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Effectiveness of Microbial Biofertilisers in Oilseed Flax Cultivation Technologies in the Conditions of Northern Kazakhstan

Nazymgul Shumenova[1], Ainash Nauanova[1*], Aigul Tleppayeva[2], Saule Ospanova[1], Sholpan Bekenova[3]

[1] Department of Soil Science and Agrochemistry, S. Seifullin Kazakh Agrotechnical University, 62, Zhenis Ave., Astana 010011, Republic of Kazakhstan
[2] Department of Agriculture and Plant Growing, S. Seifullin Kazakh Agrotechnical University, 62, Zhenis Ave., Astana 010011, Republic of Kazakhstan
[3] Department of Biology, Plants Protection and Quarantine, S. Seifullin Kazakh Agrotechnical University, 62, Zhenis Ave., Astana 010011, Republic of Kazakhstan

Corresponding Author Email: nauanovaainash16@gmail.com

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ABSTRACT

Oilseed flax plays a significant role in solving this problem, as one of the most productive grain crops. In this case, adjusting the seeding rate is an affordable and effective method for successfully managing the crop's productivity. The purpose of this study is to investigate the effect of fertilisers of microbial origin on the structural elements of the oilseed flax crop, agrochemical composition and microbocenosis of the soil in the conditions of Northern Kazakhstan. Biotesting was carried out in laboratory conditions to determine the growth-stimulating properties and toxicity of various doses of biological fertiliser in relation to oilseed flax seedlings. And the field studies were carried out in the conditions of carbonate soils of southern chernozem at the experimental site of the Barayev Research and Production Centre for Grain Farming, located in the Nauchnyi village, Akmola region. According to the results of the experiment, processing of flax seeds with biofertilisers based on effective microorganisms of complex action has a positive effect on the survivability of plants, the number of seeds in the boll. The novelty of the article lies in the fact that for the first time the influence of biological fertilizers on the yield of oilseed flax in Kazakhstan was investigated.

1. INTRODUCTION

Numerous experiences show that organic farming is a promising approach to improving degraded lands and returning them to the production cycle. Compost and vermicompost, manure, sideral fertilisers, and especially fertilisers of microbial origin are examples of organic fertilisers used to increase soil fertility [1]. Microorganisms are the natural inhabitants of the soil, ensuring the flow of the nutrient cycle and playing a primary role in soil fertility. Numerous studies have shown the positive effect of microorganisms and fertilisers based on them on the growth and development of plants. There are several methods of bacterial stimulation of plant growth. Thus, the improvement of growth can be achieved through the production of growth regulators, for example, gibberellin, responsible for the processes of germination and sprouting of seeds, growth of stems and leaves, stimulation of root growth, and abundance of root hairs [2, 3]. Another process is nitrogen fixation, as one of the ways to improve plant growth has become possible not only in legumes but also in cereals. Admittedly, inoculation of economically important crops, such as rice and wheat, by endophytic (isolated from plants) microorganisms, allows reducing the amount of nitrogen fertilisers applied and obtaining a good harvest [4]. And the use of *Burkholderia vietnamiensis* MG43 as an inoculant of sugar cane seeds allows increasing the biomass of the plant by 20% compared with an increase in the dose of nitrogen fertiliser [5]. Studies show the effectiveness of the use of biofertilisers based on microorganisms of the genus Trichoderma, Pseudomonas, Bacillus, Serratia, etc. in protecting plants from various diseases (root rot, bacteriosis, grey and white rot), common in greenhouses and, moreover, in increasing yields, germinative power, and germination capacity [6].

The use of compounds of biological origin and the development of new sustainable plant protection strategies to reduce the use of pesticides, bactericides, and fungicides in agriculture is becoming increasingly popular among agricultural producers. Among others, Trichoderma has the potential to find wide application as a biocontrol agent, due to its high mycoparasitic and antibiotic potential against various pathogens of agricultural crops. The effectiveness of many strains of fungi of the genus Trichoderma in plant protection against phytopathogens is beyond doubt and is confirmed by numerous studies [7-10]. More than 60% of all registered biopesticides are based on fungi of the genus Trichoderma [11]. The use of Trichodermin-BL improved the set of biometric and physiological parameters during plant growth, increased yield, and improved the quality of common flax [12]. The development of antibiotic substances of four Bacillus strains against oilseed rape diseases was noted. The protective effects observed for certain Bacillus strains make them very interesting for further research as biocontrol agents in oilseed cultivation [13]. The effective use of biological fertilisers in organic farming requires determining the impact on crop yields and soil fertility. The widespread introduction of biofertilisers into agricultural production will increase soil fertility, increase crop yields, and improve the ecological situation.

Kazakhstan, being an agrarian country, has sufficient resources to produce high-quality organic products that are in demand in foreign markets and can be sold at the highest price compared to non-organic analogues. In turn, organic farming is even more risky area due to many restrictions, in particular, the ban on the use of pesticides, fungicides, toxic chemicals, and mineral fertilisers. The distrust of the organic farming industry on the part of agricultural producers is justified, since there are currently no or incomplete studies in the field of the use of biological fertilisers to obtain stable crop yields [14-16]. Currently, the government of the Republic of Kazakhstan is taking measures to expand oilseed planting in order to produce vegetable raw materials in an amount that meets the needs of the national market. The expansion of the range of oilseeds is an important area in the stabilisation of zonal crop production. Sunflower has been the leading oilseed crop in Kazakhstan for many decades. However, its crops deplete the soil, which leads to irreversible consequences. An alternative to sunflower can be such crops as oilseed flax. This crop is a good precursor for many agricultural crops and has a high level of profitability of production. Such biological features as a short growing season and drought resistance make this crop suitable for cultivation in Northern Kazakhstan [17]. However, there are no studies in Kazakhstan on the effect of biological fertilisers on the yield of oilseed flax.

The purpose of this study is to investigate the effect of fertilisers of microbial origin on the structural elements of the oilseed flax crop, agrochemical composition and microbocenosis of the soil in the conditions of Northern Kazakhstan.

2. MATERIALS AND METHODS

The objects of the study are: chernozems, oilseed flax, biofertilisers of domestic production, developed by scientists of the S. Seifullin Kazakh Agrotechnical University – "Compo-MIX", "Agrarka", "Agro-MIX", and "Trichodermin-KZ". "Agrarka" biofertiliser is a liquid concentrated fertiliser made on the basis of effective strains of actinomycetes, consisting of such strains as *Streptomyces xantholiticus* piece (pcs.) 7, *Streptomyces microsporus* pcs. 12, *Streptomyces sioyaensis* pcs. 41, producing a complex of biologically active substances with fungicidal properties against fungal diseases and phytostimulating effect of agricultural crops. The composition of "Compo-MIX" biofertiliser includes strains of growth-stimulating, nitrogen-fixing, cellulose-destroying, and fungicidal microorganisms Streptomyces sindenensis *PM9, Streptomyces griseus M25, Bacillus aryabhattai PM62, Bacillus aryabhattai PM68, Bacillus aryabhattai PM69, Bacillus megaterium PM80B*, Lentzea violacea PM86B isolated from soils of Northern Kazakhstan. "Agro-MIX" biofertiliser was created on the basis of strains of growth-stimulating, nitrogen-fixing, anti-putrefactive microorganisms *Bacillus spp, Saccharomyces spp, Acetobacter spp, Streptomyces spp.* "Trichodermin-KZ" is made on the basis of effective strains of fungi of the genus *Trichoderma*.

Biotesting was carried out in laboratory conditions to determine the growth-stimulating properties and toxicity of various doses of biological fertiliser in relation to oilseed flax seedlings [18]. Oilseed flax seeds were treated with biological fertiliser of various concentrations for 24 hours. In each variant, 30 seeds were taken without external signs of the disease. After the time expired, the seeds were rinsed with tap water and transferred to filter paper in Petri dishes, where they were cultivated for 7 days at a temperature of 20-22°C. The following were analysed: the number of germinated seeds, the length of the sprout and root. The repetition of the experiment is fivefold. In this experiment, solutions of the drug were used for seed treatment 0.1%, 1%, 2.5%, 5%, 7.5%, 10% concentration. In the control variant, the seeds were treated with water.

The field studies were carried out in the conditions of carbonate soils of southern chernozem at the experimental site of the Barayev Research and Production Centre for Grain Farming, located in the Nauchnyi village, Akmola region. The soil of the experimental site is of a heavy loamy granulometric composition, having a humus content of 2.8%, pH – 7.5. It is characterised by a low content of mobile phosphorus (9.25 mg/kg) and increased content of exchangeable potassium (500.7 mg/kg), a high degree of saturation with bases (60%), and a humus content of 2.8%. The crops were sown on fallow lands, the seed material was processed with biological fertilisers "Compo-MIX", "Agrarka", "Agro-MIX", and "Trichodermin-KZ" on the day of sowing. Control – without the introduction of biofertilisers. The seeding rate is 600 seeds/m², the seed depth is 3-4 cm. The placement of variants in the experiment is randomised, with five-fold repetition. Flax harvesting was carried out manually. The structural analysis of plants included at least 300 plants for each variant in a five-fold repetition. Greentest Mini nitrometer was used to check the nitrate nitrogen content in soil, and to check the content.

Soil sampling was carried out during the growth and development of oilseed flax in a five-fold repetition from each plot, all work was carried out in compliance with maximum sterility. The number and structure of the complex of soil microorganisms were determined by sowing dilutions of soil suspension on dense nutrient media in a five-fold repetition. The number of bacteria using the organic form of nitrogen was taken into account on meat-peptone agar (MPA); bacteria and actinomycetes that use a mineral nitrogen source on starch-ammonia agar (SAA); mycelial fungi – on acidified Czapek-Doks medium. Aerobic cellulose-destroying microorganisms were detected on the Getchinson medium with subsequent differentiation into bacteria, fungi, and actinomycetes [19, 20]. To determine changes in the agrochemical parameters of the soil, mixed samples were taken from each plot from the arable horizon of the soil, which were analysed by the following methods: nitrates – by the ionometric method, humus – by the Tyurin method, mobile phosphorus and potassium – by the Machigin method in the modification of the Central Research Institute of Agrochemical Services for Agriculture [21, 22]. The economic efficiency (Eef) of biofertilisers was determined using Eq. (1):

$$Eef = (A - B)\, x100 / A \quad (1)$$

where, "B" is the yield in the control; "A" is the yield in the experimental version.

3. RESULTS AND DISCUSSION

The results of laboratory studies show that seed treatment with "Agrarka" biofertiliser increased seed germination by an average of 10% at concentrations of 0.1 and 1% (Table 1). There was an elongation of the length of the germinal roots by an average of 23.7% in all variants where the "Agrarka" biofertiliser was used. The length of the shoots of flax oilseeds did not differ significantly. The experiment was carried out under the conditions of a temperature of 20-23°C, daylight, with the use of running water and without additional fertilizers. For oilseed flax seeds, the highest percentage of germination energy was observed in the experimental variants, with concentrations of 0.1%, 1%, and 2.5%. It was revealed that the best result was achieved when using "Agrarka" biofertiliser up to 5% concentration. For oilseed flax seeds, the highest percentage of germinative energy was observed in the variants of the experiment with the treatment of seeds with "Compo-MIX" biofertiliser suspension, where the concentration was 2.5%, the result was 9.4% higher than the control variant. An increase in the germination of oilseed flax seeds was noted at low concentrations (up to 2.5%) of "Compo-MIX" biofertiliser. At the same time, the parameters of the seedling increased from 7.6 to 16%, respectively, at concentrations of 5% and 2.5%. The positive effect of different concentrations on the growth of germinal roots, regardless of the concentration of the drug, was noted. An increase in seed germination by 12.7% was noted at concentrations from 1% to 5% when treating flax seeds with "Agro-MIX" biofertiliser, the growth-stimulating effect of biofertiliser was noted on the growth of germinal roots, on average the length of the roots increased up to 33.9%.

Treatment of oilseed flax seeds with "Trichodermin-KZ" biofertiliser, created on the basis of Trichoderma micromycetes, regardless of concentration, on average contributed to an increase in the length of the roots by 35.7%. The main factor of grain productivity in Northern Kazakhstan is moisture. The content of productive moisture in a metre-deep layer of soil before sowing oilseed flax averaged 55 mm in the experimental plot. It is a very low humidity indicator for southern chernozems, which is conditioned by the low amount of precipitation in the winter period of the 2020-2021 agricultural year and it is important that the cultivated land was virgin before the start of sowing.

Table 1. The effect of different concentrations of biofertilisers on the growth of flax seedlings of the Kustanayskiy Yantar oilseed flax variety

Concentration, %	Germinative energy, % (2-3 days)	Seed germination, % (6 days)	Length of sprouts, cm	length of roots, cm
		"Agrarka"		
Control	86.6	87.3	5.1±0.06	6.1
0.1	100	98	5.2±0.1	7.0±0.14
1.0	100	98.6	5.6±0.03	7.4±0.14
2.5	98.6	92	5.3±0.07	7.5±0.14
5.0	96	97.3	5.5±0.1	8.0±0.17
7.5	96	90	5.0±0.0	7.6±0.17
10.0	94.6	92	5.0±0.09	7.8±0.08
LSD			0.3	0.37
		"Compo-MIX"		
0.1	82.6	93.3	5.40±0.12	7.36±0.14
1.0	86.6	93.3	5.05±0.03	7.37±0.11
2.5	92	96	5.92±0.07	7.41±0.06
5.0	88	92	5.49±0.13	8.12±0.11
7.5	81.3	86.6	5.12±0.02	7.44±0.2
10.0	83	90.6	4.92±0.09	7.43±0.11
LSD			0.32	0.15
		"Agro-MIX"		
0.1	91.3	92	5.35±0.08	7.44±0.11
1.0	98.6	99.9	5.75±0.11	8.39±0.09
2.5	98.6	100	5.79±0.08	8.93±0.17
5.0	98.6	100	5.52±0.11	8.06±0.20
7.5	92	93	5.35±0.11	8.02±0.20
10.0	89.3	89.6	4.98±0.15	8.20±0.17
LSD			0.4	0.44
		"Trichodermin-KZ"		
0.1	70	90.5	5.3±0.08	9.7±0.17
1.0	97.3	92	5.35±0.08	7.44±0.11
2.5	98.5	94.5	5.78±0.2	8.92±0.17
5.0	96	90	5.0±0.11	7.6±0.09
7.5	91	87	5.34±0.02	8.01±0.2
10.0	93.3	93.3	4.8±0.11	8.0±0.2
LSD			0.41	0.43

Table 2. Nitrate nitrogen content (mg/kg) in 0-40 cm soil layer under oilseed flax, 2021

Variant	Sprouting-"herringbone" stage	Budding-flowering stage	Maturation stage	Average for the growing season
Control	4.0	14.5	3	7.2
"Compo-MIX"	4.7	13.05	6.8	8.2
"Agrarka"	7	13.2	8.3	9.5
"Agro-MIX"	7.25	10.35	6.4	8.0
"Trichodermin-KZ"	4.4	13.2	9.45	9.0

In addition to the supply of productive moisture, one of the most important factors necessary for the growth and development of a plant is the provision of soil with nutrients. The availability of nitrate nitrogen in the soil before sowing oilseed flax was very low and was 3.5 mg/kg in a 0-40 cm layer. In the initial phases of growth and development of oilseed flax of the Kustanayskiy Yantar variety, the use of "Agro-MIX" and "Agrarka" biofertilisers increased the content of N-NO3 by an average of 75% compared with the control variant. In the variants with the use of "Compo-MIX" and "Trichodermin-KZ" biofertilisers, the content of nitrate nitrogen was at the level of the control variant (Table 2).

By the stage of flax maturation, the content of nitrate nitrogen decreases in all experimental variants in comparison with the previous period of growth and development. Thus, in the variants with the use of "Agrarka", "Agro-MIX", and "Compo-MIX" biofertilisers, nitrate nitrogen decreases by an average of 2 times. In the variant with the "Trichodermin-KZ" biofertiliser, the concentration of $N\text{-}NO_3$ in the soil decreased by 30%. The introduction of "Agrarka" and "Agro-MIX" biofertilisers ensure the survivability of nitrate nitrogen compared to the control option, which is on average 2 times more. However, the indicators of nitrate nitrogen in the experimental plots are 2-3.5 times higher compared to the control variant. The low content of nitrate nitrogen in the soil during the ripening stage indicates that plants use more nitrate nitrogen from the soil.

The content of mobile phosphorus in the soil before sowing flax in a 0-20 cm layer was within 9.25 mg/kg of soil, that is, in an area with low availability. It was almost the same as in the 20-40 cm layer. During the sprouting-"herringbone" stage of oilseed flax, the content of mobile phosphorus in the 0-20 cm layer was 12.9mg/kg of soil in the control variant. In the variants with the introduction of biofertilisers of microbial origin, the average content of P_2O_5 fluctuated within the value of the control variant. A slight increase in this indicator was noted when using the "Trichodermin-KZ" biofertiliser (Table 3). During the budding stage – the flowering of oilseed flax in variants with the addition of biofertiliser, there was a 2-fold increase in indicators of mobile phosphorus compared to the previous phase. The same data were obtained when chickpeas were grown with *Trichoderma* spp, which caused an increase in the growth and yield of treated plants compared with the uninoculated control variant. It was found that this result is caused by increased solubility and absorption of phosphate. In the ripening stage of oilseed flax, the indicators of mobile phosphorus noticeably decrease compared to the previous stage in all experimental variants. In the variants using biofertilisers, the values of P_2O_5 in the soil decreased by an average of 2 times and are comparable with the control variant.

Among biofertilisers, "Trichodermin-KZ" made a significant impact on the indicators of mobile potassium, causing an increase in the content of mobile potassium by 12% during the budding-flowering stage. In general, the indicators of mobile potassium in all phases of vegetation did not suffer strong changes due to the high availability of soils of this type (Table 4).

Among biofertilisers, the best indicators for organic matter were observed in the "Compo-MIX" and "Trichodermin-KZ" variants, where the average mass fraction of organic matter was 0.4% higher than in the control variant. This is conditioned by the high content of cellulose-destroying actinomycetes and fungi in these biofertilisers. No significant effect of the remaining biofertilisers on the humus content was revealed according to the results of soil analyses. In the arid regions of Northern Kazakhstan, where the yield level is limited by moisture and the high price of fertiliser, it is important to choose a more optimal type and dose of fertiliser in order to get the greatest effect from their application. The study investigated the effect of biological fertilisers of microbial origin on the quantitative and qualitative composition of microorganisms involved in the mineralisation processes of organic compounds. The established rational use of fertilisers will compensate for the lack of nutrients for plants at a low level of soil fertility.

The number of microorganisms in the southern chernozems of the experimental site was studied during the growth and development of oilseed flax. As shown in Table 6, the number of bacteria in the initial stage of growth and development of oilseed flax was significantly higher than in the other two phases. In the initial stages of growth and development of oilseed flax in all experimental variants, an increase in the number of ammonifiers that consume the organic form of nitrogen was observed. The number of nitrogen-fixing bacteria varies from 118 to 785 million/g on MPA. Microorganisms that assimilate mineral forms of nitrogen (on the SAA medium) showed good growth. The smallest growth of colonies was observed on the variant with the use of "Agro-MIX" biofertiliser – 70 million/g. During the stage of budding and full ripeness, there was a significant predominance of bacteria growing on MPA compared to bacteria growing on SAA, which indicates a decrease in the consumption of mineral forms of nitrogen and increased decomposition of organic substances. This is conditioned by the chemical composition of the soil, where organic plant residues prevail. The ratio of microbial abundance on the MPA and SAA indicates that mineralisation processes in the soil are increasing or decreasing. The immobilisation coefficient shows the degree of development of the amylolytic part of the soil microbiocenosis and, accordingly, its activity in the transformation of soil carbohydrates and the binding of free nitrogen. The higher it is (>1), the more intensive the immobilisation processes are, which indicates a very large supply of ammonia nitrogen to the soil (this may be a consequence of the strong development of ammonifiers).

In the initial stages of development on the Gause medium, the number of actinomycetes increased to 1.0-19.5 thousand/g in all variants compared to the control (Table 5). The variants with biofertilisers showed a positive growth trend of actinomycetes. During the budding stage of oilseed flax, an increase in colony forming unit (CFU) of actinomycetes was observed from 12.5 thousand/g to 40.5 thousand/g compared to the germination stage. In the stage of full ripeness, the number of actinomycetes reaches an average of 27.3 thousand/g, which is 13% more than in the flowering stage. In the process of growth and development of oilseed flax in the stage of full ripeness, the number of actinomycetes increased by 2 times on the variant using "Trichodermin-KZ". Microbiological analysis of the rhizosphere of oilseed flax during germination on the medium of Czapek-Doks showed that the number of bacteria prevails during this period of growth and development. Actinomycetes were found on all experimental variants with treatment with biofertilisers, which is related to the composition of the fertiliser. Active growth of mycelial fungi was observed during flowering-budding of oilseed flax, when the plant is particularly vulnerable to various types of diseases. As the soil analysis shows, the treatment of seeds with biofertilisers inhibits the development of mycelial fungi, thereby healing the soil.

Considering the data on the quantitative and qualitative composition of cellulose-destroying microorganisms on the Getchinson medium during germination in the rhizosphere of oilseed flax, moderate growth of actinomycetes and fungi was noted. Cellulose-destroying microorganisms developed especially well with the treatment of seeds with "Agro-MIX" biofertiliser. In the stage of full ripeness, there was a positive trend in the growth of actinomycetes, and the number of cellulose-destroying fungi exceeds in all variants. The largest number of actinomycete colonies in the full ripeness stage was estimated when seeds were treated with a microbial biofertiliser "Trichodermin-KZ" before sowing.

Table 3. Mobile phosphorus content (mg/kg) in 0-20 cm soil layer under oilseed flax, 2021

Variant	Sprouting-"herringbone" stage	Budding-flowering stage	Maturation stage	Average for the growing season
Control	12.9	17.5	6.9	12.4
"Compo-MIX"	11.45	27.3	6.2	14.9
"Agrarka"	11.25	24.3	10.5	15.3
"Agro-MIX"	11.1	21.7	6.6	13.1
"Trichodermin-KZ"	13.85	21.9	9.6	15.1

Table 4. Mobile potassium content (mg/kg) in 0-20 cm soil layer under oilseed flax, 2021

Variant	Sprouting-"herringbone" stage	Budding-flowering stage	Maturation stage	Average for the growing season
Control	548.9	546.3	550.7	548.6
"Compo-MIX"	537.8	563.0	570.2	557
"Agrarka"	558.0	543.6	610.1	570.6
"Agro-MIX"	573.4	559.4	550.5	561.1
"Trichodermin-KZ"	596.14	612.9	590.2	604.5

Table 5. Microbiological analysis of the rhizosphere of oilseed flax depending on the type of biofertiliser

Variant	MPA	SAA	Gause	Getchinson			Czapek-Doks		Ashby
	Bacteria, million/g	Bacteria, million/g	Actinomycet, thousand/g	Actinomycetes, thousand/g	Fungi, thousand/g	Bacteria, million/g	Actinomycetes, thousand/g	Fungi, thousand/g	Bacteria, million/g
Sprouting-"herringbone"									
Control	80.0	402.0	1.0	2.0	2.5	40.0	-	-	61.5
"Compo-MIX"	578.5	122.0	5.5	2.5	4.5	242.0	5.0	1.0	136.0
"Agrarka"	134.0	123.0	6.0	2.5	2.0	281.5	4.0	-	169.0
"Agro-MIX"	250.0	70.0	19.5	4.5	6.5	10.0	1.5	-	160.0
"Trichodermin-KZ"	145.0	212.0	8.5	1.0	3.5	10.0	2.0	-	194.5
Flowering-budding stage									
Control	6.5	5.5	40.5	-	9.5	9.0	-	36.0	4.0
"Compo-MIX"	44.5	9.0	12.5	15.0	2.0	-	-	-	-
"Agrarka"	13.5	6.5	35.0	9.0	3.5	49.0	2.0	13.0	5.5
"Agro-MIX"	26.5	14.5	15.0	12.0	1.0	5.0	1.5	16.0	8.5
"Trichodermin-KZ"	16.5	4.0	16.5	-	15.0	4.0	-	11.0	4.0
Maturation stage									
Control	6.5	3.5	23.5	51.5	2.5	-	-	-	5.5
"Compo-MIX"	18.5	17.5	23.0	74	4.5	-	-	-	8.5
"Agrarka"	5.0	7.0	19.0	42	4.5	-	-	-	6.5
"Agro-MIX"	7.5	6.5	24.5	52.5	2.0	-	-	-	3.5
"Trichodermin-KZ"	5.0	2.5	45.5	99.0	3.5	-	-	-	6.0

Table 6. Action of biofertilisers on the yield attributes of oilseed flax

Variant	Number			Weight	
	Plant survivability, pcs.	Bolls per 1 plant, pcs.	Seeds in 1 boll, pcs.	1000 seeds, g	Seeds from 1 plant, g
Control	351.3±4.5	14.2±2.1	7.2±0.6	5.3±0.31	0.74±0.02
"Compo-MIX"	367.6±8.3	19.04±4.0	7.2±0.3	6.6±0.4	0.81±0.02
"Agrarka"	380.00±6.0	17.11±4.1	6.58±0.01	6.5±0.28	0.80±0.02
"Agro-MIX"	399±10.7	19.6±4.7	6.71±0.1	6.38±0.31	0.73±0.02
"Trichodermin-KZ"	343.3±3.5	15.65±0.5	6.43±0.2	6.31±0.08	0.70±0.03

During the sprouting-"herringbone" stage, the number of nitrogen-fixing bacteria cells on the Ashby medium significantly increased by 1.5-2 times compared to the control. During the flowering-budding phase of flax, there was a sharp increase in the number of nitrogen-fixing bacteria from 3.5 million/g to 8.5 million/g, except for the variant with the use of "Compo-MIX" biofertiliser, where there was no growth of nitrogen fixers at all. In the stage of full ripeness, an increase in the number of nitrogen bacteria was observed compared to the control, the exception was the variant with the use of "Agro-MIX", where there was a slight decrease. In conclusion, it can be noted that the initial phases of growth and development of oilseed flax have a beneficial effect on the development of nitrogen fixators in all experimental variants compared with the control. This is conditioned by a number of physical factors, such as the abundance of moisture and the optimal temperature regime. In the further phases of development, the number of azotobacter cells decreases comparatively, as there is competition for moisture and oxygen in the soil.

The findings showed that in the field, almost all tested fertilisers had a positive effect on the survivability of oilseed flax plants (Table 6), which increased by an average of 6.0% compared to the control. The survivability of plants in the control group at the time of harvesting amounted to 78.1% of field germination. Survival rates close to control were observed in variants with the treatment of seeds with the "Trichodermin-KZ" biofertiliser. All other experimental variants showed a high survival rate of plants compared to the control variant from 367.6 to 399.0 plants, which indicates a positive effect of the use of biofertilisers on the survivability of oilseed flax plants. The use of biofertilisers in different doses significantly affected the structure of plants. So, the number of bolls per plant in the control was 14.2 pcs., and in the fertilised variants this indicator increased by 20.4-38% compared to the control variant. An important structural indicator affecting the development of yield is the number of seeds in the boll. Structural analysis of the number of seeds in the boll showed that in all experimental variants of the use of biofertilisers, the number of bolls was close to the control – 6.43-7.2 pcs. All types and doses of biofertilisers stimulated the development of bolls and seeds of oilseed flax. No negative effect of biofertilisers on seed yield was noted in any of the experiments. All fertilised variants gave an increase in yield by 0.2-1.7 c/ha. The highest increase in yield was observed on the variants with the use of "Agro-Mix" biofertiliser and on all variants with biofertiliser.

The use of biological pesticides in agricultural production is rapidly increasing as an alternative to synthetic analogues, which is conditioned by public concern about human health, the safety of agricultural products, and the impact on the environment. Organic farming implies a number of measures and technologies aimed at protecting the environment and obtaining environmentally friendly products. One such measure is to limit the use of synthetic fertilisers and pesticides, and replace them with natural agents to protect plants, increase crop yields, and improve soil fertility. Obtaining high-quality agricultural products would allow not only to compete in the international market of organic products, but first of all, to provide the population of Kazakhstan with high-quality affordable organic products.

Treatment of oilseed flax seeds with the "Trichodermin-KZ" biofertiliser, created on the basis of *Trichoderma* micromycetes, regardless of concentration, is able to stimulate the growth of primary roots. This result contrasts with previous studies showing the beneficial effects of *Trichoderma* on plants in terms of growth stimulation and induction of protection against biotic and abiotic stresses. *Trichoderma* can modify phytohormone signalling networks in plants [23]. Many strains of *Trichoderma* produce IAA, a phytohormone that is crucial for controlling the development and growth of lateral roots, as a result, promote growth [24, 25].

The predominance of the number of cellulose-destroying actinomycetes in comparison with mycelial fungi in the flowering-budding stage of oilseed flax, which is an indicator of the intensive destruction of plant residues and hard-to-reach organic compounds in the soil in arid conditions of the region. The same pattern is noted in the studies conducted by Zhang et al. [26]. The use of *Trichoderma* biofertiliser (composted cattle manure + inoculate) effectively regulated the chemical composition of the soil and microbial communities, which significantly improved the biomass of aboveground plants compared with organic fertiliser alone. In addition, the presence of *Trichoderma* can increase the relative abundance of beneficial fungi with a significant decrease in the number of phytopathogenic microorganisms [27-29]. In one Invitro study, *Trichoderma* was observed to inhibit the growth of *Fusarium solani*. *Trichoderma* tends to be compatible and live together with beneficial microbes that promote plant growth, rather than with harmful ones. In the conditions of the Central Chernozem Region, in a field experiment on segregated medium-humus heavy loamy chernozem with spring barley, it was found that pre-sowing inoculation of seeds with associative strains of soil rhizobacteria influenced the number of the main physiological groups of microbial community. To a greater extent, the activity of ammonifiers, humus mineralisers, micromycetes, and cellulolytics was activated, to a lesser extent – actinomycetes and nitrifiers [30, 31].

One of the important indicators of structural analysis affecting the yield of flax seeds is the mass of 1000 seeds. In the experimental variants, the mass of 1000 seeds increased by 1.0-1.3 grammes. This is consistent with the previous study on the use of biofertilisers of microbial origin on other plants. Analyses conducted on Basilio wheat with four endophytic *Trichoderma* showed that all of them had a positive effect on germination rate, tilling capacity, and plant growth under optimal irrigation conditions. Significant differences in the structural parameters of plants may indicate that these endophytic strains have a positive effect on seed germination and early maturity of plants [32]. *Trichoderma asperellum B1092* has demonstrated great field potential for increasing the productivity and quality of tomatoes. Studies have shown that rice plants inoculated with *T. asperellum* produced more panicles, longer panicle length, and increased plant height. The introduction of *Trichoderma* fungi into the soil caused an increase in growth parameters and the level of chlorophyll, starch, nucleic acids, total protein, and phytohormones of corn. Some researchers note that new preparations based on strains of living soil bacteria *Azotobacter* and *Bacillus:* azotobacterin, phosphobacterin, and silicobacterin are an effective factor in increasing yields and improving plant resistance to pathogenic infections and low temperature [33-35]. The introduction of microbial preparations into the soil enhances microbiological activity, while many insoluble soil complexes turn into accessible forms of macro- and microelements necessary for the vital activity of plants. During the budding-flowering stage of oilseed flax in variants with the use of biofertilisers, there was a 2-fold increase in the indicators of mobile phosphorus compared to the previous phase, which indicates the drought resistance of the strains of microorganisms that make up the biofertilisers [36].

Thus, biological fertilisers "Agrarka" and "Agro-MIX" increase the biological activity of the soil, which is confirmed by microbiological analyses of rhizosphere microorganisms on different nutrient media. Moreover, these types of biofertilisers provide an increase in the content of nitrate nitrogen by an average of 2 times compared to the control variant. Biofertiliser "Trichodermin-KZ" increases the content of mobile phosphorus by 10% and the average mass fraction of organic matter by 0.4%. Thereby confirming that the fungi of the genus Trichoderma quickly master the nutrient substrate, actively decomposing organic compounds. Due to the release of enzymes and antibiotics, they enhance the processes of ammonification and nitrification, mobilisation of phosphorus and potassium, enriching the soil with mobile forms of nutrients. "Compo-MIX" biological fertiliser increases the organic matter content by 0.4%, which proves the effective work of cellulose-destroying bacilli and actinomycetes contained in it. Microbiological activity in the southern carbonate chernozems before sowing seeds showed that the number of bacteria using organic nitrogen varies greatly and their maximum content is 143 CFU million/g of soil in arid conditions in 2021. The content of bacteria assimilating mineral forms of nitrogen was lower than organic ones, which amounted to 108 CFU million/g. The untreated soil of the deposit is depleted and the cellulose-destroying complex of microorganisms is poorly expressed. Soil fungi are an important link in the development of fresh plant and animal residues.

4. CONCLUSIONS

As the results of the analyses showed, the growth and reproduction of mycelial fungi in the deposits are smaller than other types of microorganisms, on average 2-4 CFU thousand/g. This is conditioned by both the deterioration of aeration and a decrease in the necessary forms of organic matter. According to the general results of the biological activity of the soil in the phases of the development of oilseed flax, it should be emphasised that mineralisation processes were observed in the initial phases of development, whereas during the flowering and full ripeness of oilseed flax, mineralisation decreases, since plants in this case act as strong competitors of microorganisms. In the phase of full ripeness, of all the groups of microorganisms differentiated on the Czapek-Dox medium, it was possible to notice only on the control variant without applying biological fertiliser. The absence of mycelial fungi in the experimental variants is conditioned by the microbial origin of the biological fertiliser. As the soil analysis shows, the treatment of seeds with biofertilisers inhibits the development of mycelial fungi, thereby revitalising the soil.

In conclusion, it can be noted that the initial phases of growth and development of oilseed flax have a beneficial effect on the development of nitrogen fixators in all experimental variants compared with the control. This is conditioned by a number of physical factors, such as the abundance of moisture and the optimal temperature regime. In the further phases of development, the number of azotobacter cells decreases comparatively, as there is competition for moisture and oxygen in the soil. In the arid conditions of 2021, the use of biofertilisers of microbial origin positively affected the structural elements of the oilseed flax yield. Processing of flax seeds with biofertilisers based on effective microorganisms of complex action has a positive effect on the survivability of plants, the number of seeds in the boll, the weight of 1000 seeds, and the yield of this crop.

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