Optimization of the phytosanitary condition of agrocenoses in the non-chernozem zone of the Russian Federation

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Abstract. In flax production there is a need to study the range of promising, more effective and less environmentally friendly pesticides. Under the conditions of changing climatic conditions, taking into account the aggravation of the phytosanitary situation, the tests of new preparations on linen flax are required. In this regard, we assessed the effect of the treatment of crops with protective-stimulating compositions of herbicides (Magnum + Herbitox L + Miura) and the agrochemical Nutrivant Drip of 18-0-36 – KRP grade.

1. Introduction
Flax crops in Russia require systemic protection against weeds and diseases. In the Central Administrative District, in particular, in Tver and Smolensk Regions, more than 200 species of weeds are known, and 70 of them are very widespread.

The level of weed infestation of Russian flax fields in the 21st century, obviously, has increased. Nowadays, about 60% of flax crops are polluted to a large extent. With insufficient attention to the selection and preparation of fields for cultivation of linen flax in the general spectrum of species of unwanted plants, the share of common spurrey, common chamomile, lamb’s-quarters, yellow thistle, field sow thistle, couch grass and millet increases in many cases [1]. Against each of them, appropriate herbicides are required: anti-dicotyledonous (for example, a mixture of Magnum + Herbitox-L preparations) and anti-cereal (for example, Miura) [2].

When spraying crops, the use of tank mixtures of anti-cereal and anti-dicotyledonous herbicides can increase the sensitivity to chemical weeding of not only weeds, but also cultivated plants, and therefore the addition of fertilizer-protective-stimulating, adaptogenic agents to them is justified [3].

Traditional infectious flax diseases manifest themselves in different ways, depending on weather conditions, the degree of seed contamination, weed infestation of crops, and harvest conditions [4]. Anthracnose and pasmo decease (septoria decease) of flax are annually observed.

Various violations of the optimal nutritional conditions of flax are also manifested as well as diseases. The negative effect of the imbalance in the supply of plants with macro- and microelements
on the yield and product quality of flax is more pronounced than that of other crops, because its fiber is formed in the vegetative part of plants, the biological regulation of the entry of elements into which is less pronounced than in the reproductive organs [5, 6]. The deficiency or excess of elements of mineral nutrition can cause flax diseases.

Taking into account the fact that specific dynamics of nutrient absorption by flax when comparing it with the relatively underdeveloped root system of this crop, it can be concluded that phosphorus and potassium should be applied in moderate amounts when refueling with soil fertilizers (before sowing), nitrogen and potassium should be added when feeding plants [7–9]. For foliar fertilization of flax with such parameters, the fertilizing and protectively stimulating agrochemical Nutrivant Drip of 18-0-36 grade, containing 18 % nitrogen and 36 % potassium in flax-friendly forms, can be used.

Thus, on the basis of the published literature, we can verify the need for further study and improvement of the range of new, more effective agents against weeds and diseases together with foliar fertilizers of linen flax plants.

2. Methods and materials
This problem was solved during the research at the All-Russian Scientific Research Institute of Flax. For three years, field experiments (2015, 2016 and 2017) were carried out according to the scheme shown in Table 1.

| No. | Option                                      | Consumption rate             |
|-----|---------------------------------------------|------------------------------|
| 1   | Control (without treatment of crops)        |                              |
| 2   | Magnum, WDG + Herbiotox-L, WSC + Miura, CE (herbicides) | 7 g/ha + 0.6 l/ha + 0.8 l/ha |
| 3   | Herbicides + Nutrivant Drip brand: 18-0-36  | 7 g/ha + 0.6 l/ha + 0.8 l/ha + 5.0 kg/ha |
| 4   | Herbicides + Nutrivant Drip brand: 18-0-36  | 7 g/ha + 0.6 l/ha + 0.8 l/ha + 10.0 kg/ha |
| 5   | Herbicides + Nutrivant Drip brand: 18-0-36  | 7 g/ha + 0.6 l/ha + 0.8 l/ha + 25.0 kg/ha |

Field experiments were performed in accordance with the “Guidelines for conducting field experiments with linen flax” [10]. The research results were processed using the Stadia computer program [11].

The accounting area of each plot of field experiments 2015–2017 was 25 m². Repeatability was fourfold. The agricultural technology of cultivation of linen flax is generally accepted for the zone.

The studies were carried using Tverskaya linen flax variety. It was grown at the Research Institute of Flax by hybridization followed by selection against an infectious background. It was included in the State Registry for the North-West Region since 2003. The leaves are lanceolate and green. The petal is blue, the anther is blue and the snout is blue. The box is spherical, light yellow. The seeds are brown. The mass of 1000 seeds is at the level of 4.5–5.0 g. It is mid-season. In the North-West region, the average yield of straw is 30.3 c/ha, seeds – 4.1 c/ha, the standards have 41.9 and 5.1 c/ha, respectively. The total fiber content is 27.8 %, the long fiber yield is 21.4 %. The growing season from seedlings to early yellow ripeness is 68–90 days. Resistance to lodging 3.3 is 5 points. It is considered to be resistant to rust and fusarium.

2.1. Characterization of the main agents used in the experiments
The following pesticides were used to treat seeds and crops:

Nutrivant Drip of 18-0-36 – KRP brand, 180 g/kg of nitrogen + 360 g/kg of potassium in flax-friendly forms is a fertilizing and protective-stimulating agrochemical (Fertilizers and Chemicals Ltd., 2015).

Magnum, WDG is a systemic herbicide of selective action for the control of annual and some perennial dicotyledonous weeds. Active ingredient is Metsulfuron-methyl (sulfonylurea derivatives), 600 g/kg.

Formulation: water-dispersible granules, August Company Trademark.
Herbitox – L, WSC – a systemic selective herbicide with a wide spectrum of action against annual dicotyledonous weeds. Active ingredient: MCPA acid (derivatives of phenoxyacetic acids) in the form of a mixture of potassium and sodium salts, 300 g/l. The preparative form is a water-soluble concentrate (WSC), August Company Trademark.

Miura, CE is a selective post-emergence herbicide designed to control annual and perennial cereal weeds. Active ingredient: chisalofop-P-ethyl (derivatives of 2-(4-aryloxyphenoxy) propionic acids), 125 g/l. Formulation: concentrate emulsion, August Company Trademark.

The main field experiments were carried out on sod-podzolic, loamy soil of the experimental field of All-Russian Scientific Research Institute of Flax [Torzhok district of Tver region], the agrochemical characteristics of which in the experimental sections are illustrated by Table 2. For the experiment, the sites with a relatively low potassium content were selected annually (in 2015–2017) in the soil.

**Table 2. Agrochemical characteristics of soil of studied areas**

| Years of research | pH of salt extract | Content, mg/kg (according to Kirsaneyov) |
|-------------------|--------------------|------------------------------------------|
|                   |                    | P₂O₅ | K₂O |
| 2015              | 4.7                | 240  | 32  |
| 2016              | 4.6                | 255  | 30  |
| 2017              | 4.8                | 239  | 34  |

Meteorological conditions of 2015–2017, according to the Torzhok weather station (geographical coordinates: latitude 57.02, longitude 35.01), Torzhok, Tver region) were relatively favorable for the growth and development of linen flax culture, for the manifestation of weeds and plant pathogens.

3. Results

The experimental crops of linen flax during the years of our field experiments prior to treatment with herbicides (in mixtures with Nutrivant) were mostly polluted with dicotyledonous annual plants: field broom (2–8 pcs/m²), white gauze (1–2 pcs/m²), types of hemp nettle (1–3 pcs/m²), garden pansy (2–8 pcs/m²), types of chamomile (1–2 pcs/m²), chickweed (2–7 pcs/m²), etc.

On the plots of lands the experiments of 2015–2017 the density of dicotyledonous weeds during the flax “herringbone” phase ranged from 60–78 pcs/m². Cereal weeds (mainly creeping wheatgrass) were less common (from 5 to 9 stems/m²) (Table 3).

**Table 3. Weed infestation of linen flax crops before application of pesticides, pieces/m²**

| Experiment                          | Dicotyledonous | Monocotyledonous (cereal) |
|-------------------------------------|----------------|---------------------------|
| Control (without treatment of crops)| 78             | 7                         |
| Herbicides (Magnum + Herbitox-L + Miura) | 75             | 9                         |
| Herbicides + Nutrivant (5.0 kg/ha)  | 66             | 7                         |
| Herbicides + Nutrivant (10.0 kg/ha)| 60             | 9                         |
| Herbicides + Nutrivant (25.0 kg/ha)| 64             | 5                         |
| HCP₅₀                               | 8              | 2                         |

In 30 days after the application of herbicides in untreated crops, the total number of dicotyledonous weeds annually increased significantly and amounted to 81 pcs/m² with their biological mass of 536 g. The number of cereal weeds in the control group one month after the first count increased even more – up to 47 pcs/m² and their weight was 77 g/m². With this weed infestation, the effectiveness of the mixture: Magnum (7 g/ha) + Herbitox-L (0.6 l/ha) + Miura (0.8 l/ha) 30 days after application was at 68 and 83 %, respectively, to reduce the number and mass of dicotyledonous weeds. Against cereal weeds at this time, the effectiveness of herbicides was – 91.5 and 89.6 % to reduce their number and mass (Fig. 1, 2).

The weed infestation of crops before harvesting in 2015–2017 showed that the effectiveness of the applied herbicidal mixture against dicotyledonous weeds increased to 95 %, and against cereal plants it decreased slightly to 86 %. Probably, this difference in the dynamics of effectiveness is associated
with a prolonged action of the mixture against dicotyledonous weeds (due to sulfonylurea – Magnum) and less prolonged – against cereals (Miura – quizalofop-P-ethyl).

In connection with the addition of Nutrivant to the herbicides, a regular increase in the biological effectiveness of the mixture was observed annually in all cases in the comparison with pure herbicides. The highest results were obtained with the norm of Nutrivant use – 10 kg/ha, – almost 100 % efficiency against dicotyledonous and cereal weeds.

The experiment showed a pronounced fertilizing and growth-stimulating effect of the use of mixtures of herbicides and the agrochemical Nutrivant agent on flax. Spraying vegetative flax plants with these mixtures – 122 plants/m² – increased the density of the plant stand of the crop and reduced the death of flax plants during vegetation by 9.9 % compared to pure herbicides (Table 4).

The most successful results were obtained by spraying the crops with herbicides and the agrochemical Nutrivant agent at consumption rate of 10 kg/ha.

**Figure 1.** Biological effectiveness of pesticides on linen flax, (% death of weeds)

**Figure 2.** Biological effectiveness of pesticides on linen flax, (% of the reduction in air-dry mass of weeds).

**Table 4.** density of condition of linen flax plants, depending on options of application of pesticides, pcs/m²

| Option                                         | pcs/m² | % dead during vegetation of plants |
|------------------------------------------------|--------|------------------------------------|
| Control (without treatment)                    | 704    | 42.9                               |
| Herbicides (Magnum + Herbitox-L + Miura)      | 812    | 34.2                               |
| Herbicides + Nutrivant (5.0 kg/ha)             | 934    | 24.3                               |
| Herbicides + Nutrivant (10.0 kg/ha)            | 970    | 21.4                               |
| Herbicides + Nutrivant (25.0 kg/ha)            | 961    | 22.1                               |
| HCP05                                          | 110    | 7.6                                |

Potassium-deficient necrosis was noted among non-infectious diseases of flax in the control plots, for all 3 years of testing (Fig. 3). This phenomenon significantly affected the growth and development of flax, weakening it, and reducing the morphological parameters of plants.
Figure 3. Manifestation of potassium-deficient necrosis on the leaves of linen flax

In the plots of land of variants using the Nutrivant agent, similar physiological “suffering” of flax was not noted (Table 6). Pasmo decease (septoria decease) of flax manifested itself among the traditional infectious diseases. In control plots, its prevalence was noticeably higher than in treated plots (treated by the agrochemical used in the research).

Figure 4. Effect of pesticide treatment on crops on the prevalence of diseases in flax crops, % (in average for 2015–2017)

The treatment of crops with Herbicides and Nutrivant agrochemical agent contributed to the yield of flax products exceeding the control level (without treatment) by values greater than HCP_{0.5} (Table 5). The maximum yield of both flax straw and seeds was obtained by applying the Nutrivant agrochemical agent when spraying crops at a consumption rate of 10 kg/ha of 31.6 and 5.1 c/ha, respectively (for indicators of the variant with treatment with some herbicides – 24.4 and 3.2 kg/ha; control without treatment – 20.0 and 2.1 kg/ha).

The highest indicators of palm length (71 cm), strength (31 KGF), bast content (29%), overall scores (130) and flax straw numbers (2.06) were noted in the option with the treatment of crops with herbicides and Nutrivant at consumption rate of 10 kg/ha. In this option, the minimum disease incidence of flax stems

Figure 3. Manifestation of potassium-deficient necrosis on the leaves of linen flax

Table 5. Crop yield of linen flax depending on the variant of pesticides application, c/ha

| Option                                  | Crop yield, t/ha |
|-----------------------------------------|------------------|
|                                        | Flax straw      | Flaxseed |
| Control (without treatment)             | 20.0             | 2.1      |
| Herbicides (Magnum + Herbitox-L + Miura) | 24.4             | 3.2      |
| Herbicides + Nutrivant (5.0 kg/ha)      | 29.8             | 4.8      |
| Herbicides + Nutrivant (10.0 kg/ha)     | 31.6             | 5.1      |
| Herbicides + Nutrivant (25.0 kg/ha)     | 31.3             | 5.0      |
| HCP_{0.5}                               | 1.9              | 0.3      |

The highest indicators of palm length (71 cm), strength (31 KGF), bast content (29%), overall scores (130) and flax straw numbers (2.06) were noted in the option with the treatment of crops with herbicides and Nutrivant at consumption rate of 10 kg/ha. In this option, the minimum disease incidence of flax stems
was also obtained (mainly pasmo)/(5% versus 9% in the control option). When applying the Nutrivant agrochemical agent at a consumption rate of 25 kg/ha for the treatment of crops, a slightly less tendency to increase the quality of fibrous flax products was observed, compared to the control option (Table 6).

Consequently, the field tests carried out in 2015–2017 showed high biological and economic efficiency of the use of mixtures of herbicides/Magnum (7 g/ha) + Herbitox-L (0.6 l/ha) + Miura (0.8 l/ha)/and agricultural chemical Nutrivant agent on linen flax when processing crops.

Taking into account the positive results of our field experiments, the Nutrivant Drip agrochemical brand: 18-0-36 is included in the “State catalog of pesticides and agrochemicals approved for use in the Russian Federation” on linen flax culture at consumption rates of 5–10 kg/ha during spraying of crops (foliar/nonroot fertilization) in the phase of the “herringbone” of the culture.

Table 6. Quality of fiber products of linen flax, depending on options of application of pesticides

| Option                                | Palm length, cm | Strength, KGF | Bast content, % | Disease incidence, % | General quality indicator, scores | Number of flax products in accordance with GOST |
|---------------------------------------|-----------------|---------------|-----------------|----------------------|----------------------------------|-----------------------------------------------|
| Control (without treatment)           | 68              | 28            | 29,0            | 12                   | 115                              | 1,50                                          |
| Herbicides (Magnum + Herbitox-L + Miura) | 68              | 28            | 29,0            | 9                    | 117                              | 1,50                                          |
| Herbicides + Nutrivant (5.0 kg/ha)    | 69              | 29            | 29,2            | 7                    | 129                              | 2,00                                          |
| Herbicides + Nutrivant (10.0 kg/ha)   | 71              | 31            | 29,3            | 5                    | 130                              | 2,00                                          |
| Herbicides + Nutrivant (25.0 kg/ha)   | 70              | 30            | 29,2            | 5                    | 130                              | 2,00                                          |

4. Conclusion

In the studies of 2015–2017 the high biological and economic efficiency of the use of the Nutrivant Drip agrochemical agent: 18-0-36 (5–25 kg/ha) was established on linen flax culture during foliar processing of crops/nonroot fertilization of plants together with Magnum herbicides (7g/ha) + Herbitox -L (0.6 l/ha) + Miura (0.8 l/ha). Nutrivant agent significantly increased the effectiveness of herbicides on dicotyledonous and cereal weeds.

A pronounced fertilizing and growth-stimulating effect of the use of this agrochemical was manifested (the density of the plant stand of the crop increased by 122–158 pcs/m² and the death of plants during the growing season decreased by 9.9–12.8), the manifestation of non-infectious and infectious diseases of flax decreased, and it contributed to the yield of flax products exceeding the control level by values greater than HCP05.

During the experiment on soils with a small potassium deficiency, the most successful results were obtained at consumption rate of 10 kg/ha.

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