Mineral fertilizers as a technique for regulating the productivity of fiber flax

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Abstract. The article analyzes and presents data on the growth and development of the Phoenix fiber flax variety during the growing season, depending on the type and ratio of mineral fertilizers. The object of research was the variety of fiber flax Phoenix. The use of the tested types of mineral fertilizers made it possible to obtain a yield of flax straw up to 9.49 t/ha and seeds up to 0.34 t/ha. In general, the most effective was the use of fertilizers in option 11 (pre-sowing application of NPK(S) 8:20:30(2) + 0.3B at a dose of 200 kg/ha + Ammophos NP 12:52 at a dose of 133 kg/ha + Kalimag 38 at a dose of 137 kg/ha + top dressing in the herringbone phase ammonium nitrate 34.6 at a dose of 59 kg/ha + trace elements), where the level of yield relative to the control increased by an average of 100% for straw and 70% for seeds. All yield data are confirmed by the elements of its structure. Thus, plant height ranged from 68 to 91 cm, technical length - from 54 to 70 cm, number of plants before harvesting - 1232-1616 pcs/ha, seed weight per plant - 0.16-0.22 g, straw weight - 0.40-0.60 g.

1. Introduction

Agriculture is one of the locomotives of development, which has a decisive influence on the level of food supply and the well-being of the people, and to a large extent determines the state of the country's economy.

Crop production is one of the main directions of development of this main branch of agriculture, the effectiveness of which largely depends on the correct selection and ratio of crops and varieties that are most suitable for the soil and climatic conditions of the region where they are grown. The size and quality of the crop yield is determined primarily by the provision of their life factors, which they receive, as a rule, through the soil. Land in agriculture acts as the main means of production [1].

Flax growing has been an important branch of the national economy of the Smolensk region since ancient times. Alexander Nikolayevich Engelgardt, whose name the experimental station bears, has repeatedly emphasized that flax is the main commercial crop of agricultural production, which gives real cash receipts. In his first agrotechnical experiments, he began work with fiber flax. The problems of flax growing began to be studied more widely from the beginning of the 20th century, when, in addition to agrotechnical research, selection work on flax was launched. Officially, 1913 is considered the beginning of flax breeding - from the work of K.G. Renard. The volume of research on the
problems of flax growing has constantly increased. In the 1930s, after the creation of the All-Russian Institute of Flax, the experimental station became part of it as the Western Zonal Linen Experimental Station. The successful work of the scientists of the station on the development of issues of breeding, biology, physiology and agricultural technology of flax - long-tailed flax made it possible to create 14 varieties of this crop in the pre-war period, which in 1939 occupied half of all varietal flax crops in Russia, which amounted to 805.5 thousand hectares.

The improvement of breeding methods, the development of new methodological provisions in prebreeding and breeding studies made it possible to create by the end of the last century a new generation of adaptive, ecologically plastic highly productive varieties, which are currently included in the State Register of Breeding Achievements Approved for Use [2].

All this testifies to the fact that work on selection testing and seed production should be continued due to the growing demand for flax products both in the domestic and foreign markets.

2. Materials and methods
An experiment on testing the types and ratio of mineral fertilizers in the crops of fiber flax of the Phoenix variety was carried out on an experimental field of the Smolensk State Agricultural Academy in the village. Mikhnovka of the Smolensk district of the Smolensk region in the link of the 6-field crop rotation of the Department of Agronomy, Land Management and Ecology in 2019-2021. The scheme of the experiment is shown in the table according to the results of the research.

The objects of research were: nitrogen, nitrogen-phosphorus complex solid fertilizers, as well as liquid complex fertilizer. Fertilizers were applied according to the experimental scheme.

**Liquid complex fertilizers ZhKU**
11:37 is a nitrogen-phosphorus fertilizer, which contains about 11% nitrogen-containing substances and about 37% phosphorus source substances.

In addition to nitrogen and phosphorus, the compound contains a certain amount of magnesium and sulfur components. The product is widely used in agriculture in countries such as the USA and Argentina.

ZhKU brand 11:37 is a classic representative of liquid complex fertilizers, practically the only one in our country.

According to the physico-chemical properties of the ZhKU, it is a transparent solution of a dark gray or greenish color. The density of the solution is much higher than the density of water - 1.4 g/cm³ (at a temperature of 20°C). The pH of the ZhKU solution is slightly acidic or neutral - 6-7 units. Crystallization temperature of ZhKU 11-37 - 20°C.

**Ammonium nitrate N 34.4**
Concentrated granular nitrogen fertilizer and in its composition ammonium and nitrate nitrogen in equal amounts, is a universal and highly effective mineral fertilizer. With prolonged use, it has an acidifying effect on the soil, and therefore it is necessary to periodically carry out liming.

**NPK(S) 5:15:30(5)+7CaO**
Calcium grade for crops requiring high levels of available phosphorus and potassium in the soil. Great for acidic soils. Calcium increases the biological activity of soils and the rate of decomposition of plant residues, improves the structure and water-holding capacity of soils. Recommended for crops sensitive to calcium deficiency. The brand is highly effective on soils with a low content of potassium: light in terms of granulometric composition and with a leaching water regime.

**Ammophos NP 12:52**
The best solid granular fertilizer to provide plants with readily available phosphorus and nitrogen - the most important vital nutrients that contribute to the growth and development of any crop. Due to the temporary moderate acidification of the soil solution around the fertilizer granule, the greatest effect is observed in nutrient systems on soils with a neutral and slightly alkaline reaction of the medium. The ammonium form of nitrogen contributes to a better supply of phosphorus to plants.

Composition: N 12%, P₂O₅ 52, S n.m. 1.5, P₂O₅ 90 of the substance of the solution,% of the total; MgO 0.1-0.6, P₂O₅ 95 color of the solution,% of the total.
pH 5.2-6.0. The strength of the granule Nm 8 MPa. Grain composition ≥ 97% Ø2-5 mm.

**Diammonium Phosphate NP 18:46**

Highly concentrated phosphate fertilizer. It is optimal for providing any crop with a complete phosphorus nutrition for the entire period of its growth and development, as well as a starting dose of nitrogen and a small amount of sulfur. Sulfur in the composition of the fertilizer also contributes to better absorption of phosphorus and nitrogen by plants.

Composition: N 18, P₂O₅ 46%; P₂O₅ 90 of the substance of the solution, % of the total; P₂O₅ 95 color of the solution, % of the total, S n.m. 2.5.

pH 6.0–7.2. Granule strength n.m. 6 MPa. Grain composition ≥95% Ø1–6 mm.

**PK(S) 0:20:20(5)**

Phosphorus and potassium balanced fertilizer for application on acidic and saline soils. Effectively eliminates excess acidity, as well as alkalinity of the soil in the rhizosphere of plants when applied before sowing on soils with a high supply of phosphorus and potassium. It is successfully used for the main application on soils with a low level of fertility in terms of phosphorus and potassium. Eliminates the lack of sulfur in plants.

Composition: P₂O₅ 20%, K₂O 20, S 5, MgO 0.2, CaO 20.

pH 3.6–3.8. Granule strength n.m. 3. Grain composition ≥95% Ø2–5 mm.

**Sulfoammophos NP(S) 14:40(7)**

Complex three-component fertilizer containing nitrogen, phosphorus and sulfur. Well suited for soils with a high availability of mobile potassium and a low content of mobile sulfur. The high sulfur content makes this brand indispensable for oilseeds - rapeseed, sunflower, flax, as sulfur contributes to the accumulation of oil in the seeds. Optimization of sulfur nutrition is also important for wheat and soybeans, since sulfur contributes to the accumulation of protein in the grain.

Features: Brand-NP(S) 14:40%; Composition: MgO 0.1-0.3%; N 14%; P₂O₅ 40%; S14%.

**Potassium salt (potassium chloride) K₂O-38% (Kalimag)**

(Potassium chloride K₂O-38%, magnesium chloride 6%). "Kalimag" type fertilizer is used as a concentrated water-soluble potash fertilizer in agriculture for application under all cultivated crops, trees, berry and ornamental shrubs, as well as for root top dressing. The fertilizer is especially suitable for beets, cabbage, corn and for silage crops.

TU 2184-001-50267458-02 (as amended No. 1.2) is a concentrate from a mixture of potassium, magnesium, calcium and sodium chlorides. Fertilizer type "Kalimag" is a concentrated water-soluble potash fertilizer in the form of granules or crushed product of various shades from grayish-white to dark gray, with a potassium content in terms of K₂O of at least 38% and 6% MgCl₂.

**A variety of fiber flax Phoenix.** Since 2018, it has been included in the State Register for the Central Region of the Russian Federation. Late-ripening (85-86 days), highly productive, resistant to lodging, not prone to seed shedding.

The variety is tall, plant height - 87 cm. Morphologically aligned. The color of the petal when fully developed is blue. Medium sized box. The seeds are brown. Flowering time is late.

Fungal diseases of the variety are affected to a weak degree.

The yield of flax straw is 56.5 q/ha, seeds - 5.8 q/ha, total fiber - 14.1 q/ha, long fiber - 10.6 q/ha. The content of fiber in the stems is 28.0%, including long fiber - 21.8%.

The weather conditions of the years differed from the long-term average both in terms of precipitation and temperature regime. Extremely unfavorable conditions developed in 2021 (table 1).

The soil of the experimental plot is soddy-podzolic, medium loamy, medium cultivated, slightly acidic (pHCl- 5.6). The depth of the arable horizon is 20-25 cm. Before the laying of the experiments, soil samples were taken and analyzed according to the methods adopted in the agrochemical service. The content of nutrients: humus - 1.9%; mobile phosphorus - 160 mg/kg; exchangeable potassium - 140 mg/kg of absolutely dry soil (table 2).
Table 1. Meteorological conditions for the period of research, average.

| Indicators | April      | May        | June       | July        | August      | September   |
|------------|------------|------------|------------|-------------|-------------|-------------|
| Average monthly temperature (°C) from the norm | 6.3 (+0.7) | 12.3 (+0.2) | 18.9 (+3.1) | 20.9 (+3.9) | 17.4 (+1.8) | 9.2 (-1.2) |
| Average monthly humidity, % | 69-71 | 63-68 | 67-72 | 66-74 | 77-84 | 83-86 |
| Monthly precipitation, mm from the norm | 46 (120%) | 69 (125%) | 51 (60%) | 38 (41%) | 123 (184%) | 99 (143%) |

Table 2. Characteristics of the soil of the experimental plot.

| Humus, % | H, mmol/100g | S, % | V, % | P2O5, mg/kg | K2O |
|----------|--------------|------|------|-------------|-----|
| 1.9      | 2.5          | 7.8  | 76   | 160         | 140 |

In the experiment, the predecessors were winter crops. Seeding rate - 20 million units/ha. Sowing was carried out with an AMAZONE D9-3000Super seeder (width 3 m) with row spacing of 12 cm to a depth of 2-2.5 cm. In the experiment, fertilizers were applied according to the experimental scheme.

Weeds were treated with Agritox herbicides (spraying crops in the "herringbone" phase at a crop height of 8-10 cm; drug consumption 1.0 l/ha, working fluid - 200-300 l/ha) and Panther, from a flax flea they were treated with an insecticide Gladiator (spraying of seedlings; consumption of the drug 0.1 l/ha, working fluid - 100-200 l/ha), against diseases with Abiga-Peak fungicide (spraying on seedlings in the "herringbone" phase; consumption of the drug 2.5 l/ha, liquids - 300-400 l/ha) [3-8].

3. Results and Discussion

The number of plants before harvesting characterizes field germination, survival, plant survival, and, in general, economic and biological productivity.

In our studies, the number of plants ranged from 1232 pcs/m² to 1616 pcs/m² and depended on weather conditions during the period of germination, growth and development of plants.

The highest rates were in options: 12, 11, 9.

In general, according to the experience, field germination and survival of fiber flax plants were low due to high soil moisture during the germination period (more than 35%); precipitation (125% of the norm); death of plants during their intensive growth (lack of moisture in the soil - 49-56% of the norm); elevated temperatures (+3.0-4.0°C from the norm).

During the ripening period, both soil moisture and atmospheric precipitation increased by more than 180%, which led to the death of plants by more than 15%. The death of plants over the years of research in the experiment ranged from 20 to 40%.

The height of fiber flax plants, especially its technical length, characterizes the future yield of straw (fiber content, fiber yield, etc.) and seeds.

In our studies, the total height of plants ranged from 68 cm (control) to 91 cm (option 9) and depended both on the type of fertilizer and on weather conditions. This trend is also typical for the technical length of plants, which ranged from 54 cm (control) to 70 cm (option 9), which could not but affect the yield of straw and fiber [9-15].
Table 3. The influence of mineral fertilizers on the morphological parameters of the elements of the structure of the yield of fiber flax variety Phoenix.

| Option | Plant height, cm | Technical length, cm | Number of plants before harvesting, pcs/m² | Number of boxes per 1 plant, pcs. | Number of seeds in a box, pcs. | The number of seeds per 1 plant, pcs. |
|--------|------------------|----------------------|------------------------------------------|----------------------------------|-------------------------------|--------------------------------------|
| 1. The control | 68 | 54 | 1232 | 3.4 | 6.2 | 21 |
| 2. GKU NP 11:37 KalimagK38 + top dressing | 69 | 56 | 1328 | 4.4 | 5.0 | 22 |
| 3. NPK(S) 5:15:30(5)+7CaO Ammophos NP 12:52 Kalimag 38+ top dressing | 78 | 68 | 1480 | 4.2 | 6.5 | 27 |
| 4. Ammophos NP12:52 Kalimag38 + top dressing | 79 | 65 | 1390 | 5.2 | 5.7 | 29 |
| 5. DAFNP(S) 18:46(2,5) PK(S)+CaO 20:20(5)+20 Kalimag 38+ top dressing | 84 | 68 | 1500 | 4.5 | 6.1 | 27 |
| 6. SulfoammophosNP(S) 14:40(7) PK(S)+CaO 20:20(5)+20 Kalimag 38 + top dressing | 85 | 69 | 1506 | 50 | 7.2 | 36 |
| 7. NPK+B 15:15:15 PK(S)+CaO 20:20(5)+20 +подкормка | 83 | 64 | 1493 | 5.1 | 6.7 | 34 |
| 8. NPK+7CaO+B 5:15:30+0,3B Ammophos NP 12:52 Kalimag 38+ top dressing | 87 | 67 | 1496 | 4.4 | 6.4 | 28 |
| 9. PK(S)+CaO 20:20 20:20(5)+20 Amm. Saltpeter 34.6 + top dressing | 91 | 70 | 1596 | 4.2 | 5.6 | 24 |
| 10. NPK(S)8:20:30(2)+0.3B Ammophos NP 12:52 Kalimag 38+ top dressing | 80 | 65 | 1200 | 4.2 | 6.4 | 27 |
| 11. NPK(S)8:20:30(2)+0.3B Ammophos NP 12:52 Kalimag 38 + top dressing | 82 | 68 | 1607 | 6.0 | 5.5 | 34 |
| 12. DaFNP(S) 18:46 Ammophos 12:52Kalimag 38+ top dressing | 83 | 67 | 1616 | 4.2 | 6.6 | 28 |

The number of seeds per plant ranged from 21 pcs. (control) up to 34-36 pcs. (options: 6, 7, 11) and depended on the number of bolls per plant and the number of seeds in the pod. If no significant deviations were observed in the number of bolls, then in the number of seeds the deviations were significant (4-7.2 pcs.) and finally depended on the air temperature during the pollination period and seed set, which was 10-12°C higher than the optimum. The application of fertilizers in all variants contributed to an increase in the number of seeds from 2 to 11 pcs. for one plant.
Table 4. Economic and biological yield of straw and seeds of fiber flax of the Phoenix variety, depending on the type, doses and ratios of mineral fertilizers, average.

| Option | Weight of seeds from 1 plant, g | Weight of 1 straw, g | Straw yield, t/ha | Seed yield, centner/ha |
|--------|--------------------------------|----------------------|------------------|-----------------------|
| 1. The control | 0.16 | 0.40 | 4.93 | 2.00 |
| 2. GKU NP 11:37 | | | | |
| KalimagK38 + top dressing | 0.17 | 0.52 | 6.96 | 2.25 |
| 3. NPK(S) 5:15:30(5)+7CaO | | | | |
| Ammophos NP 12:52 | 0.18 | 0.53 | 7.81 | 2.66 |
| Kalimag 38+ top dressing | | | | |
| 4. Ammophos NP12:52 | | | | |
| Kalimag38 + top dressing | 0.18 | 0.52 | 7.18 | 2.50 |
| 5. DAFNP(S) 18:46(2.5) | | | | |
| PK(S)+CaO 20:20(5)+20 | 0.17 | 0.51 | 7.64 | 2.55 |
| Kalimag 38+ top dressing | | | | |
| 6. SulfoammophosNP(S) 14:40(7) | | | | |
| PK(S)+CaO 20:20(5)+20 | 0.21 | 0.59 | 9.02 | 3.16 |
| Kalimag 38 + top dressing | | | | |
| 7. NPK+B 15:15:15 | | | | |
| PK(S)+CaO 20:20 20:20(5)+20 | 0.22 | 0.62 | 9.25 | 3.28 |
| +подкормка | | | | |
| 8. NPK+7CaO+B 5:15:30+0,3B | | | | |
| Ammophos NP 12:52 | 0.19 | 0.54 | 8.06 | 2.84 |
| Kalimag 38+ top dressing | | | | |
| 9. PK(S)+CaO 20:20(5)+20 | | | | |
| Amm. Saltpeter 34.6 + top dressing | 0.19 | 0.57 | 9.08 | 3.03 |
| 10. NPK(S) 8:20:30(2)+0.3B | | | | |
| Ammophos NP 12:52 | 0.20 | 0.66 | 7.92 | 2.46 |
| Kalimag 38+ top dressing | | | | |
| 11. NPK(S) 8:20:30(2)+0.3B | | | | |
| Ammophos NP 12:52 | 0.21 | 0.59 | 9.49 | 3.37 |
| Kalimag 38 + top dressing | | | | |
| 12. DAFNP(S) 18:46 | | | | |
| Ammophos 12:52Kalimag 38 + top dressing | 0.20 | 0.57 | 9.18 | 3.23 |
| HCP05 | 0.30 | 0.15 | | |

The data in table 4 show that the yield of fiber flax seeds ranged from 2.00 to 3.37 q/ha. All options with fertilizers relative to the control increased the yield from 0.25 to 1.37 c/ha.

In general, biotic conditions were favorable only in 2020, while in 2019 and 2021 unfavorable for the formation of seed yield. But even under these conditions, a positive effect of the use of mineral fertilizers can be traced. The best options were: 11 - 3.37 c/ha; 7 - 3.28 c/ha; 12 - 3.23 c/ha; as well as 6 - 3.16 centners /ha; 9 - 3.03 q/ha.

According to the level of straw yield formation, a similar picture was observed; the following variants stood out first of all: 11 – 9.49 t/ha; 7 - 9.25 t/ha; as well as 12 - 9.18 t/ha; 9 - 9.08 t/ha; 6 - 9.02 t/ha. The application of mineral fertilizers according to the indicated schemes made it possible to obtain record straw yields even in the conditions of 2021 [16-21].
The obtained results testify to the need to conduct fiber flax seed production with a change in a number of technical operations and, first of all, in terms of seeding rates.

4. Conclusion
The use of the tested types of mineral fertilizers makes it possible to obtain a yield of flax straw up to 9.49 t/ha and seeds up to 0.34 t/ha. In general, the most effective was the use of fertilizers in option 11 (pre-sowing application of NPK(S) 8:20:30(2) + 0.3B at a dose of 200 kg/ha + Ammophos NP 12:52 at a dose of 133 kg/ha + Kalimag 38 at a dose of 137 kg/ha + top dressing in the herringbone phase ammonium nitrate 34.6 at a dose of 59 kg/ha + microelements), in which the control yield was exceeded by 100% for straw and 70% for seeds.

At the same time, the obtained data on the yield level of fiber flax, as well as other results, cannot be considered a full-fledged basis for recommendations on the use of mineral fertilizers when growing crops, since they were carried out with one variety, at one seeding rate. Research should be continued and experiments should be carried out separately both for the production of seeds and straw not on one, but on several varieties.

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