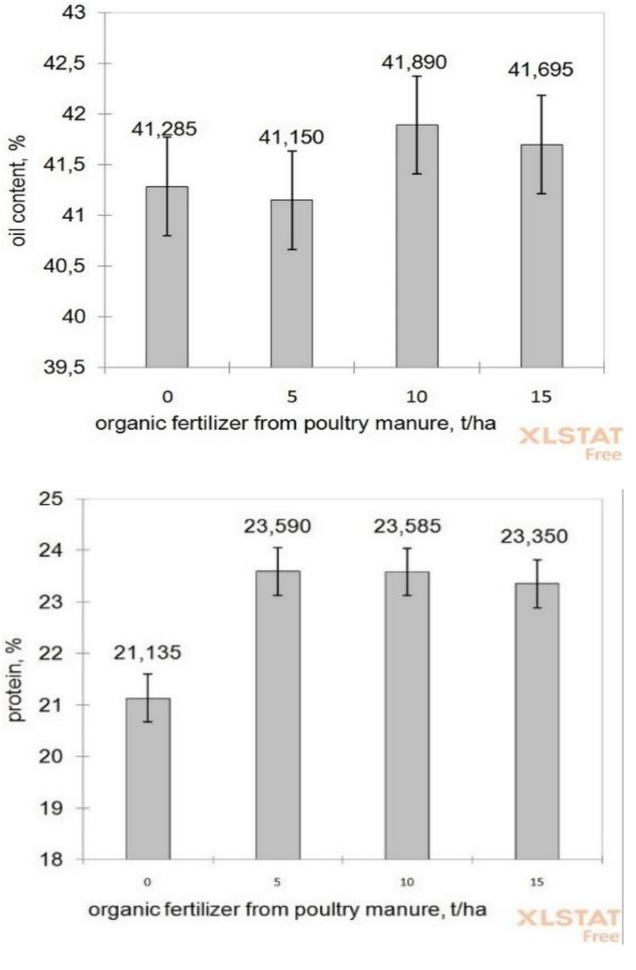

Fig. 2. The content of fat (A) and protein (B) in flax seeds of the oilseed crop in 2022.

According to Luo *et al*., (2018), a germination index (GI) exceeding 80% indicates the absence of phytotoxicity in compost. A GI below 80% suggests potential phytotoxicity to crops, while a GI below 50% indicates high phytotoxicity. In a separate study by Kebrom *et al*., (2019), the GI of kale and possibly other crops was found to be below 80% when exposed to 25% dilution of aqueous extracts of chicken manure, confirming the phytotoxicity of the organic additive at that concentration.

In the current study, the GI of oil flax seeds incubated in water extracts of the target fertilizer was above 100% for concentrations up to 10%, indicating that the target fertilizer did not exhibit phytotoxicity at the tested concentrations (Fig. 1).

According to the literature, the application of high doses of organic fertilizers from bird manure to the soil leads to the fact that some nutrients, heavy metals, and salts reach a level of toxicity, inhibit the growth and development of crops, and reduce yields (Kebrom *et al*., 2019). Aerobic composting of organic waste with biological products results in a quality organic fertilizer, with less toxic substances, and a higher content of nutrients available to plants (Barthod *et al*., 2018). Adequate dosage of organic filtrate can significantly minimize negative effects on the plant. Therefore, dose optimization and subsequent study of the effect of this dose on crop growth are considered necessary for the possible use of organic fertilizer leachate in agriculture (Cesaro *et al*., 2015). Therefore, at the next stage of field trials, taking into account our own data (Tables 1-3) and literature data (Kumari *et al*., 2014; Adekiya *et al*., 2019; Yaldız *et al*., 2019), we studied the effect of three doses of target fertilizer 5, 10, and 15 t/cwt on the growth and yield of oil flax. In a study by Adekiya *et al*., (2019), the application of bird droppings as an organic fertilizer had a significant positive impact on radish plants. It resulted in increased leaf weight, root length, root weight, and girth of radish roots. The highest values for these parameters were observed with a dosage of 5 tons per hectare (5 t/ha) of bird droppings. In another secondary research, after the application of fertilizer with the addition of bird manure in the amount of 5 t/ha, the maximum yield of peas was recorded (Kumari *et al*., 2014). A literature review indicates that proper nutrition under favorable conditions contributes to increased plant height, the number of nodules, and the number of plant branches (Yaldız *et al*., 2019). In this work, with reference to the works cited above, for the reference point, firstly, a target dose of fertilizers of 5 t/ha was chosen. Taking into account the data of the chemical analysis of the fertilizer for an insufficient amount of a potassium compound in the target fertilizer dosage of 5 t/ha (Tables 1, 2), additional fertilizer doses of 10 and 15 t/ha were chosen for field trials.

Field trials: The field experiments were conducted in the Akmola region, specifically in the village of Nauchny, Kazakhstan, located at approximately 51°37'26.9 north latitude and 71°00'57.1 east longitude. The region falls within the steppes zone, characterized by a climate of pronounced continentality, featuring long cold winters and dry, hot summers. The average annual temperature in the area is 1.7°C, and the average annual rainfall is recorded at 325.6 mm. The frost-free period typically lasts for 100-130 days. The soil type in the region is classified as southern carbonate chernozems with a heavy loamy texture. It has a humus content of 2.8% and a pH of 7.5. The soil is characterized by a low level of mobile phosphorus (9.25 mg/kg) and a high level of exchangeable potassium (500.7 mg/kg). It is also highly saturated with bases (60%).

During the flax growing season from May to September 2021, the accumulated active temperatures amounted to 3934°C, while in 2022, it was 3841°C. Regarding precipitation, 132 mm was recorded in 2021 and 125 mm in 2022. The hydrothermal coefficient (HTC) during both years ranged from 0.32 to 0.34, indicating dry crop growth and development conditions.

A closer analysis of moisture supply from June to August reveals a deficiency in precipitation, particularly in June and July 2021, where the amount was approximately half of the long-term average. Notably, heavy rainfall in the form of heavy rain occurred on July 29-30, 2022, which could have a negative impact on the yield of the studied crop in 2022 following the application of the target fertilizer (Table 4).

The effect of the organic fertilizer on the yield of oil flax seeds: Table 4 presents the results of the fertilizer's impact on the oil flax seed yield. Oil flax is known to be sensitive to abiotic conditions, and as a result, important traits that are valuable both economically and adaptively respond differently to environmental factors. Literature suggests that the seed yield of oil flax varieties in the Middle Urals region can vary significantly from 4.1 cwt/ha to 12.3 cwt/ha over different years, as reported by Goreeva *et al*., (2020). In our work in 2021, the yield of oil flax seeds under abiotic conditions was 10.6 cwt/ha or 106 g/m^2 in the control group, and in groups with the target fertilizer, seed productivity was about 154 g/m^2 (15.4 cwt/ha) at fertilizer dose of 5 t/ha, and 138 g/m2 (13.8 cwt/ha) at fertilizer dose of 15 t/ha (Table 4). The results of the effect of fertilizer on the yield of oil flax seeds are presented in Table 4.

These results are in good agreement with the data of another study (Goreeva *et al*., 2020). The authors showed different productivity of several varieties of flax culture, which are formed in the meteorological conditions of the Middle Cis-Ural region. In the mentioned study by Goreeva *et al*., (2020), the best variety outperformed all other tested varieties in terms of productivity, exhibiting the highest seed yield of 157 g/m². Additionally, several other varieties showed productivity levels ranging from 80 g/m² and above, indicating their relatively high seed yields. In the experiment (Table 4), the seed productivity of the crop without fertilization was 106 g/m^2, and the application of the target fertilizer led to an increase in yield, resembling an increase in productivity due to a change in plant variety in the cited work (Goreeva *et al*., 2020). Thus, in the cited work, the authors, by selecting crop varieties, showed a difference in productivity. Our work shows a similar effect of productivity growth from the use of a target fertilizer on one variety of the 2021 crop (Table 4). In the study cited by Goreeva *et al*., (2020), different abiotic conditions in other years of research resulted in a reduction in the average seed yield of oil flax varieties. In 2012, the average seed yield decreased to 104 g/m², representing a decline of 48% compared to the highest yield.

Similarly, in 2013, the average seed yield dropped to 182 g/m², accounting for an 83% decrease. In 2015, the average seed yield declined to 80 g/m², reflecting a reduction of 37% compared to the highest yield observed. These fluctuations in seed yield highlight the significant influence of abiotic factors on the productivity of oil flax varieties in different years. In this paper, similarly, abiotic conditions could lead to a decrease in yield. For example, in 2022, a relatively low oil flax yield was observed compared to 2021 (Table 4).

The percentage of yield increase in 2021 exceeded the figure for 2022 by 40.43% in the compared groups with the application of the target fertilizer of 5 t/ha. This difference decreased in the compared groups with 10 t/ha and 15 t/ha fertilizer applications and amounted to 20.1% and 4%, respectively (Table 4). The difference over the 2021 and 2022 years seems to be related to abiotic factors (Goreeva *et al*., 2020).Heavy precipitation in the form of heavy rain recorded on July 29-30, 2022, and/or other abiotic factors could negatively affect the yield of the studied crop with the target fertilizer (Table 4).The established fact of yield increase under the action of organic fertilizer in this work (Table 4) is in good agreement with other work, where the application of granular organic fertilizer based on bird droppings gave a significant increase in spring wheat yield by 44%, and the application of mineral fertilizers gave an increase of only 22 % (Apaeva *et al*., 2020).

T*he effect of the organic fertilizer on the elements of the crop structure:** Despite dry conditions in 2021-2022 with a hydrothermal coefficient (HTC) of 0.32-0.34, classified as severe drought, the application of the organic fertilizer at doses of 5 t/ha and 10 t/ha had a positive effect on the formation of oil flax seed yield. According to the analysis of the elements of the structure of oil flax crop, carried out in 2021 (Table 5), the application of the target fertilizer in amounts of 5 t/ha and 10 t/ha led to a significant increase in the number of oil flax plants per unit area (F:23.727; $p\leq 0.05$), and this increase as a percentage were B = 33% and 15%, respectively.

Analysis of the data on the same crop parameter in 2022 showed the constancy of this parameter concerning the control, which amounted to the increase as a percentage B = 12%, 6%, and 2% for group variants with applied target fertilizer of 5, 10, and 15 t/ha, respectively (F:1.045; $p\geq 0.05$), as shown in Table 5. The absence of an increase in plant seedling density in 2022 may indicate the influence of the abovementioned abiotic factors.

A paradoxical result was observed when studying the effect of the applied amount of the target fertilizer on the number of capsules in one plant. On average, over two years, the most significant increase in this parameter up to 25.3 pieces was in plants from the group with applied target fertilizer of 10 t/ha (Table 5), which amounted to an increase in percentage by B = 64% compared to the control variant (F:10.518; $p\leq 0.05$**). Applying 5 t/ha and 15 t/ha of fertilizer resulted in an average increase in the capsules in one plant by B=43% and B=41%, respectively, over two years compared to the control variant (Table 5). Thus, all three doses of applied fertilizers led to a significant increase in the number of capsules per plant in the experiments of 2021 and 2022.

Table 4. The effect of organic fertilizer based on bird droppings on the yield of oil flax.

Group	Productivity, cwt/ha			Yield increase					
	2021yr	2022 yr	Average over two yrs	2021 (cwt/ha)	2022 (cwt/ha)	Average over two yrs	2021yr (%)	2022yr (%)	Average over two yrs (%)
Control	10.6±0.12	10.27±2.54	10.44	-	-	-	-	-	-
Fertilizer, t/ha									
5	15.4±1.0	10.8±2.57	13.1	4.8	0.5	2.67	45.28	4.85	25.6
10	15.2±1.04	12.7±1.25	13.96	4.6	2.4	3.53	43.4	23.3	33.7
15	13.8±1.54	13.0±1.53	13.39	3.2	2.7	2.95	30.2	26.2	28.3

Table 5. The effect of organic fertilizer on the elements of the crop structure of the oilseed flax in 2021 in 2022.

Variant	The number of plants per unit area, pieces / m² (A/B)[a]			Number of capsules per plant pcs (A/B)			Number of seeds in a capsule pcs (A/B)			Weight of 1000 seeds g (A/B)			Weight of seeds from 1 plant g (A/B)		
	2021	2022	Two years average	2021	2022	Two years average	2021	2022	Two years average	2021	2022	Two years average	2021	2022	Two years average
Control	351.3±4.5 (100%/0%)	336.0±19.2 (100/0)	343.7 (100 / 0)	14.2±2.1 (100 / 0)	16.5±3.19 (100 /0)	15.4 (100 / 0)	7.2±0.6 (100 / 0)	5.68±0.23 (100/0)	6.44 (100 / 0)	5.3±0.31 (100 / 0)	6.18±0.12 (100 / 0)	5.74 (100 / 0)	0.74±0.02 (100 / 0)	0.57±0.13 (100 / 0)	0.66 (100 / 0)
Organic fertilizer 5 t/ha	466.3±10.6 (133/33)	379.0±18.5 (113/13)	422.7 (123/23)	13.13±0.1 (93 /-7)	30.9±1.6 (187 /87)	22.0 (143/43)	8.31±1.5 (115/15)	6.17±0.24 (109/9)	7.24 (112/12)	6.18±0.16 (117 /17)	6.22±0.09 (101 /1)	6.2 (108 /8)	1.31±0.05 (177 /77)	1.2±0.02 (211/111)	1.26 (191 /91)
Organic fertilizer 10 t/ha	40.5±15.9 (115/15)	338.3±26.7 (101/1)	371.7 (108 /8)	**23.31**±0.7 (164 /64)	27.2±5.41 (165 /65)	25.3 (164 /64)	7.33±0.3 (102 /2)	6.97±0.33 (123 /23)	7.15 (111 /11)	6.10±0.3 (115 /15)	6.25± 0.05 (101 /1)	6.18 (108 /8)	1.03± 0.03 (139 /39)	1.21± 0.35 (212 /112)	1.12 (170 /70)
Organic fertilizer 15 t/ha	347±11.7 (99/ 1)	342.3±12.0 (102/2)	341.7 (99 /-1)	**17.88±1.8** (126 /26)	25.6±2.56 (155 /55)	21.7 (141 /41)	7.26±0.4 (101 /1)	6.84±0.16 (120 /20)	7.05 (109 /9)	5.7±0.15 (108 /8)	6.18±0.12 (100 / 0)	5.94 (103 /3)	0.86±0.08 (116 /16)	0.85±0.06 (149 / 49)	0.85 (129 /29)

[a]A =(NF/NC) ×100] % - the ratio of experimental readings to control readings in percent; [a]B = (NF/NC−1) ×100) % - difference between experimental and control readings in percent

Where NC- - Measured parameter in the control variant without the use of organic fertilizer; NF –Measured parameter in variants with the use of organic fertilizer

An essential structural indicator that affects crop formation is the number of seeds in the capsule. In the control group of plants without fertilizer, this indicator averaged 7.2 pieces per capsule in 2021 (Table 5) and remained unchanged for groups of plants with applied fertilizer (p>0.5). A different picture was observed in 2022, when the number of seeds in a capsule significantly increased from 5.68 (in control) to 6.17 in the group with 5 t/ha fertilizer applied (p≤0.5) and up to 6.97 and 6. 84 in groups with 10 and 15 t/ha fertilizer applied, respectively (p<0.5). On average, according to the results of two years, the number of seeds in a capsule significantly increased by B = 12% in the group with 10 t/ha fertilizer applied. In the groups with 5 and 15 t/ha fertilizer applied, this parameter had similar values of 11% and 9%, respectively (Table 5). Thus, the same increase in the number of seeds per capsule was observed in the applied target fertilizer groups. The weight of 1000 seeds are another essential indicator related to the yield of oil flax (Ambika *et al*., 2014). The experimental doses of the target fertilizer did not affect the weight of 1000 seeds. This parameter was observed to be constant concerning the control, which was expressed in statistically insignificant increase as a percentage B = 8%, 8%, and 3% for group variants with applied target fertilizer of 5, 10, and 15 t/ha, respectively (F:2.592; p≥0.05), as shown in Table. 5. On the contrary, there were recorded increases as a percentage of the weight of seeds from one plant by B=91%, 70%, and 29% in the groups with applied target fertilizer of 5, 10, and 15 t/ha, respectively, due to the increase in the number of capsules per plant and the number of seeds per capsule (Table 5).

Our study findings indicate a correlation between the seed productivity of oil flax plants, meteorological and other abiotic conditions during the growing season, and the conditions created by the specific organic fertilizer. These findings align well with the information reported in scientific publications, including the works of Goreeva *et al*., (2020), Mirshekari *et al*., (2012), and Li *et al*., (2022). This suggests that both external environmental factors and the use of organic fertilizers play significant roles in determining the seed productivity of oil flax plants. The doses of target fertilizer we have chosen agree with the data from scientific periodicals. For example, the application of bird droppings as an organic fertilizer had a positive effect on most of the measured parameters of the okra plant, such as height, number of leaves, capsule yield, etc. It significantly reduced the duration of flowering and fruiting of the plant (Unagwu & Ayogu, 2022). In another work, applying a mixture of sheep manure at a dose of 8 t/ha and bird manure at 8 t/ha as a fertilizer affected the emergence rate and height of potatoes. It was superior to the control without fertilizer (Agbede & Oyewumi, 2022).

The effect of target organic fertilizer on technological qualities of oil flax seeds: This work studied the effect of three doses of the target fertilizer on the content of fatty acids in flax seeds of the 2022 harvest (Table 6). In the experimental groups (with fertilizer), the amount of linolenic (F: 4.511; p≥0.05), linoleic (F: 4.481; p≥0.05), and oleic acid (F: 4.366; p≥0.05) remained at the control level and did not undergo significant changes (Table 6). The amount of saturated fatty acids palmitic and stearic (F:

4.533; $p \geq 0.05$) in the variants of the experiment with fertilizer also remained comparable to the control variant at all doses of organic fertilizer (Table 6). Experimental doses of the target fertilizer (Table 6) did not affect the iodine value of linseed oil (F: 4.533; $p \geq 0.05$). The data in Table 6 are confirmed by measurements of the fat content in oil flax seeds (Fig. 2 A).

The results of the studies showed that the doses of applied fertilizer did not affect the fat content in the seeds. Statistical analysis showed indistinguishable values for the fat content of flax seeds (F: 3.910; $p \geq 0.05$). In contrast, similar studies in another work showed an increase in the oil content in flax seeds under the action of organic fertilizers (Yan *et al*., 2012). Obtaining such contradictory results has its explanation in the work of other laboratories, which will be discussed below.

In one study, lower levels of erucic, palmitic, and arachidonic acids in sunflower seeds with organic fertilizers were associated with higher seed protein content, and the authors referred to previous sunflower reports in their article (Shehata & El-Khawas, 2003). Another article reported that optimal doses of nitrogen increase cell wall thickness and protein synthesis and cause a decrease in fatty acids (Saneoka *et al*., 2004). The observed decrease in seed yield could be attributed to an increase in the allocation of assimilates towards the synthesis of amino acids, proteins, and enzymes, which may be a response to nitrogen application (Sayyad-Amin & Ehsanzadeh, 2008).

Akbari *et al*., (2011) reported that applying biofertilizers, nitrogen fertilizers, and manure led to increased protein content in sunflower grain and an improvement in the quality of sunflower seeds. This suggests that using these fertilizers positively influenced the nutritional composition of the sunflower seeds, particularly enhancing their protein content.

In the field trials of 2022 in this project, the doses of nitrogen in the target fertilizer were recorded (Table 2), which exceeded the recommended norms (Cui *et al*., 2022). The absence of the effect of organic fertilizer on the fat content of seeds, the iodine number of linseed oil, and, consequently, the levels of fatty acids in flax seeds observed in this work (Table 6) reflected just such a scenario described in the literature and cited above. This hypothesis is supported by experiments (Fig. 2B), which showed an increase in the content of proteins in the seeds of plants harvested in 2022 by 10-12% in the experimental groups with the target fertilizer.

Table 6. The fatty acid content of linseed oil Harvest 2022.

Variants	Iodine number	Fatty acid content, %			
		Linolenic	Linoleic	Oleinic	Palmitic and stearic
Control	202.3 3± 0.67	62.56 ± 0.34	15.16 ± 0.05	13.93 ± 0.35	8.33 ± 0.04
Fertilizer, t/ha					
5	197.57 ± 2.01	60.19 ± 1.0	14.8 ± 0.16	16.36 ± 1.04	8.63 ± 0.13
10	198.53 ± 2.01	60.66 ± 1.01	14.87 ± 0.16	15.87 ± 1.07	8.57 ± 0.13
15	201.37 ± 0.67	62.08 ± 0.33	15.09 ± 0.06	14.41 ± 0.34	8.39 ± 0.04

Conclusion

Phytotoxicity to oil flax of a local composted organic fertilizer of the Akmola-Phoenix poultry farm based on chicken manure and highly effective microorganisms was assessed. Aqueous fertilizer extract at a concentration of 2.5% caused a significant lengthening of the shoots. Inhibition of shoot growth and cessation of root elongation was caused by fertilizer at a concentration of 5.0% or more, indicating impurities toxic to the plant in the fertilizer.

The seed germination index (GI) at all tested fertilizer concentrations was above 100%, indicating the maturity and stability of the fertilizer.

The two-year field trials showed that the applied dose of the target fertilizer of 10 t/ha is optimal and caused an average yield increase of 33.7%.

Oil flax crop structure elements such as the number of plants per unit area, the number of capsules per plant, and seed weight increased due to increased fertilizer nutrient availability compared to no fertilizer control, but to varying degrees in 2021 and 2022. Different manifestations of fertilizer efficiency concerning the elements of the structure of the flax crop over the years can be associated with abiotic factors.

Doses of organic fertilizer of 5, 10, and 15 t/ha applied in the field trials increased the protein content by 12% and did not affect the oil content in oil flax seeds from the 2022 crop.

A dose of 10 t/ha of organic fertilizer tested in the project can be recommended to interested agricultural enterprises to produce oil flax.

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