Dependence of productivity of white lupine seeds on the foliar dressing with macro- and micronutrient fertilizers

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Abstract. The paper presents the results of the studies on the determination of the effect of foliar dressings with macro- and micronutrient fertilizers on linear growth, the mass of air-dry matter of plants, leaf surface, the formation of a symbiotic apparatus and the yield of seeds of white lupine (Lupinualbus L.) in the conditions of black soils of the Central Black Earth region of the Russian Federation. The field experiments were carried out in 2018-2020 at the Department of Crop production, Breeding and Horticulture of Belgorod State Agrarian University. The object of the research is a high-intensity variety of white Degas lupine. The subject of the research is microfertilizer Aquamix-TV, potassium sulfate fertilizer (K$_2$SO$_4$), phosphate-potassium monophosphate fertilizer (KH$_2$PO$_4$). The weather during the years of the experiments was hot and dry. During the critical periods of the development of lupine plants, a moisture deficit was observed with the excess of heat. The soil cover of the experimental site was represented by a typical medium-thick low-humus heavy loamy black soil with a granulometric composition. The accounting area of the plot was 18 m$^2$, the replication was fourfold and the placement was systematic. The experiment included six variants: control (without fertilizers), foliar dressing with Aquamix-TV micronutrient fertilizer, foliar dressing with potassium sulfate solution, foliar dressing with potassium monophosphate solution, foliar dressing with Aquamix-TV + potassium sulfate mixture and foliar dressing with Aquamix-TV + monophosphate mixture potassium. The analysis of the obtained data showed that the highest yield of seeds of white lupine variety Dega was obtained on variants with foliar dressing with micronutrient fertilizer Aquamix-TV in combination with potassium sulfate and monopotassium phosphate, which amounted to 3.52 and 3.51 t / ha, respectively, which is 0.52 and 0.51 t / ha or 17.3 and 17.1% more than the control variant.

1. Introduction
In modern conditions of agro-industrial complex development, a successful solution to the problem of the increase of agricultural production is associated with the rational use of land, a progressive increase in soil fertility and high and stable yields of agricultural crops. One of the most important factors in the solution of these issues in the conditions of the Central Black Earth Region is the introduction of crops of white lupine into agricultural production, as well as the improvement of agricultural technology of this valuable crop.

White lupine is a high-protein and high-yielding crop of intensive farming, characterized by a number of economically valuable traits such as the protein content in the seeds from 30 to 40%, fat content from 12 to 14%, a complete amino acid composition and a high potential seed yield. White
lupine has the ability to assimilate nitrogen from the air with the help of nodule bacteria. The protein content in seeds and green mass of lupine depends primarily on the intensity of nitrogen fixation [1, 2, 3]. In order to obtain high yields of high quality lupine, it is necessary to create conditions under which atmospheric nitrogen will be most actively absorbed by nodule bacteria. One of the factors contributing to this is the use of macro- and micronutrients, which improve the nutritional regime of plants and accelerate their growth and development. The optimization of the mineral nutrition of lupine is difficult, since the applied methods should be not only as effective as possible for the formation of the crop, but also should not have a negative effect on the nitrogen-fixing ability of plants.

Nowadays it is impossible to imagine agricultural production without the introduction of mineral fertilizers. The balanced application of fertilizers for lupine allows obtaining high yields of good quality seeds [4, 5]. The system of fertilizers for agricultural crops involves various types, doses of macro- and micronutrients, methods of their introduction, as well as different phenological phases of plants, for which it is necessary to apply fertilizers. Dressing is one of the most effective methods of fertilizing. Foliar dressing of crops with macro- and micronutrient fertilizers in various phases of the vegetation of plants allows providing them with the necessary nutrients in the required volume. In addition, the application of fertilizers through the leaves is more economical and for plants it is less energy-intensive to assimilate nutrients in comparison with the traditional methods of the use of mineral fertilizers.

2. Materials and methods
The study of effect of foliar dressing with macro- and micronutrient fertilizers on the productivity of lupine plants were carried out in 2018-2020 in the field experiments at the collection nursery of the Department of Crop production, Breeding and Horticulture of Belgorod State Agrarian University. The object of the research was a high-intensity variety of white lupine Dega, the subject of research was mineral macro- and micronutrient fertilizers.

The soil of the experimental site was a typical medium-thick low-humus heavy loamy black soil with a granulometric composition.

According to the data from the meteorological station of Belgorod State Agrarian University, weather conditions during the years of research were unfavorable for lupine, both in terms of temperature and the amount of precipitation. Throughout the entire growing season of lupine, there was a deficit of precipitation against the background of increased air temperature, which negatively affected the productivity of the crop.

The experiment included six variants: control (without fertilizers), foliar dressing with Aquamix-TV micronutrient fertilizer, foliar dressing with potassium sulfate solution, foliar dressing with potassium monophosphate solution, foliar dressing with Aquamix-TV + potassium sulfate mixture and foliar dressing with Aquamix-TV + monophosphate mixture potassium.

The field experiments were performed according to the existing methodological recommendations. The area of accounting plots was 18 m²; the placement of plots was systematic. Sowing was carried out by warming up the sowing layer of soil to 6-7 °C with a seeding rate of 1.3 million pieces of viable seeds per hectare. The sowing method was an ordinary one with row spacing of 15 cm. The predecessor of lupine was spring wheat. Macro and micronutrient fertilizers were used in flower bud stage.

3. Results and discussion
The intensity of linear growth and accumulation of the mass of air-dry matter of white lupine plants can be attributed to morphological indicators, which largely affect the yield and quality of crop seeds. In our experiments, during the growing season of lupine, we observed these indicators and identified certain patterns of changes in the height and weight of plants depending on the use of fertilizers.

Despite the arid weather conditions during the years of research, foliar dressing with macro- and micronutrient fertilizers had a positive effect on the growth of white lupine plants. In the variants of
the experiment with the combined use of microfertilizer Aquamix-TV and macrofertilizers of potassium sulfate and monopotassium phosphate for foliar dressing of white lupine, the highest plant height was noted, which in the phase of bean formation was 53.1 and 53.4 cm, respectively, which was 4.8 and 5.1 cm higher than the control. During dressing with a solution of potassium monophosphate, a solution of potassium sulfate and micronutrient fertilizer Aquamix-TV, plant height also remained at a high level and amounted to 52.4 cm, 52.3 cm and 51.3 cm, respectively, which was 4.1 cm, 4.0 cm and 3.0 cm higher in comparison with the control variant (Table 1).

In the arid conditions of white lupine growing, developed during the years of research, the largest mass of air-dry matter of plants was also noted in variants with the combined use of macro- and micronutrients. Thus, in the phase of bean formation, the mass of the air-dry matter of lupine plants during foliar dressing with a mixture of Aquamix-TV micronutrient fertilizer with potassium sulfate (variant 5) and Aquamix-TV micronutrient fertilizer with potassium monophosphate (variant 6) was 26.6 and 26.4 g, which was 3.3 and 3.1 g higher than in the control variant. The mass of air-dry matter of white lupine plants in variants with foliar feeding of plants with micronutrient fertilizer Aquamix-TV (variant 2), potassium fertilizer K2SO4 (variant 3) and phosphorus-potassium fertilizer KH2PO4 (variant 4) was inferior to the above mentioned variants, but it was above the control.

Table 1. Dynamics of linear growth, mass of air-dry matter and leaf surface of white lupine plants depending on foliar dressing with macro- and micronutrient fertilizers, 2018-2020

| №  | Experiment                                      | Average plant height by phases of vegetation, cm | Average weight of one plant by phases of vegetation, g | Average leaf surface of plants by growing season, thousand m² / ha |
|----|-------------------------------------------------|-----------------------------------------------|-------------------------------------------------------|---------------------------------------------------------------|
|    |                                                 | Flowering Bean formation                       | Flowering Bean formation                               | Flowering Bean formation                                      |
| 1  | Control – without fertilizers                   | 43.4                                           | 48.3                                                  | 12.0                                                          | 23.3                                                          | 16.4                                                          | 24.3                                                          |
| 2  | Foliar dressing of plants with micronutrient fertilizer Aquamix-TV | 46.2                                           | 51.3                                                  | 13.1                                                          | 24.4                                                          | 18.4                                                          | 26.2                                                          |
| 3  | Foliar feeding of plants with potassium sulfate (K₂SO₄) | 46.2                                           | 52.3                                                  | 12.8                                                          | 24.5                                                          | 19.1                                                          | 27.4                                                          |
| 4  | Foliar feeding of plants with potassium monophosphate (KH₂PO₄) | 45.6                                           | 52.4                                                  | 12.9                                                          | 25.0                                                          | 19.6                                                          | 27.5                                                          |
| 5  | Foliar feeding of plants Aquamix-TV + potassium sulfate (K₂SO₄) | 46.5                                           | 53.1                                                  | 14.0                                                          | 26.6                                                          | 21.5                                                          | 29.3                                                          |
| 6  | Foliar feeding of plants Aquamix-TV + potassium monophosphate (KH₂PO₄) | 46.0                                           | 53.4                                                  | 14.3                                                          | 26.4                                                          | 21.3                                                          | 29.1                                                          |

In order to increase the productivity of agricultural crops, due attention has recently been paid to the study and optimization of the photosynthetic activity of agrophytocenoses. One of the most important indicators that determine the photosynthetic activity of plants is the leaf surface. The use of macro- and micronutrient fertilizers greatly affects the process of the formation of a leaf surface.

The studies showed that the largest surface of leaves of white lupine plants was treated due to the conscientious use of Aquamix-TV micronutrient fertilizer with K₂SO₄ and KH₂PO₄ macrofertilizers for foliar feeding. Thus, in the phase of bean formation, the surface of lupine leaves in the variant of the
Aquamix-TV + potassium sulfate experiment was 29.3 thousand m² / ha and in the variant of Aquamix-TV + potassium monophosphate it was 29.1 thousand m²/ha, which was 5.0 and 4.8 thousand m²/ha more compared to the control variant.

With the separate application of microfertilizer Aquamix-TV and macrofertilizers of potassium sulfate and monopotassium phosphate for foliar feeding, the leaf surface of lupine plants varied in the phase of bean formation from 26.2 to 27.5 thousand m²/ha, which also exceeded the control variant.

Lupine has the ability to enter into symbiosis with nodule bacteria, which allows it to fix and involve air nitrogen in biological cycle. In modern conditions of the development of crop production, this process can become the main direction in the solution of the problem of increasing yields and product quality. However, the productivity of symbiosis is influenced by climatic and soil conditions, biological characteristics of crops and the presence of specific strains of nodule bacteria in the soil.

The macro- and microfertilizers studied in the experiment for foliar feeding of white lupine had a significant effect on the symbiotic apparatus of lupine plants.

The greatest number and mass of active nodules of one lupine plant was found in the case of the combined use of macro- and micronutrient fertilizers for foliar feeding. Thus, in the phase of bean formation in the variant with the treatment of lupine crops with Aquamix-TV micronutrient fertilizer together with potassium sulfate, the number and weight of active nodules on the roots of lupine plants amounted to 25.4 pcs and 122.0 mg and in the variant Aquamix-TV + potassium monophosphate it amounted to 25.3 pcs and 121.1mg, respectively, which was 3.4 pcs and 9.7mg, 3.3 pcs and 8.8mg more than control variant.

When dressing lupine crops with micronutrient fertilizer Avamiks-TV (variant 2), potassium sulfate (variant 3), and potassium monophosphate (variant 4), the number and weight of nodules were higher than in the control one, but inferior to the variants of the experiment with the combined use of macro- and micronutrient fertilizers for leaf dressing (table 2).

Table 2. Number and weight of active nodules on the roots of white lupine plants, depending on leaf dressings with macro- and micronutrient fertilizers, 2018-2020

| №  | Variant                                                        | On average for one plant by stages of vegetation |
|----|----------------------------------------------------------------|-------------------------------------------------|
|    |                                                                | flowering                                      |
|    |                                                                | number, pcs mass, mg                           |
|    |                                                                | number, pcs mass, mg                           |
| 1  | Control – without fertilizers                                  | 16.8 70.5                                     |
| 2  | Foliar dressing of plants with micronutrient fertilizer Aquamix-TV | 16.7 71.8                                     |
| 3  | Foliar feeding of plants with potassium sulfate (K₂SO₄)       | 16.8 71.5                                     |
| 4  | Foliar feeding of plants with potassium monophosphate (KH₂PO₄) | 16.6 71.4                                     |
| 5  | Foliar feeding of plants Aquamix-TV + potassium sulfate (K₂SO₄) | 17.4 72.2                                     |
| 6  | Foliar feeding of plants Aquamix-TV + potassium monophosphate (KH₂PO₄) | 16.5 72.1                                     |

Foliar feeding of white lupine plants with a highly concentrated water-soluble complex of microelements in a chelated form of Aquamix-TV in combination with macrofertilizers potassium sulfate and monopotassium phosphate had a significant effect on the yield of crop seeds, which in arid growing conditions averaged 3.51 and 3.51 t/ha over three years, which 0.52 and 0.51 t / ha or 17.3 and 17.1% higher than the control variant (table 3). The separate use of potassium sulfate and monopotassium phosphate macrofertilizers for foliar dressing of white lupine also had a positive effect on the seed yield, which in these variants was 3.25 and 3.32 t / ha, respectively, which was 0.25 and
0.31 t/ha or 8.2 and 10.4% higher than control variant. Foliar dressing with Aquamix-TV micronutrient fertilizer did not lead to a significant increase in the yield of lupine seeds.

Table 3. Yield of white lupine seeds, depending on the leaf dressing with macro- and micronutrient fertilizers

| №  | Variant                                      | Yield, t/ha | +to control |
|----|----------------------------------------------|-------------|-------------|
|    |                                              | 2018 | 2019 | 2020 | average | t/ha | % |
| 1  | Control – without fertilizers                | 3.06 | 3.02 | 2.93 | 3.00    | -    | - |
| 2  | Foliar dressing of plants with micronutrient fertilizer Aquamix-TV | 3.15 | 3.23 | 3.08 | 3.15    | 0.15 | 5.0 |
| 3  | Foliar feeding of plants with potassium sulfate (K₂SO₄) | 3.31 | 3.24 | 3.20 | 3.25    | 0.25 | 8.2 |
| 4  | Foliar feeding of plants with potassium monophosphate (KH₂PO₄) | 3.42 | 3.35 | 3.18 | 3.32    | 0.31 | 10.4 |
| 5  | Foliar feeding of plants Aquamix-TV + potassium sulfate (K₂SO₄) | 3.63 | 3.56 | 3.38 | 3.52    | 0.52 | 17.3 |
| 6  | Foliar feeding of plants Aquamix-TV + potassium monophosphate (KH₂PO₄) | 3.68 | 3.54 | 3.33 | 3.51    | 0.51 | 17.1 |
|    | LSD₀.₁₅                                      | 0.13 | 0.15 | 0.23 |

4. Conclusion
Thus, the conducted research and analysis of experimental data allowed substantiating the effectiveness of foliar dressing of white lupine with a mixture of macro- and micronutrients, which ensured the best realization of the biological potential of crop sowing. It was proved that foliar dressing with Aquamix-TV micronutrient fertilizer in combination with potassium sulfate and monopotassium phosphate in the arid conditions of the Central Black Earth region contributed to the better formation of the photosynthetic and symbiotic apparatus of lupine plants, which ensured a high seed yield of 3.52 and 3.51 t/ha, respectively.

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