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PRODUCTIVITY OF OIL FLAX DEPENDING ON DOSES OF FERTILIZERS AND CORRELATION AND STATISTICAL ANALYSIS OF THE STUDY FACTORS

A.A. Podlipnaya, D.V. Vinogradov, T.V. Zubkova

Background. *The high purchase price and the expansion of treatment volumes stimulate the production of oilseeds in general, including oilseed flax. However, it has not been enough done to determine the autecological aspects in the agrocenoses of oil flax and the scientific justification for the sustainable production of oilseed raw materials of this crop in conditions of the Central Non-Black Earth Region. Also, the problem of the sowing qualities of flax, the preservation of the crop in various weather conditions of the region has not been solved and such methods of agricultural technology as the use of biological microfertilizers, including complex interaction with mineral fertilizers, have not been worked out, which determines the relevance and necessity of conducting these studies.*

Materials and Methods. *Research methods and methodology were based on generalization of scientific sources of domestic and foreign authors, laboratory and field studies, phenological observations, records, according to recommendations and generally accepted methods, using correlation and statistical analysis of the experimental data obtained. Microsoft Office Excel 10 was used for statistical work.*

Results. *The maximum average yields were found in variants with* $N_{205}P_{35}K_{75}$ *(24.4 dt/ha);* $N_{220}P_{70}K_{105}$ *(25.1 dt/ha) against the background of Micropolidoc Plus application. The increase in oilseeds compared to options with introduction of* N_{125} *was without Micropolidoc Plus: +6.8 dt/ha (*$N_{205}R_{35}K_{75}$*) and +8.9 dt/ha (*$N_{220}R_{70}K_{105}$*), and against the background of using Micropolidoc plus it was +7.9 dt/ha (*$N_{205}R_{35}K_{75}$*) and +8.6 dt/ha (*$N_{220}P_{70}K_{105}$*).*

Conclusion. *The use of higher calculated doses of fertilizers stimulated an increase in yield, and spraying oil flax plants in the "herringbone" phase with Micropolidoc Plus microfertilizer at a dose of 0.5 l/ha, in combination with mineral fertilizers, gave a higher increase in seeds according to the options. Correlation-*

statistical analysis revealed that the relationship was enhanced when treated with agrochemical Micropolidoc Plus against the background of an average level of nutrition (r = 0.42), and an increase in the number of boxes per unit increased the crop yield by +0.84 dt/ha, which indicated the effectiveness of a biological product that improved conditions for increasing the responsiveness of yields to the formation of boxes.

Keywords: *oil flax; Moscow region; agrochemical; mineral fertilizer; microfertilizer; crop structure; yield*

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Научная статья | Общее земледелие и растениеводство

ПРОДУКТИВНОСТЬ ЛЬНА МАСЛИЧНОГО В ЗАВИСИМОСТИ ОТ ДОЗ УДОБРЕНИЙ И КОРРЕЛЯЦИОННО-СТАТИСТИЧЕСКИЙ АНАЛИЗ ИССЛЕДУЕМЫХ ФАКТОРОВ

А.А. Подлипная, Д.В. Виноградов, Т.В. Зубкова

Обоснование. *Высокая закупочная цена, расширение объемов переработки стимулирует производство масличных культуры в целом, в том числе и льна масличного. Однако, в условиях центрального Нечерноземья еще недостаточно проведена работа по определению аутэкологических аспектов в агроценозах льна масличного и научному обоснованию устойчивого производства масличного сырья данной культуры. Так же, не решена проблема посевных качеств льна, сохранности урожая в различных погодных условиях региона, плохо отработаны такие приемы агротехнологии, как применение биологизированных микроудобрений, включая комплексное взаимодействие с минеральными удобрениями, что определяет актуальность и необходимость проведение данных исследований.*

Материалы и методы исследования. *Методы исследования и методология исследования базируется на обобщении научных источников отечественных и иностранных авторов, проведении лабораторных и полевых исследований, фенологических наблюдений, учетов, согласно рекомендаций и общепринятых методик, с применением корреляцион-*

но-статистического анализа полученных экспериментальных данных. Для статистической работы применялся Microsoft Office Excel 10.

Результаты. *Максимальные средние показатели урожайности выявлены на вариантах с внесением $N_{205}P_{35}K_{75}$ (24,4 ц/га); $N_{220}P_{70}K_{105}$ (25,1 ц/га) на фоне применения Микрополидок Плюс. Прибавка маслосемян по сравнению с вариантами с внесением N_{125} составила без Микрополидок Плюс: +6,8 ц/га ($N_{205}P_{35}K_{75}$), +8,9 ц/га ($N_{220}P_{70}K_{105}$); на фоне применения Микрополидок плюс: +7,9 ц/га ($N_{205}P_{35}K_{75}$), +8,6 ц/га ($N_{220}P_{70}K_{105}$).*

Заключение. *Применение более высоких расчетных доз удобрений стимулирует увеличение урожая, а опрыскивание растений льна масличного в фазу «елочки» микроудобрением Микрополидок Плюс в дозе 0,5 л/га, в комплексе с минеральными удобрениями дает более высокую прибавку семян по вариантам. При корреляционно-статистическом анализе, выявлено, что связь усиливается при обработке агрохимикатом Микрополидок Плюс на фоне среднего уровня питания (r=0,42), а увеличение числа коробочек на единицу повышает урожайность культуры уже на +0,84 ц/га, что указывает на эффективность биопрепарата, который улучшает условия для повышения отзывчивости урожайности на формирование коробочек.*

Ключевые слова: *лен масличный; Московская область; агрохимикат; минеральное удобрение; микроудобрение; структура урожая; урожайность*

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Introduction

Oil flax is a valuable industrial and oilseed crop that produces high-quality oil and highly concentrated protein feed for animals in the form of meal and cake [1-3]. The production of oil flax in Moscow region in recent years has been a promising area, and has a tendency to increase production crops in the region [4, 5].

Thus, the gross volume of oil flax in the Russian Federation in 2021 exceeded 1 million hectares, and amounted to 1.4 million tons, and already in 2022, the figure was 1.7 million tons [6]. The cultivation of this crop stimulated production, including the absence of duties, while other oilseeds - rape, soybean and sunflower had them. The area under oil flax in Russia is also increasing: 2013 - 0.48 million hectares, 2015 – 0.64 million ha, 2018 – 0.84 million ha, 2021 – 1.56 million ha, 2022 – 2.1 million ha.

The cultivation of oil flax is not developed in Moscow region and the annual area under crop is not more than 1.5 thousand hectares with a yield of 1.4-1.6 t/ha, but there is a large reserve in increasing production.

The main buyer of oil flax is the People's Republic of China getting more than half of the volume of seeds from the country, Turkey has increased purchases. Such European countries as Belgium, Norway, Poland, Latvia also import oil flax [7-11].

The high price and the expansion of treatment volumes stimulate the production of oilseeds in general, including oil flax [12, 13]. In addition, oil flax is often sown as a good predecessor for winter cereals in crop rotation, having a stable crop yield [14]. Further production of oil flax will depend on market conditions and sales, stable and high prices for raw oil, and agricultural producers are ready to increase production of oil linseed raw materials [15, 16].

An increase in crop yield is impossible without the use of fertilizers and various modern biological products in the production technology, therefore this scientific work is devoted to these problems.

The **purpose** of the work is to identify the reaction of oil flax variety Uralsky, taking into account the applied calculated doses of mineral fertilizers, to the planned yield (1.5; 2.0; 2.5; 3.0 t/ha) in combination with the use of Micropolidoc plus microfertilizer.

Scientific novelty

For the first time in the conditions of the central part of the non-Chernozem zone, the reaction of oil flax variety Uralsky to calculated doses of mineral nutrition in combination with microfertilizer Micropolidoc plus on soddy-podzolic heavy loamy soils of Moscow region was studied. The productivity of oil flax depending on the factors was revealed and a correlation-statistical analysis of the straight-line relationship between the number of pods and the yield of the crop was carried out.

Materials and Methods

Experimental studies were carried out on fields of the All-Russian Research Institute of Agrochemistry Named after D.N. Pryanishnikov, mcr. dstr. Barybino, Domodedovsky district, Moscow region in 2021-2022.

The soil of experimental plots was soddy-podzolic heavy loamy and the D horizon was Shale drape with the following agrochemical characteristics: pH KCl - 5.25-5.33; $N\text{-}NO_3$ 7.6-7.7 mg/kg; $N\text{-}NH_4$ 1.25-1.33 mg/kg P_2O_5 151-161 mg/kg; K_2O 168-174 mg/kg; humus - 2.0 %.

The studies were according to the method presented by B.A. Dospekhov (1985). Events for sowing oil flax were generally accepted for the region. The predecessor was winter wheat. Autumn plowing was carried out to a depth of 20-22 cm (MTZ-1221 + PLN-4-35) and early-spring harrowing was carried out by BZSS-1.0 to a depth of 16-18 cm BDN-2.4 * 2, followed by presowing cultivation after 1-1.5 weeks to a depth of 6-8 cm (MTZ-1221 + KPM-6). There was application of fertilizers for pre-sowing cultivation. Sowing was with a seeding rate of 7 million units/ha (MTZ-1221 + Kverneland DL) and sowing time was the first decade of May. The variety of oil flax in the experiment was Uralsky. Harvest accounting was carried out by a continuous method using a selective harvester Tarion - 2010.

Azophoska NPK 16-16-16, ammonium nitrate was used in the experiment (factor A). Doses of fertilizers were applied based on the planned yield: 1) 1.5 t/ha; 2) 2.0 t/ha; 3) 2.5 t/ha; 4) 3.0 t/ha of seeds in doses of N_{125}; $N_{160}K_{40}$; $N_{205}R_{35}K_{75}$; $N_{220}P_{70}K_{105}$ kg/ha according to the options. As factor B in experiments, microfertilizer Micropolidoc Plus was studied at a dose of 0.5 l/ha. This agrochemical includes macro- and microelements and amino acids. The composition of Micropolidoc Plus microfertilizer declared by the manufacturer included N - 200g/l, P_2O_5 - 120 g/l, K_2O - 100 g/l, S - 1.5 g/l, Fe - 1.1 g/l, Mo - 0.5 g/l, Cu - 0.21 g/l, Zn - 0.2 g/l, Mg - 0.6 g/l, Mn - 1.1 g/l, B - 0.1 g/l, Co – 0.02 g/l, glutamic acid – 0.002 g/l, L-alanine – 0.014 g/l.

Results and discussion

The climate of Domodedovo district of Moscow region during the years of research was characterized as temperate continental with an average annual air temperature of about +4° C, a period with positive temperatures of 210-213 days and an average annual precipitation of 520-546 mm. The sum of average daily temperatures in the experimental area during the growing season was 1 970–2 120° C, on average, the hydrothermal coefficient of the HTC 2021 was 0.89, HTC was 1.09.

The soil of the experimental plot was soddy-podzolic, and therefore, the application of mineral fertilizers, taking into account the planned yield, was a mandatory technique in agricultural technology. The application of mineral fertilizers stimulated the growth and development of oil flax throughout the entire growing season (Table 1).

It was revealed that the maximum average yields were obtained on options with $N_{205}P_{35}K_{75}$ (24.4 dt/ha) and $N_{220}P_{70}K_{105}$ (25.1 dt/ha) against the background of Micropolidoc Plus application. The increase in oilseeds compared to options with the introduction of N_{125} was without Micropolidoc Plus: +6.8 dt/ha ($N_{205}R_{35}K_{75}$), +8.9 dt/ha ($N_{220}R_{70}K_{105}$); against the background of Micropolidoc plus: +7.9 d/ha ($N_{205}R_{35}K_{75}$), +8.6 dt/ha ($N_{220}P_{70}K_{105}$).

Table 1.

The structure of the crop and the yield of oil flax depending on doses of fertilizers and the use of Micropolidoc Plus

Option of application of calculated mineral fertilizers, kg/ha of active ingredient	Treatment with Micropolidoc Plus	Quantity of plants, pcs/m^2	Plant height, cm	Number of pods, pcs. / 1 plant	Weight of 1 000 seeds, g	Yield, dt/ha
N_{125}	-	604.8	43.3	14.9	6.9	15.8
	+	620.0	48.0	15.5	7.2	16.5
$N_{160}K_{40}$	-	617.8	46.7	15.9	7.0	19.0
	+	634.9	51.8	16.3	7.2	20.5
$N_{205}P_{35}K_{75}$	-	618.5	49.9	16.7	7.0	22.6
	+	650.0	59.6	17.6	7.4	24.4
$N_{220}P_{70}K_{105}$	-	609.0	55.1	18.1	7.1	24.7
	+	641.1	63.9	17.9	7.4	25.1
LSD_{05}, 2021				0.39	0.06	1.41
2022				1.04	0.15	3.40

The work included a correlation-statistical analysis of the obtained data to check the significant differences between the yield data of oil flax according to the criterion of theoretical yield (4 groups), which was equivalent to the meaning of the ranked level of nutrition in accordance with doses of mineral fertilizers. A non-parametric comparison method was used according to Kruskal-Wallis test, which was designed to check the equality of the medians of several samples. It is considered the non-parametric equivalent of one-way analysis of variance. This is determined by the fact that the values in the flax yield data, the number of pods do not have a normal distribution (according to Kolmogorov-Smirnov). To do this, each theoretical yield threshold is assigned groups.

The data allow to conclude that there are differences in the yield of flax in options with different doses of fertilizers, with the exception of the relationship between the options with a theoretical (calculated) yield of 2.5 and 3.0 t/ha. Apparently, this is due to the fact that in the range of fertilizer doses corresponding to 2.5 and 3.0 t/ha, they do not affect the increase in crop productivity. The hyperbolic-type dependence parameters shown below support this conclusion.

In terms of the number of pods, the differences were not significant between the groups of fertilizer doses for the estimated flax yield of 1.5 and 2.0

t/ha and 2.5 and 3.0 t/ha. This gives a reason to combine them when studying dependencies.

To study the direct relationship between the number of pods (an independent feature) and the yield of oil flax, a two-level grouping of the planned yield factor was carried out based on doses of mineral fertilizers. For this, two groups were created: group 1 had 1.5+2.0 t/ha (average level of nutrition) and group 2 had 2.5+3.0 t/ha (high level of nutrition). Accordingly, the data array was grouped according to the biological product treatment factor – without treatment and with treatment. Table 2 shows the general statistics of the yield and number of pods.

Table 2.

General statistics of the dependence of flax yield on the number of pods per plant

Parameter	Xaver	Confidence interval		Me	Xmin	Xмax	S	V, %	Sx
		-95%	+95%						
Yield, dt/ha	21	20	21	21	12	28	4	18	0.31
Number of pods, pcs.	16	16	17	17	10	22	2	13	0.18

Regression and correlation and their statistical parameters (standard errors and significance level) are presented in Table 3. In general, the share of such a factor as the "number of pods", judging by the values of the correlation coefficients (determination), in the formation of yield (share in variability) is small - does not exceed 20%. The total share of other factors related to weather conditions, other reasons - 80%.

Statistical treatment for the total array (without grouping) showed that correlation and regression coefficients were 0.41 (share in the variance 17%) and 0.71. Accordingly, the relationship was positive. This means that with an increase in the number of pods per yield unit of oil flax it significantly increased by 0.71 dt/ha. When no Micropolidoc Plus treatment, at an average level of nutrition, it was slightly lower than -0.68 dt/ha (r=0.36). In this case, the relationship between the features weakened.

Under a combination of conditions with treatment and nutrition level, the relationship turned out to be even weaker and unreliable (Table 4).

Mineral fertilizers and microfertilizer Micropolidoc plus contributed to an increase in the density of flax plants, by increasing resistance to adverse conditions in the early phases of crop development: increasing drought resistance in May – early June, competition with weeds, increasing resistance to pests and diseases, more intensive development of the crop was revealed in "herringbone" phase.

Table 3.

Dependence of the yield of oil flax on the number of pods at various combinations of nutrition level and treatment with a biological product

Parameter	Correlation coefficient	Standard error of correlation	Regression coefficient	Standard error of regression	Significance level
According to the general array of data					
Intersection	-	-	9.16	2.08	0.000021
Number of boxes	0.41	0.07	0.71	0.12	0.0000001
No treatment, average nutrition					
Intersection	-	-	8.39	4.54	0.072429
Number of boxes	0.36	0.15	0.68	0.28	0.020507
With Micropolidoc Plus treatment, medium nutrition level					
Intersection	-	-	6.54	4.84	0.184586
Number of boxes	0.42	0.14	0.84	0.28	0.006098
No treatment, high nutrition					
Intersection	-	-	9.66	3.89	0.017743
Number of boxes	0.45	0.14	0.71	0.22	0.003036
With Micropolidoc Plus treatment, high nutrition level					
Intersection	-	-	18.0	3.19	0.000002
Number of boxes	0.23	0.15	0.28	0.18	0.135881

Table 4.

Hyperbolic dependency parameters

Parameter	Rating	Standard error	p-value	Confidence interval	
				-95%	+95%
a	33.84	0.66	0.00	32.53	35.14
b	-26.76	1.34	0.00	-29.42	-24.11

Conclusion

Thus, according to the results of the research, we state that the maximum average yields were obtained on options with $N_{205}P_{35}K_{75}$ (24.4 dt/ha) and $N_{220}P_{70}K_{105}$ (25.1 dt/ha) against the background of Micropolidoc Plus application. The increase in oilseeds compared to options with the introduction of N_{125} was without Micropolidoc Plus: +6.8 dt/ha ($N_{205}R_{35}K_{75}$), +8.9 dt/ha ($N_{220}R_{70}K_{105}$)

and against the background of Micropolidoc plus it was +7.9 dt/ha ($N_{205}R_{35}K_{75}$) and +8.6 dt/ha ($N_{220}P_{70}K_{105}$).

The weak relationship under the combination of conditions between the treatment with Micropolidoc Plus and the application of mineral fertilizers can be explained by the absence of a response in the amount of pods formation in flax in a certain range of applied doses of mineral fertilizers. The argumentation of this statement is supported by a significant regression of the hyperbolic type (y = a + b / x) between the level of nutrition and yield.

The relationship is enhanced by the treatment with agrochemical Micropolidoc Plus against the background of an average level of nutrition (r=0.42), and an increase in the number of pods per unit increases the crop yield by +0.84 dt/ha. This may indicate that the biopreparation improves conditions for increasing yield responsiveness to pod formation.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this article.

ВКЛАД АВТОРОВ

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DATA ABOUT THE AUTHORS

Anastasia A. Podlipnaya, Postgraduate Degree Seeker of the Department of Agronomy and Agrotechnologies

Ryazan State Agrotechnological University Named after P.A. Kostychev
1, Kostychev Str., Ryazan, 390044, Russian Federation
a.podlipnaya@yandex.ru

Dmitry V. Vinogradov, Doctor of Biological Sciences, Professor, Head of the Department of Agronomy and Agrotechnologies; Professor of the Department of General Agriculture and Agroecology
Ryazan State Agrotechnological University Named after P.A. Kostychev; Lomonosov Moscow State Faculty; Yelets State University Named after I.A. Bunin
1, Kostychev Str., Ryazan, 390044, Russian Federation; 1/12, Leninskie Gory, 119234, Moscow, Russian Federation; 28, Kommunarov Str., Yelets, 399770, Russian Federation
vdvrzn@mail.ru

Tatyana V. Zubkova, Head of the Department of Agrotechnologies, Agricultural Products Storage and Processing, Candidate of Agricultural Sciences, Associate Professor
Yelets State University Named after I.A. Bunin
28, Kommunarov Str., Yelets, 399770, Russian Federation
ZubkovaTanua@yandex.ru

ДАННЫЕ ОБ АВТОРАХ

Подлипная Анастасия Александровна, соискатель кафедры агрономии и агротехнологий
Рязанский государственный агротехнологический университет им. П.А. Костычева
ул. Костычева, 1, г. Рязань, 390044, Российская Федерация
a.podlipnaya@yandex.ru

Виноградов Дмитрий Валериевич, доктор биологических наук, профессор, заведующий кафедрой агрономии; заведующий кафедрой агрономии и агротехнологий; профессор кафедры общего земледелия и агроэкологии
Рязанский государственный агротехнологический университет имени П.А. Костычева; Московский государственный университет имени М.В. Ломоносова; Елецкий государственный университет им. И.А. Бунина

ул. Костычева, 1, Рязань, 390044, Российская Федерация; Ленинские горы, 1, стр. 12, 119234, Москва, Российская Федерация; ул. Коммунаров, 28, г. Елец, 399770, Российская Федерация
vdvrzn@mail.ru

Зубкова Татьяна Владимировна, заведующая кафедрой агротехнологий, хранения и переработки сельскохозяйственной продукции, доцент
Елецкий государственный университет им. И.А. Бунина
ул. Коммунаров, 28, г. Елец, 399770, Российская Федерация
ZubkovaTanua@yandex.ru

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