The effect of new forms of micro-fertilizers on the yield and quality of white lupine

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Abstract. The limiting factor of yield is often the insufficient supply of plants with nutrients during the growing season. In this regard, it is necessary to find new techniques that provide a solution to this problem. The article presents the results of studies of micro-fertilizers on the yield and quality of white lupine grain. The use of Aquamix ST fertilizers and potassium Metaborate contributed to an increase in the yield of white lupine grain by an average of 37.5 and 35.4%. In all variants of applying Aquamix ST, an increase in the protein content in the white lupine grain of the Pilgrim variety was found. The excess over the control varied from 5.0 to 5.8%. The use of Aquamix ST and potassium Metaborate on vegetative plants reduced the alkaloid content of lupin grain by 24.7 ... 34.6%. Treatment of white lupine crops in the budding phase with Aquamix ST and potassium Metaborate increased the carotene content in the grain by 34.3 - 25.0%, respectively. The analysis of the data showed that the maximum amount of lysine and carotene was characterized by a variant that includes pre-sowing treatment of seeds with Aquamix ST and subsequent treatment of vegetating plants in the budding phase. On average, over the years of research, the use of micro and macro fertilizers led to an increase in feed units and digestible protein with the yield of lupine grain. More valuable in terms of feed were the options that combine high yield with high grain quality. The greatest collection of digestible protein of 1.26 t/ha, feed units of 6.0 t/ha and exchange energy of 54.8 GJ/ha was provided by Aquamix ST in the variant with pre-sowing seed treatment and two treatments for vegetation. Potassium metaborate, used for the treatment of vegetative plants in the budding phase, showed almost the same results.

1. Introduction
Protein deficiency in the world is currently estimated at 10-25 million tons per year. One of the ways to solve the problem is the cultivation of white lupin (Lupinus albus L.), which contains up to 40.0% in seeds, and up to 23.0% protein in the green mass. The yield of this crop is quite high - 4.0-6.0 t / ha [1, 2, 3, 4].

Lupin, like all leguminous crops, is characterized by the instability of this trait over the years of cultivation, which hinders the expansion of its areas. The realization of the genetic potential of leguminous crops is possible only in conditions of full satisfaction of biological needs, which can be carried out by a favorable combination of soil-climatic and technological factors [4]. The limiting factor of yield is often the insufficient supply of plants with nutrients during the growing season. Optimization of plant nutrition with trace elements is especially relevant. The use of narrow-leaved boron,
molybdenum, and cobalt in crops contributes to the formation of active nodules, and manganese, copper, and zinc contributes to a more active joint interaction of micro- and macro-symbionts [5, 6]. In this regard, it is necessary to find new drugs and techniques that provide a solution to the problem of providing lupin with the necessary nutrients. Currently, there are new micro-fertilizers in chelated and organomineral forms, as well as complex preparations based on trace elements and growth regulators [5, 6]. According to the data of the Lupin Research Institute, the introduction of a water-soluble fertilizer Aquarine brand 13 in the phases of stalking or budding allows you to get 4.01-4.24 t/ha of white lupin seeds. Significant increases in relation to the control variant were at the level of 0.53 – 0.76 t/ha [7]. The introduction of Aquarine grades 13 and 15 in all the studied phases increases the fixation of atmospheric nitrogen by 42.2-67.6 kg/ha. The nitrogen fixation coefficient after the use of the drug increased to 80.8-82.3 % [8]. The combined use of Aquamix T preparations and the growth regulator Zircon enhanced the "starting" development of narrow-leaved lupine plants, which ultimately affected the growth of seed yield [9]. Scientifically based treatment of seeds and vegetating plants with new-generation fertilizers will significantly improve the growth and development of plants, as well as stabilize the yield of leguminous crops, in particular white lupine. One of the stages in solving this problem is the search for promising drugs for varieties of white lupine and methods of their application. In this connection, the purpose of these studies was to study the effectiveness of a number of micro- and macro-fertilizers of a new generation and ways of their application in white lupine crops.

2. Materials and methods
The research was carried out in 2018, 2019 in the conditions of the experimental field of the Lupin Research Institute. The laying, conducting field experiments and statistical data processing were carried out according to the methodology of B. A. Dospekhov [10]. The object of research was the white lupine variety Pilgrim. The preparations of Aquamix ST were studied (Cu-0.53%, Zn-0.53%, Mn -2.57%, Ca-2.57%, Fe (EDTA)-2.1%, Fe (DTPA)-1.74%, Mo-0.13%, B-0.52%), Tiaton (5% colloidal sulfur); Potassium metaborate (K2O – 44.0%; B – 10.1%) in doses according to the experimental scheme (Table 1).

Table 1. Experimental scheme.

| Control | Aquamix ST | Aquamix ST | Tiaton | Potassium metaborate |
|---------|------------|------------|--------|-----------------------|
| Consumption rate | 150 g/t | 150 g/t; 500 g/l | 5 l/ha | 500 g/ha |
| Note | Seed treatment | Seed treatment; spraying in the budding phase | Spraying in the phase of 2-4 leaves | Spraying during the budding phase |

Agrochemical characteristics of the arable layer: pH of salt extract – 5.5; mobile phosphorus (according to Kirsanov) – 12.5 and exchangeable potassium (according to Maslova) - 14.8 mg/100g of soil, humus content-2.53%. The seeding rate of lupine seeds is 1.0 million germinating seeds per hectare, the plot area is 25 m2, the repetition rate is 4 times, the placement of plots is systematic. Chemical
analyses of grain – according to generally accepted methods of biochemical research [11], alkaloidness-according to the method described in the Methodological Recommendations for the quantitative determination of alkaloids in lupine [12].

3. Results of the research

As a result of the conducted studies, it was found that the use of micro and macro fertilizers contributed to the increase in the yield of white lupine grain of the Pilgrim variety. The fruit-forming potential of white lupine averaged 47.8% over the years of research in the control variant. The use of Aquamix ST micro-fertilizer increased this indicator in the variant with pre-sowing treatment and spraying of vegetating plants in the phases of 2-4 leaves and budding to 58.6%. This contributed to the formation of the maximum grain yield in this variant, the yield exceeded the control by 37.5%. When adding potassium metaborate to the budding phase, the yield increased by 35.4% (Table 2).

Table 2. Yield and quality of white lupine grain of the Pilgrim variety (average over the years of research).

| Version                                      | Yield (t/ha) | Increase in control (t/ha) | Content (%) per absolutely dry substance | Carotene (mg/kg) |
|----------------------------------------------|--------------|---------------------------|------------------------------------------|------------------|
|                                              |              |                           | raw protein alkaloids lysine              |                  |
| Control                                      | 2,88         |                          | 34,2 0,081 1,92                          | 3,20             |
| Aquamix ST, seed treatment                   | 3,50 + 0,62  | 36,2 0,076 2,00          | 3,35                                      |
| Aquamix ST, seed treatment + spraying in the budding phase | 3,68 + 0,80  | 35,9 0,057 2,10          | 4,30                                      |
| Aquamix ST, seed treatment + spraying in the 2-4 leaf phase+ spraying in the budding phase | 3,96 + 1,08  | 36,1 0,053 2,06          | 3,66                                      |
| Tiaton, spraying in the stemming phase       | 3,12 + 0,24  | 34,5 0,088 1,96          | 3,58                                      |
| Tiaton, spraying in the phase of 2-4 leaves, in the budding phase | 3,23 + 0,35  | 34,9 0,085 1,96          | 3,66                                      |
| Potassium metaborate, spraying in the phase of 2-4 leaves | 3,52 + 0,64  | 35,2 0,061 2,04          | 3,45                                      |
| Potassium metaborate, spraying in the budding phase | 3,90 + 1,02  | 35,6 0,053 2,07          | 4,00                                      |
| HCP05                                        | 0,11         |                           |                                           |                  |

For lupin, the main indicators of feed value are the content of protein and alkaloids in the grain. In all variants of applying Aquamix ST, an increase in the protein content in the grain was found. The excess over the control varied from 5.0 to 5.8 %. Since the content of alkaloids in seeds is an important
indicator of its feed safety and depends on the genotype, soil and climatic conditions, agricultural cultivation techniques, the quality of feed grain is largely determined by the level of its content. On average, over the years of research, the use of Aquamix ST and Potassium Metaborate on vegetating plants reduced the alkaloid content of the white lupine grain of the Pilgrim variety. In these variants, the decrease in this trait was in the range of 24.7-34.6%.

Modern protein nutrition is impossible to imagine without considering the role of individual amino acids. Even with an overall positive protein balance, the animal's body may experience a lack of protein. This is due to the fact that the assimilation of individual amino acids is interconnected with each other, a lack or excess of one amino acid can lead to a lack of another. The results of the research showed that the content of the essential amino acid lysine in the white lupine grain of the Pilgrim variety varied from 1.92 to 2.10% in the experimental variants. In all variants of the experiment, its content was higher than in the control version. The greatest effect from the use of this drug was observed in variants with the use of Aquamix ST as foliar top dressing during the budding phase. With this method of application, the amount of lysine increased by 9.3%.

In terms of the amount of carotene in the grain, lupin is significantly superior to other leguminous crops. The grain of the Pilgrim variety contained from 3.20 to 4.30 mg/kg. Treatment of white lupine crops in the budding phase with Aquamix ST and potassium Metaborate increased the carotene content in the grain by 34.3 – 25.0%, respectively. The analysis of the data showed that the maximum amount of lysine and carotene was characterized by a variant that includes pre-sowing treatment of seeds with Aquamix ST and subsequent treatment of vegetating plants in the budding phase.

The use of micro and macro fertilizers in the studied doses had a positive effect on the elements of the crop structure. First of all, it affects the linear growth of plants (Table 3). There was an increase in the productivity of one plant, the number of beans and seeds per plant when using Aquamix ST. In the variant with seed treatment and two non-root treatments, these indicators increased by 13.5, 19.1 and 16.5%, respectively.

In the variants using Tiaton and Potassium Metaborate, an increase in the mass of 1000 seeds was observed, which indicates better grain performance in these variants.

Table 3. The effect of fertilizers on the indicators of the structure of the harvest of white lupine of the Pilgrim variety (average over the years of research)

| Version                              | Plant height (cm) | Productivity (g / plant) | Number of beans (pcs.) | Number of seeds (pcs.) | Weight of 1000 seeds (g) |
|--------------------------------------|------------------|--------------------------|------------------------|------------------------|---------------------------|
| control                              | 45,5             | 5,56                     | 6,8                    | 23,0                   | 241,7                     |
| Aquamix ST, seed treatment           | 48,6             | 6,28                     | 7,2                    | 26,2                   | 239,7                     |
| Aquamix ST, seed treatment + spraying in the budding phase | 49,3 | 5,87                     | 7,9                    | 26,8                   | 241,6                     |
| Aquamix ST, seed treatment + spraying in the 2-4 leaf phase + spraying in the budding phase | 50,2 | 6,31                     | 8,1                    | 24,3                   | 259,4                     |
| Tiaton, spraying in the stemming phase | 52,5             | 7,30                     | 5,7                    | 23,4                   | 309,6                     |
| Tiaton, spraying in the phase of 2-4 leaves, in the budding phase | 51,2 | 6,50                     | 6,6                    | 21,7                   | 300,9                     |
| Potassium metaborate, spraying in the phase of 2-4 leaves | 54,9 | 5,30                     | 4,6                    | 16,8                   | 314,9                     |
| Potassium metaborate, spraying in the budding phase | 56,8 | 7,00                     | 5,4                    | 19,8                   | 352,6                     |
| HCP₀₅                                | 3,08             | 0,28                     |                        |                        |                           |
On average, over the years of research, the use of micro and macro fertilizers led to an increase in feed units and digestible protein with the yield of lupine grain. More valuable in terms of feed were the options that combine high yield with high grain quality. The greatest collection of digestible protein of 1.26 t/ha, feed units of 6.06 t/ha and exchange energy of 54.8 GJ/ha was provided by Aquamix ST in the variant with pre-sowing seed treatment and two treatments for vegetation. The potassium metaborate used for the treatment of vegetating plants in the budding phase showed almost the same results.

**Table 4. Feed value of white lupine grain of the Pilgrim variety (average over the years of research)**

| Option                                      | Digestible protein yield (t / ha) | Output of feed units (t / ha) | Metabolic energy, (GJ / ha) |
|---------------------------------------------|----------------------------------|------------------------------|-----------------------------|
| Control                                     | 0.79                             | 4.18                         | 38.79                       |
| Aquamix ST, seed treatment                  | 1.02                             | 5.36                         | 48.3                        |
| Aquamix ST, seed treatment +                | 1.06                             | 5.37                         | 50.0                        |
| Aquamix ST, seed treatment + spraying in the budding phase | 1.26                             | 6.06                         | 54.8                        |
| Tiaton, spraying in the stalking phase      | 0.86                             | 4.84                         | 43.4                        |
| Tiaton, spraying in the phase of 2-4 leaves, in the budding phase | 0.91                             | 4.91                         | 44.5                        |
| Potassium metabolite, spraying in the phase of 2-4 leaves | 0.99                             | 5.32                         | 48.3                        |
| Potassium metabolite, spraying in the budding phase | 1.11                             | 6.08                         | 54.4                        |

4. **Conclusion**

The use of micro-and macro-fertilizers, which allow for a significant increase in yield and improve the quality of grain at low costs, has recently become the main link in the technologies of cultivation of feed lupine. Therefore, the substantiation and development of the elements of the technology of their application is an important stage both from a theoretical and practical point of view. The conducted studies allowed us to draw the following conclusions:

Micro and macronutrients used in various phases of the development of the white lupine variety Pilgrim increased the yield and quality of the products obtained, increased the yield of digestible protein, feed units and metabolic energy, which is especially important in conditions of protein deficiency. The highest rates were observed with the complex use of the drug Aquamix ST, containing trace elements in chelated form (Si, Zn, Mp, Ca, Fe, Mo, B) and potassium metaborate (K₂O, B) for foliar treatment in the budding phase.

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