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Improving elements of agricultural technology in the cultivation of new varieties of fiber flax in the conditions of the Central region of Russia

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Abstract. This paper presents the results of a study of the responsiveness of new flax varieties bred domestically (Universal, Phoenix) and Belarusianally (Grant) to agrochemical techniques for optimizing growing conditions, including the application of different doses and timing of nitrogen fertilizers, as well as the use of fungicidal and insecticidal seed treatments. The paper demonstrates the impact of the studied agricultural techniques on field seed germination, seedling mortality during the spring-summer period, and plant survival before harvest. The resistance of the resulting phytocenoses to lodging is assessed. A comparison of the flax straw performance indicators revealed the advantages of the Grant and Phoenix varieties over the Universal variety, which was inferior in terms of technical stem length, soapiness, taper, and straw weight. Pre-sowing seed treatment and the split application of nitrogen fertilizers contributed to an increase in the quantitative and qualitative straw indicators. The analysis of the yield data for flax straw, trust, fiber and seeds allowed us to identify the most economically and agro-technologically justified method of using the studied chemicals, which consists in the combined use of seed treatment with Tebu-60 (0.5 l/t) and Imidor Pro (2.5 l/t) with fractional application of nitrogen fertilizers according to the N45P45K90 + N15 scheme, which allowed us to obtain the highest yield of all types of products in most cases. Depending on the variety, it amounted to 8.18-8.61 t/ha of straw, 6.19-6.38 t/ha of trust, 2.27-2.35 t/ha of fiber and 0.93-1.21 t/ha of seeds. At the same time, the average trust number of fiber flax varieties was approximately at the same level and varied from 1.50 to 2.00 depending on the studied agricultural practices; fiber number – from 11 to 13 units.

1 Introduction

Flax is one of the most valuable agricultural crops, yielding two main products: flax fiber and flaxseed, with a wide range of applications [1, 2]. Strengthening domestic production of this crop, aimed at creating a self-sufficient and competitive raw material base, is a key vector for the development of modern crop production [3].

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When developing cultivation technologies for modern high-yielding varieties, their characteristics must be taken into account, as their productivity is determined by both their genotype and growing conditions. Under modern conditions, the biological potential of a variety can be fully realized with the maximum activation of external factors present in optimal quantities and ratios, while missing elements can be replenished through agricultural practices [5].

Nevertheless, the task of simultaneously achieving high yields and high-quality fiber remains complex [4]. Cultivation techniques can be divided into two blocks: the basic block, which determines the primary results (varieties, seeding rates, sowing dates, primary mineral nutrition, precursor, etc.) and the variable block (biologically active substances, plant protection techniques, micronutrients, etc.), which is effective only when the former is optimized [6].

Among all environmental factors, fertilizers play a key role in increasing plant productivity. Furthermore, the optimal agrochemical characteristics for fiber and seed production differ [5, 6]. The use of differentiated cultivation technologies aimed at producing only one specific primary product - fiber or seed (while not excluding the possibility of producing both) - helps resolve these conflicts.

The objective of this study is to identify opportunities to increase the yield and quality of flax products from new flax varieties bred domestically and internationally by optimizing growing conditions, the application of nitrogen fertilizer doses and timing, and the use of fungicidal and insecticidal seed treatments.

2 Research materials and methods

The research was conducted from 2023 to 2025 on the experimental field of the Smolensk State Agricultural Academy in a six-field crop rotation, located in the village of Mikhnovka, Smolensk District.

The experimental plot soil is sod-podzolic light loam with the following agrochemical and agrophysical characteristics: slightly acidic pH, 1.89% humus content, high mobile phosphorus content (according to Kirsanov) (221 mg/kg), and elevated potassium content (126 mg/kg). Micronutrient levels varied across the soils: low levels of zinc, cobalt, and molybdenum; average levels of boron, manganese, and copper. The soil density of the experimental plot was 1.13 g/cm3, porosity was 56.4%, and the lowest water capacity was 25.9%. The above characteristics are typical for sod-podzolic soils of the Smolensk region and are acceptable for growing fiber flax.

The studies were conducted in accordance with the Field Experiment Methodology of B.A. Dospekhov [7], the Methodological Guidelines of 1978 and 2004 [8, 9], the Fundamentals of Scientific Research in Agronomy [10], and the Fundamentals of Experimental Work [11]. The experiments were conducted using the split-plot method in triplicate. The size of the experimental plots, depending on the order, ranged from 30 to 360 m2. The total area of each experiment was 3,240 m2.

A total of two three-factor field experiments (separately for fiber and seeds) were conducted using a single design. The factorial design of the experiments included a study of the influence of three factors: factor A – variety (Belarusian selection – Grant; domestic selection – Universal and Phoenix); Factor B – pre-sowing seed treatment (with and without treatment); Factor C – rates and timing of fertilizer application (N45P45K90 – control; N60P45K90; N75P45K90; N45P45K90 + N15; N45P45K90 + N30; N60P45K90 + N15).

The agricultural practices in the experiment were generally accepted for fiber flax in the Non-Chernozem zone. The predecessor crop was spring grains. Seeds were sown on April 24-26, depending on the weather conditions.

The sowing qualities of the seeds corresponded to class 1 of the sowing standard. The seeding rates were: 26 million seeds/ha – in the fiber experiment; 14 million seeds/ha – in the seed experiment. Before sowing, the seeds were treated according to the experimental design (factor B) using the fungicide Tebu-60 (0.5 l/t) and the insecticide Imidor Pro (2.5 l/t).

Nitrogen fertilizer doses were applied according to the experimental design during pre-sowing soil cultivation (nitrogen phosphate, ammonium nitrate) and during the "Christmas tree" stage. Potassium fertilizers were applied in the fall before plowing. Plant care and harvesting were carried out according to generally accepted agricultural practices for the Non-Chernozem Zone of the Russian Federation.

Field observations and laboratory analyses were conducted in accordance with current GOST standards and methods:

1) Agrochemical soil analysis – in the 0-20 cm layer before sowing according to GOST 23740-2016, 26483-85, 26212-91, 27821-88, 54650-2011;

2) Phenological records and observations – according to the state variety testing method for fiber flax [12];

3) Straw, straw straw, and seed yield – using the test plot method from each plot with subsequent recalculation for standard moisture content (19%) and standardized weed infestation (5%); seed yield – for 12% moisture content and 100% purity;

4) Statistical data processing – according to Dospekhov [7];

5) Economic performance indicators – according to Standard Process Maps;

6) Straw quality – according to GOST 24383-89; scutched flax – according to GOST R53484-2022.

The climatic and weather conditions of the Smolensk region play a key role in the growth, development, and optimal yield of fiber flax. The active growing season of this crop is primarily determined by the number of days with an average temperature above 10°C. The total number of such days in the region ranges from 1850 to 2190°C. Total annual precipitation reaches 665 mm, of which approximately 335 mm occurs during the growing season. Consequently, the region's agroclimatic environment creates very favorable conditions for the development of flax cultivation. During the study period (2023-2025), agrometeorological factors were unstable and deviated from long-term averages, both in temperature and precipitation. This variability in weather conditions allowed for a more accurate characterization of the impact of agricultural practices on the yield, varietal characteristics, and technological quality indicators of fiber flax.

3 Research results

Seeding quality, which depends on many factors (soil preparation, preceding crop, seed quality, soil moisture and temperature, etc.), can be judged by field germination. For example, at a seeding rate of 26 million seeds/ha in the fiber experiment, seedling density varied widely – from 2,079 seeds/m^2 to 2,369 seeds/m^2. The highest average seedling density was observed for the Phoenix variety – 2,340 seeds/m^2, while for the Universal variety it was 2,262 seeds/m^2, and for the Grant variety – 2,184 seeds/m2. With an increase in the single dose of nitrogen N45 → N60 → N75, a tendency towards a decrease in seedling density was noted in the Grant variety: when using untreated seeds, it was 2282 → 2223 → 2103 pcs/m^2; against the background of treatment - 2315 → 2099 → 2079 pcs/m^2. A similar trend was observed for the Phoenix variety: 2369 → 2334 → 2329 pcs/m^2 and 2359 → 2348 → 2302 pcs/m^2, respectively. For the Universal variety, when using untreated seeds, an increase in single doses of nitrogen did not affect the seedling density (2241 → 2251 → 2241 pcs/m^2). The highest average plant density before harvesting was also observed for the Phoenix variety – 1985 pcs/m^2; for the Universal variety it was 1944 pcs/m2, and for the Grant variety – 1834 pcs/m^2. With an increase in the single dose of nitrogen N45→N60→N75, the Grant variety showed a tendency to decrease the plant density before harvesting, which without seed treatment was 1960→1898→1760 pcs/m^2, and with seed treatment – 1931→1728→1724 pcs/m^2. A similar trend was observed for the Universal variety with untreated seeds: 1940 → 1884 → 1760 seeds/m^2, as well as for the Phoenix variety with treatment: 1989 → 1906 → 1836 seeds/m^2. For the latter variety, increasing single doses of nitrogen, on the contrary, led to an increase in plant density before harvest: 1995 → 2056 → 2128 seeds/m^2.

Average field germination rates over the three years of research were: 84% for the Grant variety, 87% for the Universal variety, and 90% for the Phoenix variety, which directly correlates with their sowing suitability. Seedling mortality in the spring and summer period averaged 10-14% over the three years. This indicator inevitably impacted plant survival before harvest, which was 84% for the Grant variety, 86% for the Universal variety, and 85% for the Phoenix variety. Seed treatment resulted in a slight (1-3%) increase in field germination, reduced plant mortality during the spring and summer, and increased plant survival before harvest.

Flax plant height development essentially ends at the early yellow stage. On average, over the years of research, 94-98% of stem length was formed by this stage; by the flowering stage, 91-94% was formed.

Pre-sowing seed treatment increased plant height by 4% (Universal, Phoenix) to 7% (Grant). Applying nitrogen fertilizers to treated seeds further increased plant height: the increase relative to the control (no fertilizers or treatment) was 9-11%. At the same time, nitrogen fertilizer application at a dose of N30 led to a tendency toward increased lodging, which is associated with the onset of intensive plant growth and rapid stem elongation (budding and flowering stages).

Plant height significantly determined their lodging resistance (r = 0.522). The Grant variety demonstrated higher lodging resistance across all development stages (4.9 points), while the Universal variety averaged 4.4 points, and the Phoenix variety 4.8 points.

For all varieties, regardless of seed treatment, increasing the single nitrogen dose from 45 to 75 kg/ha reduced lodging resistance by 1-2 points. The use of nitrogen fertilizers also reduced lodging resistance, and the negative impact on this indicator tended to increase with increasing fertilizer application rates.

Future yield, fiber yield, and fiber quality can be assessed by the technological parameters of the straw, beginning with the green stage of fiber flax development (green flax). The best fiber quality indicators are formed during the early yellow ripeness stage. However, seeds harvested during this stage of fiber flax development will be unsuitable for sowing the next crop. For this and other reasons, and given the recommended reduction in seeding rates (no more than 16 million seeds/ha) for seed crops, growing and using fiber flax from the same "field" for both fiber and seed is not recommended.

A factor analysis of the obtained data revealed that, in terms of straw performance (Table 1), the Grant variety, a foreign variety bred in the Republic of Belarus, and the Phoenix variety, a domestic variety, stood out. Universal was inferior to both of these varieties in terms of technical stem length, soapiness, taper, and straw weight.

Table 1. Flax Straw Performance by Variety, Pre-Sowing Seed Treatment, and Nitrogen Fertilizer Application Rates and Timing (average over 3 years).

Factors	Indicators						
	Total length, cm	Technical length, cm	Diameter, mm	Soapiness, units	Taper, mm	Weight of straw, g	Bast fiber content, %
Factor A – grade							
Grant	88	75	1.56	477	0.81	0.61	36
Universal	88	72	1.65	436	0.74	0.56	36
Phoenix	88	74	1.67	442	0.79	0.58	36
Factor B – seed treatment							
Without seed treatment	85	71	1.68	420	0.81	0.55	35
With seed treatment	90	76	1.57	485	0.74	0.60	37
Factor C – doses and timing of application of nitrogen fertilizers							
N45P45K90 – control	85	70	1.67	422	0.79	0.59	33
N60P45K90	87	72	1.64	442	0.81	0.60	35
N75P45K90	87	74	1.60	459	0.77	0.56	37
N45P45K90 + N15	88	76	1.62	466	0.72	0.58	36
N45P45K90 + N30	89	74	1.59	462	0.74	0.57	38
N60P45K90 + N15	89	75	1.63	457	0.83	0.57	36

Pre-sowing seed treatment with fungicidal and insecticidal seed treatments resulted in reduced disease and pest infestations in flax crops, which had a positive impact on the technical properties of the resulting straw. The following parameters increased: total stem length by 6%, technical length by 7%, soapiness by 15%, straw weight by 9%, and bast fiber content by 2%. Stem diameter decreased by 7% and taper by 9%. The improved straw technical properties affected not only the quality of the flax fiber but also its count.

Increasing single nitrogen doses from 45 to 75 kg/ha under different seed treatment conditions resulted in contrasting changes in the straw technical properties. When using treated seeds, nitrogen fertilizers increased overall stem length and bast fiber content, decreased straw weight, and did not change diameter. In contrast, when using untreated seeds, increasing single nitrogen doses from 45 to 75 kg/ha did not significantly increase straw fiber content. However, this combination of factors was accompanied by relatively clear trends toward increased overall stem length and soapiness, as well as decreased straw taper.

The use of split nitrogen fertilizer applications resulted in improved straw quantitative and qualitative parameters across all treatments. The highest parameters were observed in the treatments with N45P45K90 + N15 and N45P45K90 + N30. The studied fertilizer application systems resulted in an increase in the total and technical length of straw by 3-6 cm, a decrease in stem diameter by 0.05-0.08 mm, an increase in soap content by 40-44 units, and a decrease in taper by 0.05-0.07 mm compared to the control.

Thus, the combined use of pre-sowing seed treatment and split nitrogen fertilizer application during the herringbone stage improves the technological properties of fiber flax straw and enhances its spinning properties.

Yield yield provides an integrated assessment of the cultivated varieties and the effectiveness of each agricultural practice. In the experiment with fiber flax cultivation, straw yield varied widely – from 5.46 t/ha to 8.48 t/ha. Overall, the Phoenix variety exceeded the Universal variety in flax straw yield by 5% and was on par with the Grant variety (Table 2).

Table 2. Effect of varieties, pre-sowing seed treatment, nitrogen fertilizer rates, and timing on straw and straw yield, t/ha (average over 3 years).

Doses and timing of fertilizer application (factor C)	Straw			Trusts		
	Varieties (factor A)					
	Grant	Station wagon	Phoenix	Grant	Station wagon	Phoenix
Without seed treatment (factor B)						
N45P45K90 – control	6.37	6.01	6.15	5.61	5.17	5.11
N60P45K90	6.41	6.04	6.39	5.44	5.32	5.60
N75P45K90	6.02	5.90	6.23	5.04	5.03	5.50
N45P45K90 + N15	7.61	7.16	7.43	5.59	5.99	6.00
N45P45K90 + N30	7.45	7.16	7.50	5.31	5.56	6.42
N60P45K90 + N15	6.86	7.06	7.16	5.11	5.08	5.62
On average (combination AB)	6.79	6.56	6.81	5.35	5.36	5.71
On average (factor B)	6.72			5.47		
With seed treatment (factor B)						
N45P45K90 – control	6.88	6.21	6.85	5.35	5.30	5.54
N60P45K90	6.72	5.66	6.20	5.39	5.38	5.69
N75P45K90	5.65	5.46	5.96	4.14	4.28	4.64
N45P45K90 + N15	8.61	8.18	8.48	6.38	6.19	6.28
N45P45K90 + N30	7.33	7.87	8.19	5.72	5.85	5.91
N60P45K90 + N15	8.09	7.79	8.26	5.13	5.19	5.70
On average (combination AB)	7.21	6.86	7.32	5.35	5.37	5.63
On average (factor B)	7.13			5.45		
On average (factor A)	7.00	6.71	7.07	5.35	5.36	5.67
HCP_{05} by factor A	0.30			0.24		
HCP_{05} by factor B and AB	0.24			0.19		
HCP_{05} by factor C and AC	0.26			0.21		
HCP_{05} private differences	0.63			0.50		

Pre-sowing seed treatment with seed treatment agents increased flax straw yield by 6% for the Grant variety, 5% for the Universal variety, and 7% for the Phoenix variety.

For the Grant variety, the use of single, increasing doses of nitrogen fertilizer, both with and without seed treatment, was ineffective. The highest straw yield (6.37-6.88 t/ha) was obtained with N45. Increasing the dose to N60 did not significantly change this indicator, while increasing it to N75 reduced the yield per unit area by 5-18%.

For the Universal and Phoenix varieties, the use of single, increasing doses of nitrogen fertilizer with untreated seeds did not change straw yield, while with treated seeds, it significantly decreased this indicator. The use of fertilizers increased straw yields across varieties, both without seed treatment and with pre-sowing cultivation. The highest straw yields were obtained with seed treatment and the N30P45K90 + N15 fertilizer regimen, and were as follows: 8.61 t/ha for the Grant variety, 8.18 t/ha for the Universal variety, and 8.48 t/ha for the Phoenix variety. A decrease in yield with high nitrogen doses, both with single applications (over 60 kg/ha) and with the N60P45K90 + N15 fertilizer regimen, is due to plant elongation and lodging. The average flax straw yield over the three years of research was 5.35 t/ha for the Grant variety, 5.36 t/ha for the Universal variety, and 5.67 t/ha for the Phoenix variety. Pre-sowing seed treatment did not significantly change this indicator.

When using a single application of mineral fertilizers, the N60P45K90 dose proved to be the most effective in most cases. The flax straw yield in this treatment, using untreated seeds, was 5.44 t/ha for the Grant variety, 5.32 t/ha for the Universal variety, and 5.60 t/ha for the Phoenix variety; in the treatments with pre-sowing seed treatment, the yields were 5.39, 5.38, and 5.69 t/ha, respectively. Variations with lower and higher nitrogen fertilizer applications (N45P45K90 and N75P45K90) resulted in a decrease in flax straw yield of up to 30%.

Under both seed treatment conditions (with and without seed treatment), the application of N45P45K90 + N15 fertilizer increased flax straw yield to 5.99-6.38 t/ha (by 13-19%). The exception was the application of fertilizer to the Grant variety of fiber flax without seed treatment, which did not significantly change flax straw yield.

With single and split nitrogen applications at a rate of 75 kg/ha of active ingredient. Split application according to the N45+30 schedule was more effective: its use with both seed treatments increased the yield of the flaxseed to 5.31-6.42 t/ha (5-38% compared to a single application of an equivalent dose), depending on the variety. Application of nitrogen fertilizers according to the N60+15 schedule was less effective than the previous schedule for all studied varieties and seed treatment options. This trend demonstrates that the studied flax varieties are similar in phenotype and morphobiological characteristics of growth and development in our region.

Fiber content in the flaxseed, on average, over the three years of research, fluctuated between 30-42% and was highest under 2025 conditions. The average value of this indicator for all three varieties was 36%. The use of pre-sowing seed treatment led to an increase in this indicator by an average of 2% (from 35 to 37%). The fractional application of nitrogen fertilizers according to the scheme N45+15 and N45+30 had some advantage compared to the corresponding options of their full application in a single dose, which was expressed in an increase in the content of flax fiber in the trust from an average of 35-37 to 36-38%.

The use of single applications of increasing doses of nitrogen fertilizers when growing the Grant variety of fiber flax under both seed treatment backgrounds was more effective with nitrogen applied at a rate of 60 kg/ha, resulting in a yield of 1.82–1.88 t/ha of flax fiber (Table 3). Single applications of nitrogen fertilizers at rates of 45 and 75 t/ha were 4–13% inferior to the above-mentioned variant in fiber yield. Split applications of nitrogen fertilizers (N45+15) resulted in an increase in yield to 2.14–2.35 t/ha (by 14–29% compared to the single application of nitrogen fertilizers at the same rate). For the Universal variety, the use of single, increasing doses of nitrogen fertilizer from 45 to 60 kg/ha under both seed treatments did not significantly change fiber yield. However, increasing the single dose of nitrogen fertilizer to 75 kg/ha resulted in a significant decrease in fiber yield to 1.68-1.70 t/ha, or 6-9% compared to the initial treatment.

Splitting nitrogen fertilizer at a dose of 60 kg/ha using the N45+15 schedule when growing this flax variety under both seed treatments resulted in an increase in fiber yield to 2.06-2.27 t/ha, or 14-23% compared to a single application of nitrogen fertilizer at the same dose. When using untreated Phoenix seeds, the most effective single dose of nitrogen fertilizer was N60, increasing fiber yield from 1.76 to 1.90 t/ha (an 8% increase). However, a further increase in the single dose of nitrogen fertilizer to 75 kg/ha did not result in an increase in flax fiber yield.

When using treated seeds of the same variety, the best dose of nitrogen fertilizer was also N60, increasing fiber yield by 22% compared to N45. A further increase in the single dose of nitrogen fertilizer to N75 negatively impacted fiber yield, reducing it to 1.76 t/ha.

The highest flax fiber yield of the Phoenix variety was obtained with split nitrogen fertilizer application using the N45+30 schedule, using treated seeds; For the Grant and Universal varieties, the N45+15 and N45+30 treatments, when using treated seeds, did not produce significant differences in flax fiber yield.

Table 3. Effect of varieties, pre-sowing seed treatment, and nitrogen fertilizer application rates and timing on flax fiber and seed yield, t/ha (average over 3 years).

Doses and timing of fertilizer application (factor C)	Straw			Trusts		
	Varieties (factor A)					
	Grant	Station wagon	Phoenix	Grant	Station wagon	Phoenix
Without seed treatment (factor B)						
N45P45K90 – control	1.74	1.79	1.76	0.67	0.72	0.69
N60P45K90	1.88	1.81	1.90	0.73	0.77	0.75
N75P45K90	1.70	1.68	1.90	0.64	0.70	0.72
N45P45K90 + N15	2.14	2.06	2.13	0.97	0.94	0.90
N45P45K90 + N30	1.99	1.84	2.34	0.93	0.78	0.88
N60P45K90 + N15	1.88	1.83	2.00	0.86	0.70	0.79
On average (combination AB)	1.89	1.84	2.01	0.80	0.77	0.79
On average (factor B)	1.91			0.79		
With seed treatment (factor B)						
N45P45K90 – control	1.59	1.86	1.80	0.71	0.78	0.72
N60P45K90	1.82	1.84	2.19	0.84	0.84	0.92
N75P45K90	1.75	1.70	1.76	0.70	0.81	0.82
N45P45K90 + N15	2.35	2.27	2.27	1.21	0.93	1.12
N45P45K90 + N30	2.31	2.27	2.39	0.98	0.87	1.07
N60P45K90 + N15	1.94	1.92	1.97	0.86	0.84	0.79
On average (combination AB)	1.96	1.98	2.06	0.88	0.85	0.91
On average (factor B)	2.00			0.88		
On average (factor A)	1.92	1.91	2,03	0,84	0,81	0,85
HCP_{05} by factor A	0.10			0.04		
HCP_{05} by factor B and AB	0.05			0.06		
HCP_{05} by factor C and AC	0.10			0.07		
HCP_{05} private differences	0.24			0.17		

Thus, the average flax fiber yield across varieties in the trial was 1.92 t/ha for Grant, 1.91 t/ha for Universal, and 2.03 t/ha for Phoenix. The maximum yield for Grant was 2.35 t/ha, for Universal 2.27 t/ha, and for Phoenix 2.39 t/ha.

An integral indicator of flax fiber quality is its fiber number. No significant differences in fiber number were observed between the tested varieties. The average fiber number of the flax varieties was approximately the same, ranging from 1.50 to 2.00 depending on the techniques studied; fiber number ranged from 11 to 13 units. and depended more on mineral nutrition ($r = 0.568$) and variety ($r = 0.543$) than on seed treatment ($r = 0.284$). The highest fiber and fiber yields were observed in the variants with seed treatment and fractional nitrogen fertilizer application at a rate of N45+15.

One of the priority tasks in the development of flax cultivation, determining the success of the entire industry at the present stage, is the production of high-quality seeds. Currently, the yield of fiber flax seed in the Non-Chernozem Zone of the Russian Federation in flax-growing regions ranges from 0.34 to 0.56 t/ha. This volume is insufficient not only for technical purposes but also for further expansion of the cultivated area of this crop.

In our studies, the yield of fiber flax seed was high and, depending on the agricultural practices studied, ranged from 0.64 to 1.21 t/ha. Pre-sowing seed treatment increased the seed yield of fiber flax varieties by increasing field germination and uniformity of seedlings by 2-4%, survival and the number of plants before harvest by 4-9%, and reducing plant damage by pests (flax flea beetle) by up to 16% or more. On average, the yield of fiber flax crops formed with treated seeds was 0.88 t/ha, significantly higher than that of crops from untreated seeds (0.79 t/ha).

The effect of nitrogen fertilizers on seed productivity of fiber flax was mixed. In the absence of treatment, increasing the single nitrogen dose above 60 kg/ha resulted in a decrease in the number of capsules and seeds per plant and an increase in the weight of seeds per capsule. Compared to seed treatment, there was a decrease in capsule weight and 1,000-seed weight.

Split application of nitrogen fertilizers increased the fiber flax seed yield by 7-45% compared to a similar single application, depending on the variety. The exception was variants using fertilizers according to the N60P45K90 + N15 schedule, which did not result in an increase in seed yield.

The highest fiber flax seed yield was observed with the N45P45K90 + N15 schedule. The seed yield in this variant was: 0.97-1.21 t/ha for the Grant variety; 0.93-0.94 t/ha for Universal; and 0.90-1.12 t/ha for Phoenix. Both single and split applications of nitrogen fertilizers at a rate of over 60 kg/ha of active ingredient were effective. Reduced seed yield due to less uniformity of seeds within the capsule and their number, as well as uneven flowering and capsule formation. However, the above-mentioned factors do not affect fiber yield. This further confirms the feasibility of separate cultivation of flax for fiber and seed using differentiated cultivation technologies.

4 Conclusion

Modern flax varieties of domestic and Belarusian selection, under favorable agronomic and natural-climatic conditions, are capable of forming high productivity of straw, straw, fiber, and seeds. In a field experiment, cultivation of the Belarusian variety Grant allowed to obtain an average yield of 7.00 t/ha of straw, 5.35 t/ha of straw, 1.92 t/ha of fiber, and 0.84 t/ha of seeds. Under similar conditions, the Russian varieties Universal and Phoenix formed 6.71 and 7.07 t/ha of straw, 5.36 and 5.67 t/ha of straw, 1.91 and 2.03 t/ha of fiber, and 0.81 and 0.85 t/ha of seeds, respectively.

Seed treatment with Tebu-60 (0.5 l/t) and Imidor Pro (2.5 l/t) increased the productivity and quality of flax products. The most justified method of using the studied chemicalization agents (seed treatment agents and fertilizers) from the economic and agrotechnological points of view was the option combining seed treatment with fractional application of nitrogen fertilizers according to the scheme N45P45K90 + N15, which allowed in most cases to obtain the highest yield of straw, straw, fiber and seeds. For fiber flax of the Grant variety, it was 8.61; 6.38; 2.35; 1.21 t/ha; for the Universal variety - 8.18; 6.19; 2.27; 0.93 t/ha; for the Phoenix variety - 8.48; 6.28; 2.27; 1.12 t/ha, respectively.

The contribution of biotic and abiotic factors to straw and straw yield was as follows: climatic conditions – 18%, variety – 22%, fertilizers – 24%, treatment – 11%, and other factors – 25%. The impact of these same factors on fiber content and yield was 20, 26, 17, 4, and 33%, respectively.

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