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Mineral fertilizers and insecticides in the formation of seed yield of the oil flax varieties

Elena Korepanova
Department of horticulture
Izhevsk State Agricultural Academy
Izhevsk, Russia
k_evital@mail.ru

Vera Goreeva
Department of horticulture
Izhevsk State Agricultural Academy
Izhevsk, Russia
k_evital@mail.ru

Ramis Galiev
Department of horticulture
Izhevsk State Agricultural Academy
Izhevsk, Russia
k_evital@mail.ru

Ildus Fatihov
Department of horticulture
Izhevsk State Agricultural Academy
Izhevsk, Russia
k_evital@mail.ru

***Abstract*—The effect of fertilizers and insecticides on the yield of oil flax varieties in the Middle Ural in years 2016-2018 were determined under our study. The soil of the experimental locations was characterized as semi-cultivated. The preceding crop before our study was the winter triticale. The experiment scheme included the following options: factor A – grade: VNIIMK 620 flax (standard); Severniy flax; factor B – fertilizer: no fertilizers (for the control group); the planned seed yield of 12 kg/ha; factor C – insecticide: no treatment (control); water spraying of seeding (for the control group); seed treatment with "Tabu"; "VSK" (1.0 l/t); seeding processing with "Karate", "MKS" (0.1 l/ha); seeds and seeding treatment with "Tabu", "VSK", "Karate", "MKS". Mineral fertilizers increased the seed yield by 1.0 kg/ha or 10.8% in the cultivation of oil flax varieties VNIIMK 620 and Severniy. Seed treatment before sowing with an insecticide "Tabu" or spraying of the seedlings with "Karate" insecticide, or their sequential use, (with the use of mineral fertilizers and without them), increased the flax seed yield by 0.5-1.5 metric centners/hectare. The increase in seed yield with the use of fertilizers is caused by an increase in seed germination by 2%. At the same time, more plants were ready for harvesting – by 16 units/m^2, which had more capsules – by 0.7 pieces; and seeds – by 2.7 units, which led to an increase in the seed mass by 0.04 g. Increase in seed yield, when using the insecticide "Tabu" as a seed treatment before sowing, and the "Karate" insecticide for processing seedings separately and with their sequential use, contributed to the germination capacity increase by 4–5%. As a result, the viability of plants during the growing season was improved by 2–3%, which affected the density of the plants before harvesting and the productivity of the oil flax, increasing the abovementioned indicators by 34–48 units/ m^2; by 0.2-0.8 units – capsules quantity; by 2.5-2.7 units – seeds quantity; 0.01-0.02 g – seed mass.**

Keywords*— *oilseed flax, VNIIMK 620, Severniy, fertilizer, seed yield, insecticide, seed treatment, crop treatment

I. Introduction

Oilseed flax is known both in Russian agriculture and worldwide due to its valuable economic and biological properties [1; 2]. The main objective in the cultivation of any crop is the yield increasing and improvement of product quality. To do this, it is necessary to provide the soil with optimal doses of mineral fertilizers, to develop and introduce preventive measures for pest control [3; 4; 5; 6; 7].

Indicators of the removal of the main nutrients per unit of the main products, including the secondary ones, were established on the sod-podzolic clay-loam soils of the Ural region of the Nonblack soil zone of Russia by V.N. Goreeva [8], when she was determining the optimal doses of fertilizers for the VNIIMK 620 flax, and by E.V. Korepanova [9], when she was doing the same for the Linum elongata flax.This made it possible to adjust the previously recommended doses of fertilizers, taking into account the compensation of the removal of nutrients to the planned flax yield. The positive influence of various insecticides on the productivity of field crops is well known. However, not enough research has been conducted to study the comparative effectiveness of the methods of using various insecticides on flax oilseed in the Ural region of the Nonblack soil zone of Russia.

The aim of the study is to reveal the influence of fertilizers and insecticides on the formation of the seed yield of oil flax varieties in the Ural region of the Nonblack soil zone of Russia.

The objectives of the study are:

- To determine the productivity of flax oilseed varieties: VNIIMK 620 and Severniy, when using mineral fertilizers and insecticides;
- Scientific substantiate of the formation of yield by indicators of the elements of its structure.

II. Methods

Scientific research was carried out during years 2016–2018 on the experimental field of "Training farm Iulskoe of Izhevsk State Agricultural Academy". The experiments were based on generally accepted methods [10; 11]. The experiment scheme contained the following options: factor A – grade: VNIIMK 620 flax (standard); Severniy flax; factor B – fertilizer: no fertilizers (for the control group); the planned seed yield of 12 kg/ha; factor C – insecticide: no treatment (control); water spraying of seeding (for the control group); seed treatment with "Tabu"; "VSK" (1.0 l/t); seeding processing with "Karate", "MKS" (0.1 l/ha); seeds and seeding treatment with "Tabu", "VSK", "Karate", "MKS". It was a three-factor and field experiment. The options were placed by the method of split plots. The repetition of the options is fourfold; surveys were carried out on the area of 15m^2.

The topsoil of the sod-podzolic clay-loam soils was characterized by the following agrochemical indicators (Tab. 1): low and higher humus content (1.6-2.7%); high content of mobile phosphorus (187-240 mg/kg); medium and high content of exchangeable potassium (110-189 mg/kg); slightly acid and close to neutral exchange acidity (pH_{KCl} = 5.5 ... 6.1).

TABLE I. AGROCHEMICAL INDICATORS OF THE TOPSOIL OF EXPERIMENTAL LOCATIONS

Year	Humus %	Physical and chemical indicators, mmol/100g of soil		pH_{KCl}	V%	Content of mobile elements, mg/kg of soil	
		H_r	S			P_2O_5	K_2O
2016	2.7	1.6	12.2	5.5	88.4	240	189
2017	1.7	1.7	8.5	5.9	88.4	187	110
2018	1.6	1.9	8.6	6.3	79.3	211	114

Meteorological conditions were scattered over the years. In 2016, the development of VNIIMK 620 flax took place at a relatively hot and dry growing season (Sielianinow hydrothermal index – 0.73) with an average air temperature of 19.1°C with a total precipitation of 208 mm. In 2017, the first half of the vegetation of oil flax passed through wet and cool weather (Sielianinow hydrothermal index – 5.45 ... 2.34), which led to a delay in germination for up to 31 days and lengthening the vegetation period up to 123 days, in relation to similar indicators in 2016. In 2018, more favorable meteorological conditions developed during the vegetation period (Sielianinow hydrothermal index – 0.91). At the same time, the average daily air temperature was 16.7°C, the sum of positive temperatures was 1786°C. In the period of sowing and sprouting, when the severity of flax fleas increases, cold and rainy weather was noted with a Sielianinow hydrothermal index – 2.39. Therefore, during this period, the number of flaxseed fleas did not exceed the Economic threshold of harmfulness index.

III. RESEARCH RESULTS

The applied fertilizers and insecticides had an impact on the yield of flax seeds of oilseed varieties VNIIMK 620 and Severniy (Tables 2, 3).

Under the conditions of 2016, regardless of the use of fertilizers and insecticides, standard flax oilseed formed seed yield by 0.4 metric centners per hectare, or 4% higher (HCP_{05} for main effects of A – 0.2 metric centners/hectare). The introduction of mineral fertilizers in the cultivation technology of the standard and studied varieties of oil flax did not have the advantage in seed yield over the option without their use. Presowing treatment of flax seeds of both types with pesticide “Tabu”, spraying the crops with “Karate”, as well as alternately using both insecticides increased the seed yield by 1.4-1.6 metric centners/hectare in comparison to the yield in the control group, that is, without processing seeds (HCP_{05} for the main effects of C – 0.6 metric centners/hectare).

The flax variety Severniy provided an increase in seed yield by 1.4-1.6 metric centners/hectare and by 1.3-1.5 metric centners/hectare whith treating seeds before sowing with “Tabu” separately and followed by spraying the seedlings with insecticide “Karate” without mineral fertilizers and against the background of their use, in relation to the abovementioned indicator in the control group variants (HCP_{05} for partial distinctions of C – 1.2 metric centners/hectare). The seed yield between options with insecticides was not significantly different.

Under the abiotic conditions of 2017, the studied flax varieties did not have a significant difference in seed yield. Introduction of mineral fertilizers into the technology of cultivation of oil flax varieties VNIIMK 620 and Severniy increased seed yield by 0.9 metric centners/hectare or by 10.6% with HCP_{05} for main effects of C – 0.3 metric centners/hectare. The technology of cultivation of oil flax, including pre-sowing seed treatment with the “Tabu” insecticide, followed by seedling treatment with “Karate” insecticide, increased the seed yield by 1.0–1.1 metric centners/hectare a (11.8–12.9%) in the second year of research (HCP_{05} for main effects of C – 0.6 metric centners/hectare).

During the growing season of 2018, the studied varieties of flax oilseed VNIIMK 620 and Severniy formed seed yield of 9.6 and 9.2 metric centners/hectare, respectively, which did not differ significantly. The inclusion of mineral fertilizers in the technology of cultivation of flax oilseed standard variety and the second studied variety had a superior seed yield of 2.4 metric centners/hectare or 29.3% (HCP_{05} for main effects of B – 0.3 metric centners/hectare). Regardless of the variety and the use of fertilizers, the options with the pre-sowing treatment of seeds with the “Tabu” insecticide, with the pre-seed treatment of the seeds with this insecticide and the subsequent spraying of the crops with the “Karate” insecticide contributed to a significant increase in seed yield by 1.9–2.1 metric centners/hectare (22–24%) with HCP_{05} for main effects of C – 0.5 metric centners/hectare. Spraying of seedlings of flax oilseed insecticide was lower by 1.7–1.9 metric centners/hectare in seed yield options, including the presowing treatment of seeds with the insecticide “Tabu” in the cultivation technology.

The increase in seed yield by 1.8-2.4 metric centners/hectare of oilseed flax VNIIMK 620 was obtained with the pre-sowing treatment of seeds with the “Tabu” insecticide separately and followed by spraying the crops in the seedling phase with the “Karate”, without using mineral fertilizers; by 1.8-2.6 4 metric centners/hectare - in the above-mentioned options with the background of mineral fertilizers (HCP_{05} for main effects of C – 1.0 metric centners/hectare). The reaction of Severniy flax manifested itself by an increase in seed yield by 1.5–2.0 metric centners/hectare and 1.8–1.9 metric centners/hectare with the seed treatment before planting with “Tabu” separately and with subsequent spraying of seedlings with “Karate” without using mineral fertilizers and with the background of their use, respectively.

On average, during the years of the research, the oil flax varieties VNIIMK 620 and Severniy formed a seed yield of 9.8 and 9.6 metric centners/hectare, respectively, which did not differ significantly (Table 3). The inclusion of mineral fertilizers in the technology of cultivation of oil flax varieties VNIIMK 620 and Severiy increased the planned yield by 1.0 metric centners/hectare or by 10.9% (HCP_{05} for main effects of B – 0.2 metric centners/hectare).

TABLE II. THE EFFECT OF MINERAL FERTILIZERS AND INSECTICIDES ON THE SEED YIELD OF OIL FLAX VARIETIES, IN METRIC CENTNERS/HECTARE

Variety (A)	**Fertilizer (B)**	**Insecticide (C)**					**Mean value of B**	**Mean value of A**
		No treatment (κ)	***Water treatment of sprouts***	***Tabu***	***Karate***	***Tabu, Karate***		
2016								
VNIIMK 620 (st.)	No fertilizer (κ)	10.3	10.2	11.3	11.3	11.4	10.6	10.8
	Planned yield	10.0	9.8	11.4	11.2	11.4	10.7	
Severniy	No fertilizer (κ)	9.5	9.6	10.9	10.6	11.1		10.5
	Planned yield	10.0	9.7	11.3	11.2	11.5		
Mean value of C		9,9	9.8	11.2	11.1	11.3		
2017								
VNIIMK 620 (st.)	No fertilizer (κ)	8.0	8.2	8.8	8.4	8.9	8.5	8.9
	Planned yield	8.7	8.7	10.1	9.0	10.2	9.4	
Severniy	No fertilizer (κ)	8.3	8.3	9.1	8.4	9.1		9.0
	Planned yield	8.9	8.8	10.0	9.1	10.1		
Mean value of C		8,5	8.5	9.5	8.7	9.6		
2018								
VNIIMK 620 (st.)	No fertilizer (κ)	7.5	7.6	9.9	8.4	9.4	8.2	9.6
	Planned yield	9.8	9.9	12.4	9.4	11.7	10.6	
Severniy	No fertilizer (κ)	7.2	6.8	8.7	8.0	8.8		9.2
	Planned yield	10.0	10.0	11.8	9.2	11.9		
Mean value of C		8,6	8.6	10.7	8.8	10.5		

HCP_{05}	***2016***			***2017***			***2018***		
	A	B	C	A	B	C	A	B	C
Partial distinctions	0.9	$F_ф<F_{05}$	1.2	$F_ф<F_{05}$	0.8	1.2	$F_ф<F_{05}$	1.0	1.0
Main effects	0.3		0.6		0.3	0.6		0.3	0.5

Regardless of the variety and fertilizers, the seed yield in the options without seed treatment and spraying of sprouts with water amounted to 9.0 metric centners/hectare, while the options with pre-sowing seed treatment with the insecticide "Tabu" and spraying of seedlings with "Karate" and with their consistent use contributed to a significant increase of seed yield by 0.5–1.5 metric centners/hectare (5.5–16.7%) with HCP_{05} for main effects of C – 0.3 metric centners/hectare. Spraying of crops in the seedling phase with the insecticide "Karate" was less than 1.0 metric centner/hectare in seed yield by the options that included the seed treatment with the "Tabu" insecticide.

TABLE III. THE EFFECT OF MINERAL FERTILIZERS AND INSECTICIDES ON THE SEED YIELD OF OIL FLAX VARIETIES, IN METRIC CENTNERS/HECTARE (AVERAGE FOR 2016–2018)

Variety (A)	**Fertilizer (B)**	**Insecticide (C)**					**Mean value of B**	**Mean value of A**
		No treatment (κ)	***Water treatment of sprouts***	***Tabu, Vsk***	***Karate, MKS***	***Tabu, Karate***		
VNIIMK 620 (st.)	No fertilizer (κ)	8.6	8.7	10,0	9,4	9,9	9,2	9,8
	Planned yield	9.5	9.5	11,3	9,9	11,1	10,2	
Severniy	No fertilizer (κ)	8.3	8.3	9,7	9,1	9,8		9,6
	Planned yield	9.6	9.5	11,0	9,8	11,2		
Mean value of C		9,0	9.0	10.5	9,5	10,5		

HCP_{05}	A	B	C
Partial distinctions	$F_ф<F_{05}$	0.7	0.6
Main effects		0.2	0.3

The seed yield of VNIIMK 620 flax increased by 1.3–1.4 metric centners/hectare, when treating seeds before sowing with the "Tabu" insecticide separately and followed by spraying the seedlings with "Karate" without the use of mineral fertilizers, 1.6–1.8 metric centners/hectare - in the abovementioned options with the background of the use of mineral fertilizers (HCP_{05} for main effects of C – 1.0 metric centners/hectare). In relation to seed yield in the option without seed treatment before sowing and insecticide treatment of flax seedlings, the reaction of the Severniy variety was manifested by an increase in seed yield by 1.4–1.5 metric centners/hectare and by 1.4–1.6 metric centners/hectare on the pre-sowing seed treatment with "Tabu" separately and with subsequent spraying of crops with "Karate" in options without the use of mineral fertilizers and with the background of their use, respectively. Fertilization on the planned yield caused an increase by 2% of seed germination with HCP_{05} for the main effects of B – 1% (table 4).

Inclusion of insecticide "Tabu" in the cultivation technology for presowing treatment of seeds with the background of mineral fertilizers use increased the seed germination by 4-5%, without their use – by 4% in the control variety group; and by 3 and 4%, respectively, in the second studied variety, in comparison to the seed germination in the option without treatment (HCP_{05} for partial distinctions of C – 3%). Regardless of the variety and mineral fertilizers, the use of the "Tabu" insecticide for pre-sowing seed treatment separately and alternately with the "Karate" insecticide – for use in vegetation during the sprouting phase, increased by 2-3% plant survival during the vegetation period with HCP_{05} for the main effects of C – 2 % (Table 4).

In the terms of plant density, the options with mineral fertilizers exceeded by 16 units/m^2 the options without fertilizers for HCP_{05} for the main effects of B – 7 units/m^2 (Table 4). The use of "Tabu" separately and with the following spraying of the seedlings with insecticide "Karate" ensured an increase in the number of productive plants for harvesting in the flax variety VNIIMK 620 by 41–46 units/m^2 and in the Severniy variety by 38–40 units/m^2 in the option without mineral fertilizers, by 45–48 units/m^2 and by 34–45 units/m^2, respectively - in the option with mineral fertilizers, in comparison to the control group (HCP_{05} for partial distinctions of C – 20 units/m^2). This led to a difference in seed yield for every studied insecticide.

The application of mineral fertilizers contributed to an increase of the seed mass by 0.04 g per plant at HCP_{05} for the main effects of B — 0.01 g (Table 5). The increase in the abovementioned indicator was observed with the growth of the following indicators of plant productivity: capsules quantity - by 0.7 units (HCP_{05} for main effects of B – 0.1 units), seeds quantity – by 2.7 units (HCP_{05} for main effects of B – 0.7 units). All this led to an increase in the flax seed yield by 1.0 metric centners/hectare or 10.9%.

TABLE IV. THE EFFECT OF MINERAL FERTILIZERS AND INSECTICIDES ON THE STRUCTURE ELEMENTS OF THE OIL FLAX VARIETIES YIELD (AVERAGE FOR 2016-2018)

Variety (A)	**Fertilizer (B)**	**Insecticide (C)**					**Mean value of B No treatment (к)**	**Mean value of A Water treatment of sprouts**
		No treatment (к)	***Water treatment of sprouts***	***Tabu***	***Karate***	***Tabu, Karate***		
Seed germination in %								
VNIIMK 620 (st.)	No fertilizer (к)	68	68	72	69	72	70	71
	Planned yield	70	70	75	72	74	72	
Severniy	No fertilizer (к)	68	68	72	70	72		71
	Planned yield	70	71	74	71	74		
Mean value of C			69	73	70	73		
Plant viability in %								
VNIIMK 620 (st.)	No fertilizer (к)	80	80	84	82	83	82	82
	Planned yield	81	81	83	82	84	82	
Severniy	No fertilizer (к)	81	80	83	81	83		82
	Planned yield	80	81	83	81	83		
Mean value of C			80	83	82	83		
Plant density at harvesting in %								
VNIIMK 620 (st.)	No fertilizer (к)	428	427	473	444	469	448	457
	Planned yield	443	445	490	460	491	464	
Severniy	No fertilizer (к)	429	429	469	444	467		455
	Planned yield	443	447	488	453	481		
Mean value of C			437	480	450	477		

HCP_{05}	***germination %***			***viability %***			***density units/m^2***		
	A	B	C	A	B	C	A	B	C
Partial distinctions	$F_ф<F_{05}$	3	2	$F_ф<F_{05}$		3	$F_ф<F_{05}$	22	20
Main effects		1	1			2		7	10

TABLE V. THE EFFECT OF MINERAL FERTILIZERS AND INSECTICIDES ON THE PRODUCTIVITY OF OIL FLAX VARIETIES (AVERAGE FOR 2016-2018)

Variety (A)	**Fertilizer (B)**	**Insecticide (C)**					**Mean value of B No treatment (к)**	**Mean value of A Water treatment of sprouts**
		No treatment (к)	***Water treatment of sprouts***	***Tabu***	***Karate***	***Tabu, Karate***		
Capsules quantity								
VNIIMK 620 (st.)	No fertilizer (к)	4.6	4.7	5.2	5.1	5.3	5.1	5.3
	Planned yield	5.2	5.4	6.1	5.5	6.3	5.8	
Severniy	No fertilizer (к)	4.7	4.9	5.6	5.2	5.4		5.5
	Planned yield	5.6	5.6	6.2	5.6	6.2		
Mean value of C		5,0	5.1	5.8	5.3	5.8		
Seeds quantity								
VNIIMK 620 (st.)	No fertilizer (к)	32.3	32.9	34.8	34.0	34.9	33.3	34.9
	Planned yield	35.4	34.9	38.3	34.5	37.6	36.0	
Severniy	No fertilizer (к)	31.9	31.7	33.7	32.6	34.4		34.4
	Planned yield	34.9	34.2	37.6	35.4	37.4		
Mean value of C		33,6	33.4	36.1	34.1	36.1		
Seed mass, g								
VNIIMK 620 (st.)	No fertilizer (к)	0.25	0.25	0.26	0.26	0.26	0.25	0.26
	Planned yield	0.26	0.26	0.28	0.26	0.27	0.27	
Severniy	No fertilizer (к)	0.24	0.23	0.25	0.25	0.25		0.26
	Planned yield	0.27	0.26	0.28	0.27	0.28		
Mean value of C		0,25	0.25	0.27	0.26	0.27		

HCP_{05}	Capsules			Seeds			Seed mass. g		
	A	B	C	A	B	C	A	B	C
Partial distinctions	$F_ф<F_{05}$	0.4	0.4	$F_ф<F_{05}$	0.7	2.2	$F_ф<F_{05}$	0.01	0.01
Main effects		0.1	0.2		0.2	1.1		0.01	0.01

The increase in seed yield, with the inclusion of the insecticide "Tabu" for pre-sowing seed treatment, the "Karate" insecticide for use during the seedling phase, and their different combinations, is caused by the improved productivity of the oil flax plant. Oil flax plants have formed a larger number of capsules by 0.2–0.8 units (HCP_{05} for the main effects of C – 0.2) for harvesting, which provided an increase in the seed yield by 2.5–2.7 units and seed mass – by 0.01–0.02 g (HCP_{05} for the main effects of C – 1.1 units and 0.01 g, respectively).

IV. CONCLUSION

The introduction of mineral fertilizers into the technology of cultivation of VNIIMK 620 and Severniy oil flax varieties led to an increase in seed yield by 1.0 metric centners/hectare or by 10.8%. Pre-sowing treatment of seeds with the "Tabu" insecticide, spraying of crops with the "Karate" insecticide in the seedling phase, separately or alternate, both without mineral fertilizers and with their use, affected the yield of oil flax seeds, increasing it by 0.5-1.5 metric centners/hectare. The increase in seed yield during fertilizer application is caused by an increase in field germination of seeds by 2%. At the same time, more plants were matured for harvesting by 16 units/m^2, and they had more capsules – by 0.7 units, and more seeds – by 2.7 units, which led to an increase in the seed mass by 0.04 g. The seed germination increased by 4-5% after using insecticides "Tabu" and "Karate" in various combinations, it had also improved plant viability during the growing season by 2–3%, which had an impact on the plants density before harvesting and the productivity of an oil flax plant, increasing the abovementioned indicators by 34–48 units/m^2, respectively; by 0.2–0.8 units in the capsules quantity; by 2.5-2.7 units in the seeds quantity; by 0.01-0.02 g in the seed mass. As a result, all this led to an increase in the seed yield in the abovementioned options of the experiment.

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