Productivity and grain quality of a new spring wheat variety Stolypinka depending on the rates of mineral fertilizers under conditions of the Pre-Baikal region

F S Sultanov, A A Yudin and O B Gabdrakhimov
Irkutsk Agricultural Research Institute, Pivovarikha village, Irkutsk region, Irkutsk district, 664511, Russian Federation

E-mail: olegabdrakhimov@yandex.ru

Abstract. The presented article reveals the extent of mineral fertilizers impact on plant growth and development, and the ripening periods of a new spring wheat (Triticum aestivum L.) cultivar Stolypinka. The research objectives included the study of the influence of mineral fertilizer rates on yield structure, productivity, grain quality and economic efficiency of the variety Stolypinka. Field observations and the laboratory analysis of the data obtained proved the positive effect of mineral fertilizers on the yield structure components (the amount of productive stems, the number of kernels in a spike, the weight of 1000 seeds) in the studied cultivar. As a result of the research it has been found that the application of fertilizers at the rate for the planned yield is optimal for obtaining the maximum yield 3.5 t/ha of good quality grain containing the crude protein 15.8 % and gluten 32.3 %. In terms of economic efficiency, at the rates of fertilizers application N30 and N60 we have got the highest payback output (8.2 and 9.0 thousand rub./ha, respectively) and the lowest prime cost of 1 t grain (4.6 and 4.7 thousand rub./ha, respectively). The highest level of profitability (92.3 %) was observed in the option with the application of sole nitrogen at the rate 30 kg of active substance per 1 ha. Of the variants with a complex mineral fertilizer, using N60P45K45 is the most expedient in case of the gross grain harvest in the amount recouping the invested production costs.

1. Introduction
Wheat takes the leading place in food grain production in the world and in the Russian Federation. Its spring and winter types are cultivated [1].

Due to severe climatic conditions, only spring wheat is sown in the Irkutsk region. It takes more than a half of the area in the structure of grain crops. The increasing production and the raising grain quality of this crop are the main objectives of agrarian science and farmers in our region [2].

Higher crop yields are critical to satisfy the rising global food demand. Russia holds untapped potential for increasing agricultural production because current grain yields are often far below the potentially attainable yields. Western Siberia is an important breadbasket in Russia, where wheat yields fall particularly short of their potential [3].

In modern conditions, to avoid such negative tendencies as decrease in volumes of bread production and deterioration of quality of the products, it is necessary to analyze the available data on the domestic market of bakery products, assess the factors resulting in increase of the bread consumption, and...
opportunities of improvement of technological properties of flour and dough through the realization of the genetic potential of bread wheat varieties, taking into account environmental factors [4].

Sowing varieties of spring wheat at the best agrotechnical terms with optimal seeding rates will enable to manifest the yield potential of cultivars and accelerate their implementation into production [5].

The most cost-effective source of increasing productivity and quality indicators of wheat grain is the sowing of new, more productive varieties adapted to natural growing conditions. New cultivars should not only be productive, but also have high grain quality [6].

Scientific research and production practice have established that a new variety can only expose its potential when creating the necessary agroecological conditions. Irrespective of the weather conditions fluctuations of vegetation periods, the differentiated use of chemicalization shows the yield growth from 5 to 76 % under increase in the payback of 1 kg of nitrogen fertilizer with the rise in the grain yield of the wheat cultivars at 1.7 times [7].

The critical situation is developing in the agriculture of Russia: growing nutritional degradation of arable land. During the 25-year period of cultivation, the removal of nitrogen, phosphorus and potassium by crop yields exceeded the introduction of these elements with all types of fertilizers by 3 times. Such a high deficit in the balance of nutrients in Russian arable farming means that the agricultural production is largely not implemented the potential of such factors, as variety, plant protection chemicals and others. As a result, Russia’s agricultural productivity is one of the lowest in the world. So, food security is currently impossible to achieve without the use of fertilizers and other chemical aids [8].

The most powerful tool for increasing crop yield and quality is mineral fertilizers. Thus, applying nitric fertilizers in the dose 30 kg a. s. per 1 ha increases the yield of wheat new cultivars by 11.8-19.3 %; when nitrogen dose amounts to 60 kg a. s./ha, the yield increment reaches 0.55-0.63 t/ha, or 29.8-35.8 %. The increasing rates of fertilizers considerably improve qualitative characteristics of grain in wheat cultivars: there is a rise in the weight of 1000 grains, grain nature and hardness, gluten and protein content in them [9].

The yield mainly depends on previous crops and pesticides, while a fertilizer shows a relatively small impact in the year. Favorable for wheat growth and the lack of effect in the year, adverse for that. The maximum power of influence on the productivity is marked for the factor "Previous crop" (the power of influence value is equal to 70.9 %), the minimum – for the factor "Fertilizer" (the power of influence value = 4.5 %) [10].

Nitrogen fertilizers, regardless of the type, rate and frequency of application, significantly increase the protein and gluten content in the grain, compared to the unfertilized control, by 0.8-3.9 % and 1.3-10.2 %, respectively [11].

The use of mineral fertilizers not only raises the yielding capacity, but also improves the quality values of grain. They are applied at the rates calculated for the planned yield taking into account the content of nutrients in the root layer of soil [12].

Issues associated with meeting the nutrition needs of plants, as well as clarifying optimal doses and methods of administration of trace elements within the soil remain to be highly relevant. The introduction of NPK elements at doses calculated for 3 t/ha and 4 t/ha provides an increment in the wheat yield of 1.06 t/ha and 1.56 t/ha, respectively [13].

A positive effect of mineral fertilizers on the fertility of light gray forest soils and the yields of wheat and barley grain in the Baikal region has been experimentally established [14].

The expediency of differentiation of doses of nutrients depending on agrochemical properties of various soils is evidence-based. Such approach to establishment of doses of nitrogen, phosphoric and potash fertilizers will promote more rational use of fertilizers as it will allow to lower specific costs of nutrients of formation of productivity of agricultural products and to increase their payback a harvest increase [15].

A spring wheat cultivar Stolypinka was created in the Irkutsk Agricultural Research Institute. Its yielding capacity exceeds by 0.2…0.4 t/ha that of the varieties cultivated in the production. The grain
contains protein 13.0-14.1 %, fluid gluten 32 %. It is more resistant to adverse environmental conditions [16].

The purpose of the research is to determine optimal rates of mineral fertilizers for the cultivar Stolypinka under conditions of the Pre-Baikal forest-steppe belt.

The research objectives included studying the influence of mineral fertilizers rates on plant growth and development, yield structure, productivity and quality of grain, as well as the economic efficiency of the Stolypinka variety.

2. Conditions, objects and methods
The studies were conducted in the test field of FSBSI “Irkutsk ARI” located near Irkutsk-city.

The climate of the forest-steppe belt in the Irkutsk region is sharply continental: winter is cold and a little snowy, summer is hot and dry. During the years of research, the weather conditions of the growing season were unequal and differed from the average annual ones. 2016 was more favorable year for the growth and development of wheat plants. In the last years, summer was hot and arid. From May to September, precipitation was 68.7...69.7 mm lower, and the sum of active temperatures (above 10 °C) was 405.8...461.8 °C higher than the long-term average values (1637 °C).

The objects of the study are the cultivar of spring soft wheat Stolypinka and the rates of mineral fertilizers in its crops.

Seeding was made on 10 May in a grain-fallow crop rotation.

The soil of the experimental plot is typical grey forest heavy loam containing humus 4.6…5.0 % in a layer of plowing (0…20 cm), total nitrogen 0.27 %, P2O5 – 108…114 and K2O – 89…96 mg/kg of soil, pH60 is 4.6…5.0, the aggregate amount of absorbed bases 22.5…24.7 mg-equ./100 g, the degree of base saturation – 70.1…78.6 %.

The soil tillage system elaborated for the forest-steppe belt of the region was used at the experimental plot.

There were 8 options included to the trial scheme: 1. Fertilizer-free (st); 2. N30; 3. N60; 4. N60K45; 5. N60P63K45; 6. N60P60K60; 7. N60P60K60; 8. For the planned yield 4.0 t/ha.

Laying the trial down, observations and accounts were carried out according to the Methods of state variety testing of agricultural crops [17].

Grain yield was fitted to the standard 14 % humidity and 100 % purity. Laboratory assays of soil and grain quality were fulfilled in the laboratory of agrochemical analysis according the commonly accepted methods.

Statistical processing of the experimental data was performed by the method of dispersion analysis with the help of the applied programs Snedekor [18].

3. Results and discussion
Seedlings of wheat emerged in 10…12 days after sowing. Field germination of seeds was 69.6…72.9 %. Mineral fertilizers had a considerable effect on growth and development of wheat plants. Thus, in case of applying nitric fertilizers at the rate 60 kg of active substance per 1 ha, the plant height rose by 7.8…9.3 cm, but, at the same time, the vegetation period delayed by 3…4 days. The addition of phosphorous and potash fertilizers to the nitrogenous ones promoted to reducing the terms of ripening by 1…2 days.

The use of fertilizers provided the better preservation of plants to the harvest. Even the application of solely nitrogenous fertilizers at the rate 30 kg of a. s. per 1 ha raised the number of plants by 3.2…3.6 % compared with the control. Their maximum amount was when using fertilizers at the rate N90P60K60 and in the variant for the planned yield 4.0 t/ha.

Applying fertilizers increased the number of spikelets in an ear by 1…4 un., the amount of kernels in a spike by 1…6 un., the weight of 1000 seeds by 0.6…2.8 g.

The use of fertilizers contributed to significant growth of productivity from a new cultivar of wheat. The applied rate of nitrogen 30 kg/ha made the yield higher by 0.28 t/ha, or by 13 %. In case of raising the nitrogen rate up to 60 kg a. s. the yield increment reached 0.57 t/ha which is 26.6 % higher than the
control. In this option, the payback of 1 kg a.s. was 9.7 kg of grain. Nitric fertilizers supplemented with phosphorous ones at the rate 45 kg of a.s. per 1 ha gave the gain in yield just only 0.23 t/ha. The payback of 1 kg a.s. of phosphorous fertilizers was 5.1 kg of wheat grain. When potash fertilizers were applied (45 kg of a. s. per 1 ha) on the background of N₆₀P₄₅ in the conditions of the years of carrying out the experiments, a very low yield increment was obtained – only 0.14 t/ha.

Using the fertilizers rate N₆₀P₆₀K₆₀ supplied the rise in yield by 1.24 t/ha, or by 57.9 % in comparison to the control. The highest rise in yield 1.36 t/ha was achieved after applying fertilizers at the rate for the planned yield 4.0 t/ha. However, because of summer droughts in the years of observations, the expected productivity failed to be reached.

The increasing rates of fertilizers significantly improve qualitative characteristics of wheat grain. At the same time, the increase in the weight of 1000 seeds by 0.6...2.8 g, the test weight – by 6...19 g/l, kernel hardness – by 0.9...8.4 %, crude protein – by 0.7...2.6 % were observed.

When using fertilizers, due to their expensiveness, production costs considerably increase, prime cost raises by 120.3...458.0 rub./t and the profitability decreases by 2.8...55.7 %. Of different options of using fertilizers, the highest payback and the lowest prime cost of grain were got in case of applying nitrogenous ones at the rate 30 kg of a.s. per 1 ha. The further bringing it to 60 kg of a.s. per 1 ha leads to reducing profitability by 3.3 %, growing prime cost of grain by 100.1 rub./t, but in this variant, the largest net income from 1 ha is obtained.

In the options with complex application of nitrogen, phosphorous and potash fertilizers, especially their increased rates, the expenses significantly raise, prime cost of production increases, and profitability falls. However, thanks to the rise in yield, the pure income output from 1 ha remains high.

**Table 1.** Impact of mineral fertilizers on yield, grain quality and economic efficiency of the spring wheat cultivar Stolypinka (average for 2017-2019).

| Rates of mineral fertilizers, kg a. s./ha | Yield, t/ha | Test weight g/l | Kernel hardness, % | Weight of 1000 seeds, g | Content of crude protein, % | Content of fluid gluten, % | Relatively pure income, rub./ha | Prime cost of 1 t grain, rub. | Payback level % |
|------------------------------------------|-------------|----------------|---------------------|--------------------------|-----------------------------|-----------------------------|-------------------------------|-----------------------------|-----------------|
| Without fertilizers (control)            | 2.14        | 761            | 58.4                | 32.4                     | 13.2                        | 23.9                        | 7544.0                        | 4474.3                      | 91.8            |
| N₃₀                                      | 2.42        | 766            | 59.7                | 33.0                     | 13.9                        | 24.8                        | 8241.5                        | 4594.5                      | 92.3            |
| N₆₀                                      | 2.71        | 769            | 61.5                | 33.8                     | 14.4                        | 25.3                        | 9017.8                        | 4694.6                      | 89.0            |
| N₆₀P₄₅                                   | 2.94        | 770            | 63.5                | 34.1                     | 14.6                        | 25.8                        | 8107.4                        | 4542.3                      | 75.9            |
| N₆₀P₆₀K₄₅                                | 3.08        | 773            | 64.8                | 34.4                     | 14.9                        | 27.4                        | 7153.0                        | 4406.4                      | 52.6            |
| N₆₀P₆₀K₆₀                                | 3.21        | 775            | 65.4                | 34.7                     | 15.1                        | 26.0                        | 7649.2                        | 4432.5                      | 42.8            |
| N₆₀₉₀P₆₀K₆₀                              | 3.38        | 779            | 67.1                | 34.9                     | 15.5                        | 30.1                        | 7168.1                        | 4641.6                      | 42.4            |
| For planned yield 4.0 t/ha               | 3.50        | 780            | 67.7                | 35.2                     | 15.8                        | 32.3                        | 7525.0                        | 4879.3                      | 36.1            |
| Average value for the trial              | 2.91        | 771            | 63.5                | 34.1                     | 14.7                        | 27.2                        | 7800.8                        | 4583.2                      | 65.4            |

**HCP₀₅ 0.23  60.10  5.14  2.73  1.21  2.23**

4. **Conclusion**

Mineral fertilizers have a considerable effect on growth and development of wheat plants, the ripening terms of a new spring wheat variety Stolypinka. In the yield structure, there is a rise in the amount of productive stems, in the number of kernels in a spike, in the weight of 1000 seeds.
The use of fertilizers provides the increase in the yield of the studied wheat cultivar by 13.1...63.6\%. The highest productivity 3.5 t/ha of good-quality grain with the content of crude protein 15.8 \% and gluten 32.3 \% was obtained in case of applying them at the rate for the planned yield 4.0 t/ha.

The greatest pure income (8.2 and 9.0 thousand rub./ha) and the lowest prime cost of 1 t grain (4.6 and 4.7 thousand rub.) were achieved after applying N_{30} and N_{60}.

In case of combined application of nitrogenous fertilizers with phosphorous and potash ones, especially their increased rates, economic values decline. However, in connection to the raising yield, the pure income output from 1 ha remains high and ranges from 7.1 to 7.6 thousand rub./ha.

References
[1] Kolomeichenko V V 2007 Spring Wheat. Textbook (Moscow: Agrobusinesscenter) p 132-5
[2] Dmitriyev N N et al. 2019 Current techniques of adaptive agricultural technology of field crops for sustainable development of farming in Irkutsk region (Irkutsk: OOO “Megaprint”) p 232
[3] Prishchevov A V et al. Land Use Policy https://doi.org/10.1016/j.landusepol.2018.09/038
[4] Khlestkina E K et al. 2017 Modern opportunities for improving quality of bakery products via realizing the bread wheat genetic potential-by-environment interactions (review) Agricultural Biology 52(3) 501-14
[5] Raphael Rossi Silva, Giovani Benin, Juliano Luiz de Almeida, Inês Cristina de Batista Fonseca and Claudemir Zucareli 2014 Grain yield and baking quality of wheat under different sowing dates Acta Scientiarum Agronomy Maringá 36(2) 201-10
[6] Technologies of field crop cultivation under conditions of the Pre-Baikal region. Scientific and practical recommendations 2020 (Irkutsk: OOO “Megaprint”) p 223
[7] Yakushev V P, Lekomtsev P V, Voropaev V V, Konev A V and Pervak T S 2017 Discriminatory application of the chemicals under the spring wheat cultivation Herald of Russian Agricultural Science 4 13-7
[8] Kudeyarov V N 2018 The Balance of Nitrogen Phosphorus and Potassium in Agriculture of Russia Agrochemistry 10 3-11
[9] Sultanov F S, Yudin A A, Gabdrakhimov O B and Krasnoshapko V V 2019 The impact of mineral fertilizers on productivity of new cultivars of spring wheat under conditions of Cisbaikal area Bulletin of IrSAA 92 81-8
[10] Keler V V and Khizhnyak S V 2019 The aspects of productivity and profitability increasing in spring wheat grain production in Krasnoyarsk region Bulletin of KrasGAU 6(147) 28-34
[11] Esaulko A N, Garibdzhanyan G A, Golosnoi E V and Gromova N V 2020 Efficiency of liquid and solid nitrogen mineral fertilizers under early spring top dressing of winter wheat Zemedelie 3 38-40
[12] Ya M Ivan’o and Dmitriyev N N 2019 System of Agriculture in the Irkutsk Region (Irkutsk OOO “Megaprint”) p 319
[13] Amirov M F and Toloknov D I 2019 Influence of Mineral Nutrition Level and Trace Elements on the Formation of Spring Wheat Yield Dostizhenija nauki i tekhniki APK 33(5) 18-20
[14] Dmitriyev N N and Gamzikov G P 2015 Systematic application of fertilizers as a stabilizing factor for the fertility of gray forest soils and the productivity of wheat and barley in grain-fallow crop rotation Agrochemistry 2 3-12
[15] Shafran S A 2019 Improvement of Standard and Help Base for Definition of Need of Crops for Mineral Fertilizers Agrochemistry 7 27-34
[16] Gabdrakhimov O B, Konstantinova T V, Manuilova G M, Sultanov F S and Yudin A A 2017 Selection of spring soft wheat under conditions of Irkutsk region Bulletin of IrSAA 78 26-31
[17] Methods of State Variety Testing of Agricultural Crops (Moscow: Kolos) p 195
[18] Sorokin O D 2004 Applied statistics on the computer (Krasnoobsk: Izd-vo GUP RPO SO RACHN) p 162