Impact of mineral fertilizers on yield and grain quality of spring wheat cultivar Marsianka

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Abstract. The article gives the results of studies on the effect of mineral fertilizers on yielding capacity and grain quality of a new variety of soft spring wheat (Triticum aestivum L.) Marsianka. The research objectives included the study of mineral fertilizers impact on plant growth and development, ripening terms, yield structure, productivity, grain quality and economic efficiency of Marsianka cultivar. Field observations and laboratory assays of the obtained data confirmed that mineral fertilizers make a significant effect on plant growth and development, on yield components (the amount of productive stems, grain number per spike, thousand-grain weight) of the new variety. Resulting from the studies it has been established that the application of fertilizers rate for the planned yield 4.0 t/ha provides max. productivity 3.43 t/ha of good-quality grain containing crude protein 15.9 % and gluten 35.0 %. In terms of economic efficiency, the lowest prime cost of 1 t grain (5171.0 and 5242.1 rub.) and high payback level were obtained with N₃₀ and N₆₀ application. In these options, the cost recovery of 1 kg a. s. fertilizers was 11.6 and 10.7 kg of grain, respectively. The greatest pure income 15.2 thous. rub/ha was provided in the variant using N₆₀P₆₀K₆₀. The further increase of fertilizers application rate leads to products overpricing and decline in economic indicators when cultivating the new spring wheat cultivar Marsianka.

1. Introduction
Wheat (Triticum aestivum L.) is a valuable and widely cultivated cereal throughout the world. Many different grains use (consumption, feed, industrial products, and biofuels) have caused a continuous increase in the demand and resulted in an expansion of the wheat growing area [1].

Bread wheat is used for making a wide variety of foods, such as bread, noodles, cakes, cookies, pastries, pasta, crackers and porridges. The wide usage of wheat flour is mainly due to variations in kernel hardness, which is also a major factor affecting international wheat trade. Therefore, kernel hardness is a key quality trait of common wheat [2].

Soft spring wheat is a basic cereal crop in the Irkutsk region. Within the structure of grain crops it takes 57 % of the area. At many farm enterprises the yielding capacity of this crop remains not high and amounts 2.4-3.0 t/ha, though it is placed mainly on good predecessors [3].

Production growth and improvement of wheat grain quality is one of the main objectives for arable farmers of our region [4].

The most available and cost-effective source of increasing the yield of field crops, including wheat, is the use of new most productive varieties adapted to natural growing conditions for sowing [5].
Plant breeders create new cultivars with a high genetic potential of productivity and a complex of resistance to adverse environmental factors. However, they are not fully implemented in production conditions [6].

Scientific research and production practice have established that a new variety can realize its potential only in case of creating the necessary agroecological conditions. Particularly, the conditions of mineral nutrition are especially important for cultivating new varieties of intensive type [7].

Mineral fertilizers are one of the basic means significantly increasing the yield and quality of wheat grain. Their effect on spring wheat productivity in our country and abroad has been extensively studied [8].

The researchers note that wheat makes increased demands on soil nutrition due to its poorly developed root system compared to other cereal crops. It takes no good use of hard-to-dissolve soil nutrients [9]. In this regard, to obtain high yields of this crop, it is necessary to use mineral fertilizers. They should be applied accounting soil and climatic conditions, the content of nutrients in the soil and the level of intensification [10].

Compared to the non-fertilized control, N fertilization increases protein concentration in grain and flour in most soil type combinations [11].

For the last 5 years FSBSE “Irkutsk SRIA” has created several new cultivars of spring wheat. Among them the variety Marsianka is essentially distinguished in grain quality. In its grain, the content of gluten reaches 25.6-36.0 %, protein – 13.8-16.0 %, and in yielding capacity it is not inferior to the standard cultivar Tulunskaya II. The plants of Marsianka are more resistant to lodging and diseases [12].

Determining appropriate rates of mineral fertilizers for the Marsianka variety is the aim of the research in the conditions of forest-steppe zone of the Irkutsk region.

The objectives of the observations were the study of the impact of mineral fertilizers doses on growth and development of plants, productivity, yield structure, grain quality and the cost-effectiveness of growing the Marsianka cultivar.

2. Conditions, materials and methods

The observations were carried out in the experimental field of the FSBSE “Irkutsk SRIA” situated by Irkutsk in 2018-2020.

The forest-steppe belt of the Irkutsk region has the sharply continental climate with frosty and little-snowed winter and hot and arid summer. For the vegetation period, the difference between day and night temperatures reached 14-18 °C. In the years of conducting the observations, the climatic conditions of the cropping season were not the same and differed from the average long-run annual values. 2020 was the most suitable for wheat growth and development. The summers in other years were characterized as hot and dry. For May-August period, precipitation fell by 70.6-78.4 mm below the norm (298.5 mm), and the aggregate amount of active temperatures (above 10 °C) by 405.8-411.4 °C exceeded the average long-run annual values (1637 °C).

The variety of soft spring wheat Marsianka and the doses of applied mineral fertilizers were the objects of the present study.

The wheat seeds were sown early in the second decade of May on a bare fallow.

The test plot has the typical gray soil, heavy loam in granulometric composition. Prior to laying down the trial in the plow layer (0-20 cm) it had the following agrochemical indicators: pH – 4.6-4.9; humus content 4.6-4.9 %, total nitrogen 0.24-0.26 %, P2O5 – 106-113 and K2O – 91-95 mg/kg of soil, total absorbed bases 22.8-24.7 mg-eq./100 g, degree of base saturation – 72.9-78.3 %.

The trial scheme included 8 variants: 1. Without fertilizers (st); 2. N30; 3. N60; 4. N60K35; 5. N60P45K35; 6. N60P60K40; 7. N90P60K60; 8. For the planned yield 4.0 t/ha.

Ammonium nitrate, double granulated superphosphate, and potassium chloride were used as mineral fertilizers.

The seeding rate of wheat was calculated based on 7.0 mln germinable seeds per 1 ha. The trial was laid down in four-fold replication. The total area of the plot was 75 m², the accounted area – 55 m².
The field trial was laid down, as well as accounts and observations were fulfilled according to the Methods of State Variety Testing of Agricultural Crops [13].

The yield of grain was brought under the standard 14 % humidity and 100 % purity.

The assays of soil and grain quality were made in the laboratory of agrochemical analysis according the generally accepted techniques.

The applied programs Snedecor [14] involving the method of dispersion analysis were used in statistical processing of the experimental data.

3. Results and discussion

The emergence of wheat seedlings occurred in 11-12 days after sowing. Seed germination in the field was 70.2-72.6 %. Mineral fertilizers made a significant impact on growth and development of wheat plants. For instance, after applying nitrogen fertilizers in the dose 60 kg of active substance per 1 ha, the plant got higher by 8.1-9.2 cm, but simultaneously the growing season delayed by 3-4 days. Phosphorous and potassium fertilizers added to the nitric ones contributed to shortening the terms of maturing by 2-3 days.

Table 1. Effect of mineral fertilizers on yield, grain quality and cost-effectiveness of the spring wheat cultivar Marsianka (average for 2018-2020)

| Doses of mineral fertilizers, kg a. s./ha | Yield, t/ha | Test weight, g/l | Kernel hardness, % | Weight of 1000 grains, g | Content of crude protein, % | Wet gluten, % | Relatively net profit, rub./ha | Prime cost of 1 t grain, rub. | Payback level, % |
|------------------------------------------|-------------|-----------------|-------------------|------------------------|---------------------------|---------------|-------------------------------|-------------------------|------------------|
| Without fertilizers (control)            | 2.14        | 769.3           | 59.4              | 31.8                   | 13.8                      | 25.6          | 10179.8                       | 5243.1                  | 90.7             |
| N_{30}                                   | 2.49        | 775.1           | 60.9              | 32.7                   | 14.3                      | 27.9          | 12024.1                       | 5171.0                  | 93.4             |
| N_{60}                                   | 2.78        | 778.0           | 62.7              | 33.1                   | 14.8                      | 28.8          | 13226.9                       | 5242.1                  | 90.8             |
| N_{60}P_{35}                             | 2.96        | 782.4           | 63.9              | 33.9                   | 15.0                      | 29.1          | 13681.8                       | 5377.8                  | 85.9             |
| N_{60}P_{60}K_{35}                       | 3.09        | 785.2           | 65.4              | 34.5                   | 15.4                      | 30.6          | 13801.8                       | 5501.0                  | 81.2             |
| N_{60}P_{30}K_{60}                       | 3.25        | 787.0           | 66.5              | 34.8                   | 15.6                      | 32.5          | 15221.5                       | 5301.1                  | 88.4             |
| N_{60}P_{60}K_{60}                       | 3.41        | 795.6           | 67.8              | 35.1                   | 15.9                      | 34.8          | 14543.5                       | 5694.7                  | 74.8             |
| For the planned yield 4.0 t/ha           | 3.43        | 797.5           | 68.4              | 35.2                   | 15.9                      | 35.0          | 14824.8                       | 5677.9                  | 76.1             |
| Average value for the trial              | 2.94        | 783.7           | 64.4              | 33.9                   | 15.1                      | 30.5          | 13363.0                       | 5423.6                  | 84.6             |
| HCP_{05}                                 | 0.25        | 61.8            | 5.17              | 2.72                   | 1.22                      | 2.43          | 107.61                        | 43.52                   | 6.81             |

It should be mentioned that the increased air thermal regime throughout the vegetation period and the lack of soil moisture since the end of May to the mid of July in the years of undertaking the experiments led to a notable suppression of wheat plants and their more accelerated maturing.

The use of mineral fertilizers promoted plants to better survive and preserve for the harvest. Their largest amount was observed with the application of N_{60}P_{60}K_{60} and in the option for the planned yield 4.0 t/ha. When using fertilizers, the number of spikelets in an ear raised by 1-3 pcs, the amount of kernels in a spike – by 1-5 pcs. All the studied doses of mineral fertilizers gave a true rise in the yield of the new wheat cultivar, and the difference, relative to the control, was 0.35-1.29 t/ha, or 16.3-60.3 %.
The minimum growth of yield was obtained with nitrogen application at the rate 30 kg of a. s. per 1 ha, but this variant was distinguished with the highest payback of 1 kg a. s. – 11.6 kg of grain. In case of nitrogen rate increased to 60 kg of a. s., the yield increment reached 0.64 t/ha which is by 35.1 % higher than the control. Here, the cost recovery of 1 kg a. s. was 10.6 kg of grain. The phosphorous fertilizer added to the nitric ones at the rate 45 kg a. s. per 1 ha gave the yield increment just only 0.18 t/ha. The recoupment of 1 kg a. s. phosphorous fertilizers was 4.0 kg of wheat grain. After potash fertilizers application a very low yield increment was got – just 0.13 t/ha.

In case of N\textsubscript{30}P\textsubscript{30}K\textsubscript{60} application the yield rose by 1.27 t/ha, or by 59.3 % compared to the control. The highest yield increases 1.29 t/ha was obtained in the variant of using fertilizers rated for the planned yield 4.0 t/ha. Still, summer droughts in the years of observations prevented to get the expected yield.

The studied doses of mineral fertilizers positively affected the wheat grain quality by raising the weight of 1000 seeds by 0.9-3.4 g, the test weight – by 5.8-28.2 g/l, kernel hardness – by 1.5-9.0 %, wet gluten – by 2.3-9.4, crude protein – by 0.5-2.1 %. The largest contents of gluten 35.0 % and protein 15.9 % were observed in the option for the planned yield 4.0 t/ha.

Because of high cost of fertilizers, their application essentially increases production expenses with prime cost growth and falling profitability. Among the studied options of fertilizers rates, N\textsubscript{30} provided the highest payback and the lowest prime cost of grain. The consequent rising it to N\textsubscript{60} makes profitability lower by 2.2 % and prime cost of grain higher by 71.1 rub./t, but the pure income becomes greater by 1202.8 rub./ha.

As for the variants with integrated use of nitric, phosphorous and potassium fertilizers, in particular their higher doses, the expenses considerably increase, production prime cost grows, and profitability declines. Nevertheless, due to the yield increment, the net income output from 1 ha keeps high. In the trial, the higher net profit was obtained in the option with N\textsubscript{60}P\textsubscript{60}K\textsubscript{60} application.

4. Conclusions

Mineral fertilizers positively affect wheat plants growth and development, the maturing periods of the new cultivar of spring wheat Marsianka. They improve the yield structure by increasing the number of productive stems, the amount of kernels in a spike, and the 1000 grains weight.

The wheat yield rises by 16.3-60.3 % was reached due to the use of fertilizers. When applying them rated for the planned yield 4.0 t/ha, the greatest productivity 3.43 t/ha of good-quality grain containing crude protein 15.9 % and wet gluten 35.0 % was obtained. The largest net profit 15.2 thousand rub./ha was provided by applying N\textsubscript{30}P\textsubscript{30}K\textsubscript{60}. The higher profitability 93.4 and 90.8 % and lower prime cost 5.2 thousand rub/t of grain were supplied by the nitrogen use at the rates 30 and 60 kg of active substance per 1 ha.

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