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Влияние препаратов биологического происхождения на урожайность семян льна масличного в условиях Кировской области

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Представлены результаты изучения производства экологически чистых масел из семян и плодов сельскохозяйственных культур по технологиям, рационально сочетающим химические и биологические направления защиты растений. Лен масличный является ценным источником полиненасыщенных жиров, содержит значительное количество белка, пищевых волокон, относится к продуктам функциональной направленности. В условиях Кировской области проведены исследования влияния препаратов биологического происхождения на урожайность семян льна масличного. В полевом опыте изучено применение препаратов гумат +7 «Здоровый урожай» и псевдобактерин-2Ж. Исследования проводили на льне масличном сорта Северный, обрабатывая его семена, вегетирующие растения в фазу «елочка», а также сочетая эти два способа обработки. Применяли препараты в чистом виде и использовали их комплексное сочетание. Установлено, что препараты биологического происхождения достоверно повышают полевую всхожесть на 2,4% в среднем по вариантам опытов. Максимальное превышение контроля отмечено в вариантах с обработкой семян гуматом +7 «Здоровый урожай» (85,6%), а также с комплексом препаратов биологического происхождения (гумат +7 «Здоровый урожай» + псевдобактерин-2Ж) (86,3%), двукратное использование комплекса приводит к увеличению сохранности на 7,4%. Наибольший эффект применения на урожайность семян отмечен при проведении изучаемыми препаратами предпосевной обработки и использовании их двукратно. Максимальный уровень урожайности отмечен при двукратном использовании комплекса препаратов биологического происхождения (1,43 т/га). Установлено достоверное положительное влияние двукратного применения комплекса препаратов биологического происхождения на число коробочек на одном растении (12,3 шт.). Число полноценных семян в коробочке увеличивает обработка семян гуматом +7 «Здоровый урожай», а также двукратное применение изучаемых препаратов и их комплекса (в среднем на 16%). Не установлено достоверного влияния препаратов биологического происхождения на массу 1000 семян. Для выращивания масличного льна по технологии, предусматривающей увеличение степени биологизации, можно рекомендовать использование комплекса гумат +7 «Здоровый урожай» + псевдобактерин-2Ж для предпосевной обработки семян и последующей обработки растений в фазу «елочка».

Ключевые слова: лен масличный, биологизация, продуктивность, растительные жиры, пестицидная нагрузка

The effect of preparations of biological origin on the yield of oil flax seeds in the conditions of the Kirov region

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The results of studying the production of ecologically pure oils from seeds and fruits of agricultural crops using the technologies rationally combining chemical and biological directions of plant protection are presented. Oil flax is a valuable source of polyunsaturated fats, contains a significant amount of protein, dietary fiber, belongs to the products of functional orientation. The research on the effect of preparations of biological origin on the yield of oil flax seeds was carried out in the Kirov region. The application of the preparations humate +7 “Healthy Harvest” and pseudobacterin-2L was studied in the field experiment. The studies were conducted on oil flax of the Severny variety, treating its seeds, vegetative plants in the “herringbone” phase, as well as combining these two methods of treatment.

The preparations were applied in pure form and their complex combination was used. It was found that preparations of biological origin significantly increase field germination by 2.4% on average in the variants of the experiment. Maximum excess of control was observed in the variants with seed treatment with humate +7 "Healthy Harvest" (85.6%), as well as with a complex of preparations of biological origin (humate +7 "Healthy Harvest" + pseudobacterin-2L) (86.3%), double use of the complex leads to an increase in viability by 7.4%. The greatest effect of application on seed yield was observed when the studied preparations were used for pre-sowing treatment and applied twice. The maximum level of yield was observed with twofold use of a complex of preparations of biological origin (1.43 t/ha). A reliable positive effect of double application of the complex of preparations of biological origin on the number of bolls on one plant (12.3 pcs.) was established. Treatment of seeds with humate +7 "Healthy Harvest" as well as double application of the studied preparations and their complex (on average by 16%) increases the number of full-grown seeds in a boll. No reliable effect of biological origin preparations on 1000 seed weight was found. The use of complex humate +7 "Healthy Harvest" + pseudobacterin-2L for pre-sowing seed treatment and subsequent treatment of plants in the "herringbone" phase can be recommended to grow oil flax according to the technology that provides for an increase in the degree of biologization,

Keywords: oil flax, biologization, productivity, vegetable fats, pesticide load

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INTRODUCTION

Due to the increasing number of people living on the planet, the needs of the population and the processing industry to intensify and expand the range of work of the industry involved in the production of oils and fats are increasing [1]. Vegetable fats are of great importance both directly in human nutrition and for the production of various products (food or technical).

Our country is characterized by very diverse soil and climatic conditions. In this regard, the list of oilseed crops capable of producing sustainable yields of seeds of a given quality differs by regions of the Russian Federation [2]. According to the Federal State Statistics Service, 18,728.0 thousand hectares of crops that are a source of vegetable oil were sown in our country in 2022, of which a significant share (6133.8 thousand hectares) accounts for the Volga Federal District[1].

Among oilseed crops in our country the most widespread are soybean, sunflower, rape (spring and winter) [3], as well as oilseed flax. In the Kirov Oblast, significant areas are allocated to spring rape. However, there is a tendency to increase the area of oil flax. In 2022 it was sown on the area of 2.9 thousand hectares, which is 73% more than in 2021.

The main part of the crops for 2023 in the Kirov region is occupied by the varieties VNIIMK 620, Severny (9.1–9.6% each) and Lirina (13.0%), as well as a high share of unsorted flax (more than 60%). In 2024, the crops increased to almost 7.0 thousand hectares, and the share of unsorted flax decreased to 37%, while the crops of the Severny variety increased to 14.4% and Lirina to 37.4% (with an average yield level of 10–16 c/ha depending on the conditions of the year).

[1]URL: https://rosstat.gov.ru/

Oil flax seeds are a source of fat and protein. Flax oil belongs to the category of drying oils. Due to its ability to form a thin strong film in the air, it is widely used in various industries: pharmaceutical, aviation, printing, etc. [4]. [4]. Fatty acidic composition of flax oil allows us to refer it to the food products of functional orientation. The lack of essential fatty acids affects the cardiovascular system, functioning of biological membranes, fat metabolism processes, etc.[2]

High content of unsaturated fatty acids in the oil, when used for food purposes, helps to reduce the risk of alimentary-dependent diseases.

Flax seed protein is characterized by a significant list of essential amino acids, its composition is close to soy protein. Its introduction into the diet will help to achieve a balanced diet by filling the deficiency of amino acids [5–8].

The document "On the Strategy of Scientific and Technological Development of the Russian Federation"[3] identifies as a priority the need "... to ensure food security...", which can be realized by obtaining environmentally friendly products.

Currently, the level of pesticide load in agriculture remains quite high [9, 10]. Nevertheless, the trend of increasing the degree of biologization of the industry remains significant [11, 12]. An actual direction of research is the search for a balance between the use of chemical plant protection products and the use of biopesticides [13, 14].

The search for analogs of chemical preparations that have a protective effect on plants from abiotic and biotic stressors corresponds to the priority directions of agricultural research. The study of the effectiveness of the integrated plant protection components that increase the degree of its biologization is an important aspect of the introduction of new format farming elements into the practice of agricultural production.

The purpose of research was to study the effectiveness of the effect of preparations of biological origin on the yield of oil flax seeds and their quality.

Objectives of the research were as follows: analyzing the influence of the use of preparations of biological origin on the formation of the density of oil flax crops; studying the level of yield formed under the influence of the preparations of biological origin; determining their influence on the elements of the productivity structure.

MATERIAL AND METHODS

The object of research were oil flax plants and seeds of the Severny variety, a reproduction of sown elite seeds. It is bred in the Federal Scientific Center "V.S. Pustovoit All-Russian Research Institute of Oil crops". Pedigree: created by repeated individual selection from a hybrid population from crossing a line from the VIR collection sample (Morocco K-1994) to breeding line No. 157. The variety was included in the State Register in 1994 and allowed for cultivation in the Volga-Vyatka region. Plants of this variety are characterized by uniform flowering and maturation, and the growing season in the Kirov region is characterized by an average duration of 91–95 days. Depending on the meteorological conditions, the height of the Severny flax can vary between 50–70 cm. Its flattened stalks are suitable for mechanized harvesting.

The effectiveness of two preparations of biological origin was studied on oil flax: humate +7 "Healthy Harvest" and pseudobacterin-2L (both produced in the Kirov branch of the Rosselkhozcenter). In the conditions of the Kirov region (north-east of the Non-Chernozem zone), which is part of the fourth agroecological (Volgo- Vyatka) region, these products were studied on cereals, leguminous crops and perennial grasses. No studies have been conducted on oil flax. Both products are approved for use in our country.

The basis for production of humate +7 "Healthy Harvest" is natural raw materials of organic origin (peat or coal), from which humic substances are extracted. The product is additionally enriched with trace elements in chelate form and can be used both for pre-sowing

[2]*Zaporozhskaya L.I., Gammel I.V.* Characterization and biological role of essential polyunsaturated fatty acids // Medical Council, 2012, N 12, pp. 134–137.

[3]Strategy of Scientific and Technological Development of the Russian Federation: approved by the Decree of the President of the Russian Federation of February 28, 2024, N 145, 2024 // URL: http://publication.pravo.gov.ru/document/0001202402280003?index=2 (date of reference 29.02.2024).

treatment of seed material and for application to vegetative plants. Pseudobacterin-2L is a product of biological synthesis based on the bacterium *Pseudomonas aureofaciens BS* 1393, which has a positive effect on the phytosanitary condition of plants by suppressing the development of pathogenic microorganisms. In addition, the preparation stimulates the growth of the root system of plants.

Field experiments to study the effect of the preparations of biological origin were laid in 2022–2023 on the extrafield of Agrotechnopark of the Vyatka State Agrotechnological University, sod-podzolic soils of which were characterized as light- and medium-loamy in granulometric composition. The content of mobile forms of phosphorus (P_2O_5) was very high (288 mg/kg according to Kirsanov), exchangeable potassium (K_2O) was high (178 mg/kg). The content of organic matter was low at 1.34%, the soils were very acidic with pH 4.1[4].

According to the results of the agrochemical survey, acidic soils occupy 3/4 of arable land in the Kirov region. In general, soil conditions meet the requirements of oil flax, the limiting factor in obtaining high yields is the soil acidity (optimally pH 5–6 is required).

The forecrop in both years was spring barley. Tillage in the spring period is aimed at weed control and creation of granular and finely compacted layer. It consisted of harrowing at physical ripeness of the soil (harrow cart SG-15), two-fold complete cultivation (cultivator KBM-4,2) and final combined cultivation (cultivator KOMBI 3). The rate of the applied fertilizer was $N_{30}P_{30}K_{30}$ kg a.i./ha with the spreader RMU 950 "Farmer". Sowing was carried out by a row method (row spacing of 15 cm) with a seed drill SSFK-7M in the middle of the second ten-day period of May with a seeding rate of 8 million germinated seeds/ha to a depth of 3–4 cm. Placement was randomized, fourfold repetition, the accounting area of plots was 4.5 m^2. Harvesting of the plots was carried out by combine harvester Terrion SR 2010. Laying of the experiment, observations, research and evaluation of the results were carried out according to standard and generally accepted methods (see Table 1)[5, 6].

When treating the seeds, the preparations dosage of 1 l/t was used, when treating vegetative plants – 1 l/ha (pseudobacterin-2L) and 0.5 l/ha (humate +7 "Healthy Harvest").

RESULTS AND DISCUSSION

Unfavorable conditions during the sprouting period can have a significant impact on crop yields. In the conditions of the Kirov region optimal (for sowing and sprouting) soil and air temperatures are observed at the end of I and beginning of II ten-day period of May. In 2022, the beginning of the II ten-day period was characterized by an average air temperature of 14.5 °C. In 2023 at the same time there was cooler weather (11.5 °C), but it fully corresponded to the needs of oil flax to the temperature factor at the initial stage of development. Usually at this time there is a sufficient degree of soil moistening. The amount of precipitation practically did not differ from the usually observed norms, and it also did not become a limiting factor for seed germination. The Selyaninov Hydrothermal Coefficient of humidification (HTC) for the growing season 2022 was 2.3 (due to high precipitation in June–July – 117–130 mm), which characterizes it as overwatered, in 2023 it was quite humid – HTC 1.9 (high precipitation was observed in July – 177 mm). Field germination of oil flax seeds of the Severny variety in all the variants was, as a rule, more than 80% (see fig. 1).

In the control, the field germination of the seeds averaged 82.2% over the years of research.

[4]The data are presented according to the results of analyses of the accredited laboratory of soil and agrochemicals analyses of FSBI SCAS "Kirovsky".

[5]*Dospekhov B.A.* Methods of field experiment: with the basics of statistical processing of research results. 5th edition, suppl. and revised. Moscow: Agropromizdat, 1985, 351 p.

[6]Methods of field experiments with oil crops / edited by V.M. Lukomets. Krasnodar, 2010, 327 p.

Табл. 1. Схема опыта
Table 1. Experiment scheme

Full name	Short name
1. Control – without treatment	1. C
2. Seed treatment with humate +7 “Healthy Harvest”	2. Hum (S)
3. Seed treatment with pseudobacterin-2L	3. Ps-2L (S)
4. Seed treatment with humate +7 “Healthy Harvest” + pseudobacterin-2L	4. Hum (S) + Ps-2L (S)
5. Treatment of plants in the “herringbone” phase with humate +7 “Healthy Harvest”	5. Hum (P)
6. Treatment of plants in the “herringbone” phase with pseudobacterin-2L	6. Ps-2L (P)
7. Treatment of plants in the “herringbone” phase with humate +7 “Healthy Harvest” + pseudobacterin-2L	7. Hum (P) + Ps-2L (P)
8. Double treatment (seeds and plants in the “herringbone” phase) with humate +7 “Healthy Harvest”	8. Hum (S) + Hum (P)
9. Double treatment (seeds and plants in the “herringbone” phase) with pseudobacterin-2L	9. Ps-2L (S) + Ps-2L (P)
10. Double treatment (seeds and plants in the “herringbone” phase) with humate +7 “Healthy Harvest” + pseudobacterin-2L	10. Hum + Ps-2L (S) + Ps-2L (P)

The lower value compared to the control was observed in the variants with no seed pre-sowing treatment (variants 4–6) and ranged from 77.4 to 80.8%. The coefficient of variation by years of the indicator characterizing the presence of favorable conditions for the development of plants from the seed and for the emergence of seedlings in field conditions ranged from 11.2 to 14.3 depending on the variants of the experiment. No significant deviations in the coefficient of variation between varieties were observed.

The meteorological conditions of the growing season affect not only the amount of yield, but also the safety of plants for harvesting (plant survival rate). During the period from the emergence of sprouts to the onset of the “herringbone” phase, meteorological conditions 2023 slightly differed from the average annual values. The observed air temperatures during this period ranged from 16 to 20°C on average for 1 day, and the amount of precipitation was small, but not affecting the period of sprouting - “herringbone”. In 2022, during the similar period of development of young flax plants, air temperatures were 30–70% lower than the mean annual data. Night temperatures during this period ranged from 0 to 7°C, while daytime temperatures ranged from 5 to 13°C. Low temperatures were accompanied by precipitation in the form of rain. The development of flax plants in 2022 was slower compared to the following year.

The period of rapid growth, observed in flax from the end of the “herringbone” phase to budding, occupied 30–33 days during the study period. Temperature characteristics of June 2022 and 2023 were close to the mean annual. A distinctive feature of this period was the amount of precipitation, which in 2022 exceeded the norm by 48%, and July 2023 could be characterized as dry. Plant development was slower at this time, but rainfall at the end of the period of rapid growth had a favorable effect on plant growth.

The transition from budding to flowering averaged 8 days in 2022 and 7 days in 2023. Precipitation was absent during most of the period, and air temperatures were at or slightly below the long-term average (18–20°C) in 2023 (14–16°C) in 2022.

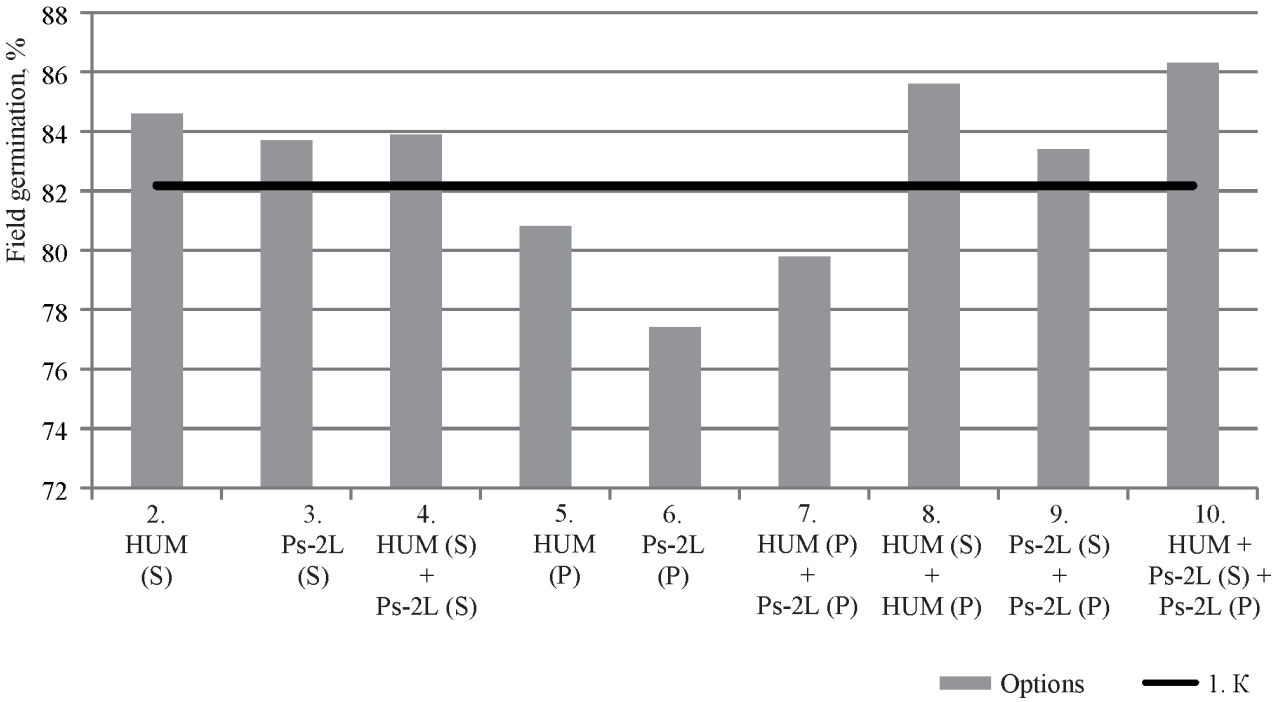

Рис. 1. Полевая всхожесть семян масличного льна (в среднем за 2022–2023 гг.)
Fig. 1. Field germination of oil flax seeds (average for 2022–2023)

During the period from flowering to ripening, the weather was warm enough for the north-east of the Non-Chernozem zone in both years. In the second half of July and most of August 2022, the average temperature per day was about 19–20 °C, which is 2–3 °C higher than the usually observed values. This period 2023 was characterized by an increase in average temperatures by 2.5–4.5 ° C compared to the mean annual data. The amount of precipitation in August was significantly below the norm both in 2022 and 2023. Seed formation and maturation were under favorable conditions in the Kirov region. The duration of the ripening period in flax did not differ significantly by year and amounted to 52–54 days.

In general, during the vegetation periods of the studied years the conditions were quite favorable for flax development and the final safety of plants was quite high and ranged from 84.0 to 88.7% (see fig. 2).

In the control, which was not subjected to any treatment with preparations of biological origin, the safety of plants for harvesting amounted to 81.3% on average across the repetitions. In the variants, the excess of the proportion of surviving plants was from 3.3 to 9.1 p.p., which indicates the influence of the use of preparations on this parameter in the prevailing meteorological conditions. The survival rate was higher in the variants with double application. Treatment of the seeds and vegetative plants with humate +7 “Healthy Harvest” and pseudobacterin-2L increases survival rate by 6.3 and 6.8%, respectively. Joint treatment with the complex of preparations according to the same scheme increases the proportion of surviving plants by 7.4%.

The use of biological origin preparations contributed to the growth of seed yield in most of the studied variants (1.37 t/ha on average for the variants) (see Table 2).

During the period under consideration, there was no reliable decrease in any case. As a rule, seed treatment or application of the preparations twice had a greater effect on the yield. On average for 2022–2023, the yield significantly higher than the control was recorded in such variants and reached 1.37–1.43 t/ha. More significant germination was recorded in the variant with double treatment with complex preparations and

amounted to 0.14 t/ha with the control yield of 1.29 t/ha.

Sowing density in the described experiment was sufficient due to good field germination and favorable meteorological conditions during growth and development. In this case, branching in the lower part of the stem was absent in most plants and formation of a single stem took place. The number of productive stems was 1.12 per plant.

On average, 11.62 bolls were formed on each flax plant (see Table 3). More bolls than the control were formed in the variants with double treatment with humate +7 "Healthy Harvest" (12.1 bolls) and double treatment with a complex of preparations of biological origin (12.3 bolls).

In the control variant, an average of 6.2 full-grown seeds were formed in a boll. In a number of variants, the increase in the number of seeds amounted to more than 11%. More than seven seeds were formed in variants 2 and 7 (7.1 pieces each), as well as in variants 8 (7.4 pieces) and 9 (7.3 pieces).

The weight of 1000 seeds varied from 7.4 to 7.5 g. This indicator in the studied variants was at the level of control or exceeded it. The proportion of the variants with 1000 seeds weight below the control level was 30%. At the same time, there was no significant effect of application of the preparations of biological origin on this parameter.

CONCLUSION

When analyzing the influence of meteorological factors on the density of oil flax crops, their significant negative and reliable influence on this parameter was not observed. Pre-sowing treatment of oil flax seeds influenced its field germination. On average, it was higher by 2.4% compared to the control. The best field germination was observed in the variants that provided seed treatment with humate +7 "Healthy Harvest" (85.6%), as well as with a complex of preparations of biological origin (humate +7 "Healthy Harvest" + pseudobacterin-2L) (86.3%). Preservation of plants for harvesting in agrometeorological conditions of the experiment was higher when flax was treated with preparations of biological origin. The percentage of safety was higher in case of double treatments (pre-sowing

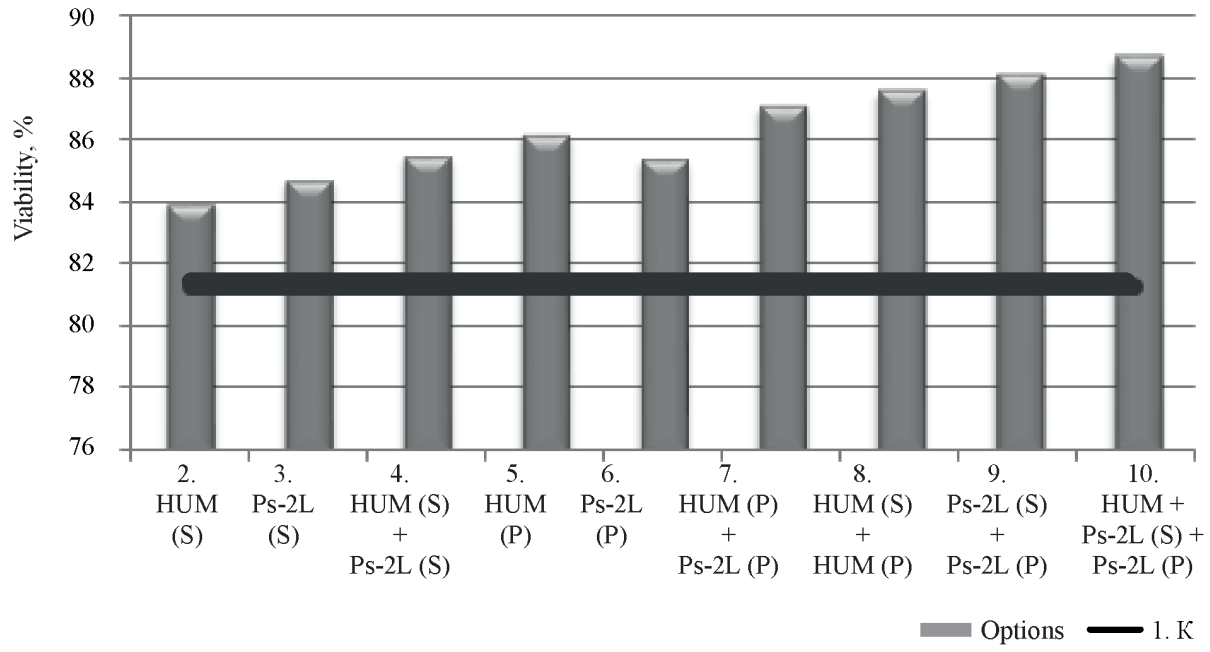

Рис. 2. Сохранность растений масличного льна, %
Fig. 2. Preservation of oil flax plants, %

Табл. 2. Урожайность семян масличного льна, т/га
Table 2. Yield of oil flax seeds, t/ha

Option	2022		2023		Average	
	t/ha	± to 1. C	t/ha	± to 1. C	t/ha	± to 1. C
1. C	1,27	—	1,31	—	1,29	—
2. Hum (S)	1,34	0,07	1,41	0,10	1,38	0,09
3. Ps-2L (S)	1,37	0,10	1,44	0,13	1,41	0,12
4. Hum (S) + Ps-2L (S)	1,31	0,04	1,43	0,12	1,37	0,08
5. Hum (P)	1,31	0,04	1,34	0,03	1,33	0,04
6. Ps-2L (P)	1,33	0,06	1,31	0,00	1,32	0,03
7. Hum (P) + Ps-2L (P)	1,28	0,01	1,34	0,03	1,31	0,02
8. Hum (S) + Hum (P)	1,35	0,08	1,47	0,16	1,41	0,12
9. Ps-2L (S) + Ps-2L (P)	1,37	0,10	1,39	0,08	1,38	0,09
10. Hum + Ps-2L (S) + Ps-2L (P)	1,39	0,12	1,46	0,15	1,43	0,14
LSD_{05}		0,06		0,08		0,07

treatment of seeds and vegetative plants). Application of the same-name preparations gives an increase in safety by 6.3–6.8%. Twofold use of complex humate +7 "Healthy Harvest" + pseudobacterin-2L increases plant density by 7.4%.

The use of preparations of biological origin contributed to the growth of seed yield in most of the studied variants. The greatest effect of application was observed in case of influence on the seeds by pre-sowing treatment and use of preparations twice. On average for two years, the maximum yield level, characterized by a reliable excess, was observed when using the complex of preparations of biological origin twice (1.43 t/ha).

A significant positive effect of double application of the complex of preparations of biological origin on the number of bolls per plant (6%

Табл. 3. Элементы структуры продуктивности льна масличного (в среднем за 2022–2023 гг.)
Table 3. Elements of the structure of oil flax productivity (on average for 2022–2023)

Option	Bolls on one plant, pcs.	Seeds in one boll, pcs.	Weight of 1000 seeds, g
1. C	11,6 ± 0,2	6,2 ± 0,3	7,5 ± 0,1
2. Hum (S)	11,8 ± 0,3	7,1 ± 0,2*	7,4 ± 0,1
3. Ps-2L (S)	11,2 ± 0,3	6,1 ± 0,3	7,6 ± 0,2
4. Hum (S) + Ps-2L (S)	10,8 ± 0,4	6,8 ± 0,2	7,6 ± 0,2
5. Hum (P)	11,2 ± 0,3	6,5 ± 0,2	7,4 ± 0,2
6. Ps-2L (P)	11,4 ± 0,3	6,2 ± 0,3	7,5 ± 0,2
7. Hum (P) + Ps-2L (P)	11,9 ± 0,3	6,8 ± 0,2	7,4 ± 0,1
8. Hum (S) + Hum (P)	12,1 ± 0,2	7,1 ± 0,3*	7,5 ± 0,1
9. Ps-2L (S) + Ps-2L (P)	11,9 ± 0,3	7,4 ± 0,2**	7,5 ± 0,1
10. Hum + Ps-2L (S) + Ps-2L (P)	12,3 ± 0,3*	7,3 ± 0,2**	7,5 ± 0,2

Note. The differences are significant at the probability level:*P>0,95; **P>0,99.

more than the control) was found. The formation of full-grown seeds in one boll was significantly influenced by seed treatment with humate +7 "Healthy Harvest", as well as by double application of the studied preparations and their complex (by 16% on average). No significant effect of humate +7 "Healthy Harvest", pseudobacterin-2L and their complex on the weight of 1000 seeds was recorded.

Thus, it is possible to recommend the double application (treatment of seeds and vegetative plants) of the complex of preparations of biological origin humate +7 "Healthy Harvest" + pseudobacterin-2L for oil flax in order to increase seed yield in the system of biological farming in the agrometeorological conditions of the north-east of the Non-Chernozem zone.

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