Influence of chemicalization levels on productivity and grain quality of zoned spring wheat varieties in Pre-Baikal area

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Abstract. The article has shown the dependence of the yield value and grain quality indicators (protein, gluten, hardness, test weight) of six zoned varieties of spring wheat on the use of different levels of chemicalization (the control without fertilizers and herbicides, herbicides, fertilizers at the rate N60P60K60 kg of active substance per hectare, fertilizers at the rate N60P60K60 kg of a.s./ha + herbicides). The research objectives included the identification of differences in grain yield and quality indicators between spring wheat cultivars according to the options of the field trials conducted in 2016-2019. It was found that under conditions of insufficient moisture during vegetation periods of the mentioned years, different varieties showed unequal results both in yield amount and grain quality. The cultivar Buryatskaya ostistaya proved to be the most productive and provided the grain output 2.70-3.29 t/ha depending on a level of chemicalization, but in protein and gluten content it was inferior to other varieties. In protein content, the cultivars Novosibirskaya 15 and Iren had the best values. At different levels of chemicalization their protein content was 16.0-18.6 %. In gluten amount, the best varieties were Novosibirskaya 15 – 36.1-39.9 % depending on a chemicalization level and Iren – 40.8 % on the background of fertilizers with herbicides. As for the indicator of kernel hardness, the best cultivar – Yunata 54.7-58.1 %. The share of a cultivar influencing the protein content in grain was 75.2 %; the gluten amount – 71.2 %; the kernel hardness – 85.4 %; the natural weight of grain – 87.4. The low share of the influence of the chemicalization factor on the quality indicators of grain can be explained by arid conditions in the years of the research.

1. Introduction

Among the various food crops used by humans since ancient times, soft wheat (Aestivum) takes the most important place in the world's agricultural production. On the territory of our country, wheat crop has already been known for several millennia [1].

Spring wheat is the basic food crop in many regions of the Russian Federation, characterized by different climates. Pre-Baikal region does not belong to a region with favorable natural conditions for spring wheat cultivation, which makes it difficult to harvest high grain yields [2].

In the Irkutsk region, alongside with cultivation of conventional varieties, new cultivars of spring wheat are annually zoned. As practice has shown, the introduced cultivars vary in different ripening periods and target purposes. Under conditions of ordinary farms, these varieties are grown at different levels of soil fertility and chemicalization. It makes a significant impact on productivity of cultivars and...
duration of their use. As a rule, in the conditions of variety test plots, chemicalization levels are not studied that does not enable to make true conclusions about their adaptive potential. In this regard, this problem deserves to be studied on a scientific basis.

Wheat yield is formed under the influence of a complex set of conditions, each of which affects its amount and grain quality. The natural potential, inherent in wheat, allows you to harvest from 1 ha up to 80-100 kg of grain [3].

Currently, it is important to search for reserves to increase crop yield and improve grain quality. The leading role here is given to a cultivar since it accounts for 20% or more of the total yield increment [4].

Of the wheat varieties included in the State Register for use in our region, the best are Tulunskaya 12, Iren, Novosibirskaya 29, Novosibirskaya 15; Tulunskaya 11; and for the coastal part of the Bratsk reservoir in the 2rd and 4th zones – the cultivars Selenga and Buryatskaya ostistaya [5].

The systematic use of mineral fertilizers for spring wheat of the Buryatskaya ostistaya variety has a positive effect on the physical (weight of 1000 seeds, test weight of grain, kernel hardness) and chemical (amount and quality of gluten) indicators of grain quality [6].

Due to their genetic characteristics, spring wheat cultivars of Siberian selection show different response according to the quality of grain to the application of mineral fertilizers in arid conditions of vegetation periods [7].

The most important requirement that prospective varieties must meet is adaptability, that is, the ability to resist the effects of adverse environmental factors reducing productivity and yield. In this system, special attention is paid to the potential of a plant resulting from the genetics of a cultivar [8].

Weeds are a serious threat to crop production as they reduce the yield of wheat, on average, by 23%. The integration of weed control methods such as crop rotation, tillage, planting date and pattern, herbicides, and allelopathy would lead to the effective and sustainable management of weeds [9].

On the background of herbicides and fertilizers, spring wheat significantly exceeds the yield and grain quality of wheat cultivated without chemical aids [10].

Herbicides are used in many crops, but not necessarily increased the prevalence of herbicide use, especially in wheat. Wheat is one of the most widely grown crops in the world. However, the occurrence of herbicide-resistant weed populations forces us to eliminate the repeated use of specific herbicides for maintaining sustainable wheat production with good grain quality [11].

Analysis of the current state of the domestic market of bakery products shows that the output of bread production is decreasing, and the quality of products is falling. The application of nitrogen fertilizers promotes to increase the protein content in grain [12].

The field observations have found that when nitrogen fertilizers are applied at the rate of 60 kg a. s. per 1 ha, the increment in spring wheat yield reaches 0.55-0.63 t/ha [13].

Each of the three components of a complete mineral fertilizer (nitrogen, phosphorus, and potassium) has a positive effect on the growth and development of wheat plants. Thus, for instance, phosphorus fertilizer supports protein synthesis, accelerates the maturing process, or shortens the vegetation period of wheat (in some cases, up to two weeks) [14].

The purpose of the study was to reveal the relationship between the levels of chemicalization, the productivity and grain quality of spring wheat varieties cultivated under conditions of the forest-steppe zone in the Irkutsk region.

2. Conditions, materials and methods
The studies were carried out at the test field of the Irkutsk Scientific Research Institute of Agriculture in 2017-2019. The field trials were laid down on bare fallow in the second decade of May.

The soil of the experimental plot is grey forest heavy loam with a humus content of about 5% in a layer 0-30 cm, total nitrogen 0.22 %, gross phosphorus 0.23 %, pH is 5.5, aggregate amount of absorbed bases 21...25 mg-eq./100 g, hydrolytic acidity 7.3...8.0 mg-eq./100 g, degree of base saturation 73...83 %, the supply with available phosphorus and potassium is average.

In the field trial two factors of intensification – the factor of chemicalization at two levels (mineral fertilizers and herbicides) and the varietal difference of the crop (by origin and ripening period) have
been studied. The first factor is represented by a complete mineral fertilizer (N\textsubscript{60}P\textsubscript{60}K\textsubscript{60}) in the form of ammonium nitrate and diammonphoska applied prior to sowing and a tank mixture of the herbicide Super Star, WDG – 0.025 kg/ha and the gamicidin Lastic TOP, OCE – 0.4 l/ha. As a second factor, six zoned varieties of spring wheat of different originators and maturity groups have been taken. They are the objects of the research being selected from the State Register of the Russian Federation including the varieties of spring wheat approved for use in the production within the East Siberian region. All of them are of intensive type and relate to the following groups of ripeness: early-maturing – Iren (Ural SRIA) and Novosibirskaya 15 (Siberian SRIA), mid-early – Tulunskaya 11 (st), Pamyati Yudina and Yunata (Irkutsk SRIA) and mid-late – Buryatskaya ostistaya (Buryat SRIA).

The cultivars were observed on four levels of chemicalization: the control (without fertilizers and herbicides), herbicides without fertilizers, fertilizers without herbicides and herbicides + fertilizers.

Harvesting was carried out by direct combining. Grain yield was fitted to the standard 14% humidity and 100% purity. Statistical processing of experimental data was performed by the method of dispersion analysis. The amount of gluten was determined according to GOST 27839-2013, kernel hardness – according to GOST 10987-76, protein content – according to GOST 10846-91.

The weather conditions during the growing season varied in temperature regime and precipitation amount over the years of the study. In 2017 for the period of vegetation (since May to August) there were 239.8 mm of precipitation fallen, but their distribution by months and decades was extremely uneven which greatly affected the yield. In May, there were 67.1 mm of rainfall, and in June – only 13.1 mm, which was 21% of the norm. In July, the amount of precipitation was at the level of the average annual value – 104.8 mm, and in August – 54.8 mm, which was 58% of the average annual value. The average daily temperatures of the growing season were 3.5 °C higher than the long-term average values. The sum of active air temperatures above 10°C was 2098 °C.

The conditions of 2018 according to the amount and distribution of precipitation (220.1 mm for the period of vegetation – 26% below the average annual values and rainfall deficiency in May-June when passing the tillering-earring phases by plants – 46.6% of the long-term average) were unfavorable for the formation of high yield and good for producing high quality grain.

The growing season of 2019 with 227.6 mm of precipitation (23.8% below normal) and its uneven distribution proved to be close to 2018: May was characterized by a lack of rainfall (30% of normal) and temperature (1.7 °C below the average annual one). The growth of average daily temperatures and precipitation was observed in June: in its first and second decades there was a deficiency (77 and 35% of the norm, respectively), in the third decade – 52.9 mm. In July, 99.3 mm fell (or 90% of the average annual norm), in August – 2 times less. Meanwhile, the average daily air temperature for the vegetation period exceeded the average long-term indicators by 2.4 °C. Thus, it can be noted that according to precipitation, accompanied with high temperatures, the agricultural climatic conditions of 2019 were more beneficial for the formation of high-quality grain and productivity than those of 2017 and 2018.

3. Results and discussion

The impact of mineral fertilizers and herbicides resulted in more intensive growth and development of wheat plants, but the yield and quality of grain changed in different ways depending on a wheat variety.

Buryatskaya ostistaya was the most productive among all the studied varieties at all levels of chemicalization, its highest productivity 3.29 t/ha was obtained when using N\textsubscript{60}P\textsubscript{60}K\textsubscript{60} with herbicides (table 1). The largest grain increase when applying N\textsubscript{60}P\textsubscript{60}K\textsubscript{60} fertilizers compared to the unfertilized background was shown by Yunata and Novosibirskaya 15 varieties – the increment was 95.7 and 73.3%, respectively. They also proved to be optimal in the variant with herbicides (an increase of 35.9 and 31.3%, respectively, compared to the control). They also proved to be optimal in the variant with herbicides (the gain 35.9 and 31.3%, respectively, compared to the control).
Table 1. The yield of the zoned wheat cultivars (average for 2017-2019), t/ha.

| Cultivar                      | Chemicalization level         |
|-------------------------------|-------------------------------|
|                               | control | herbicides | N\textsubscript{60}P\textsubscript{60}K\textsubscript{60} | N\textsubscript{60}P\textsubscript{60}K\textsubscript{60+} herbicides |
| Tulunskaya 11 (st)            | 1.88    | 1.62       | 1.74               | 2.57                                 |
| Iren                          | 1.53    | 1.46       | 1.80               | 2.17                                 |
| Buryatskaya ostistaya         | 2.71    | 2.70       | 3.04               | 3.29                                 |
| Pamyati Yudina                | 1.58    | 1.49       | 1.92               | 1.53                                 |
| Yunata                        | 1.17    | 1.59       | 2.29               | 2.24                                 |
| Novosibirskaya 15            | 1.31    | 1.72       | 2.19               | 2.27                                 |

HCP\textsubscript{0.05} cultivar - 0.25

HCP\textsubscript{0.05} chemicalization level - 0.22

In our research the analysis of grain quality covered its basic indicators directly affecting the baking characteristics of bread: the mass fraction of protein, the content of crude gluten, kernel hardness and its test weight.

Novosibirskaya 15 and Iren varieties were superior to the other studied cultivars in protein content in all trial options (Table 2), having reached a maximum with complex chemicalization (18.0 and 18.6 \%, respectively). The largest increment of the parameter in comparison with the control was in Iren – 16.3 \%, then in Novosibirskaya 15 – 9.8 \%. The remaining cultivars showed insignificant rise in chemicalization levels.

As for gluten content in grain, Novosibirskaya 15 in the control variant surpassed other varieties (36.1 \%), and with the combined use of fertilizers and herbicides Iren had the best value (40.8 \%). And the largest increment 41.2 \% was in Tulunskaya 11, a little less in the cultivars Yunata (37.9 \%) and Iren (38.3 \%). The herbicide background made the best effect on the gluten content in grain of the varieties Buryatskaya ostistaya and Yunata (+23.4 and +13.4 \% to the control, respectively). Mineral fertilizers without herbicides maximized the share of gluten in Tulunskaya 11 since 26.0 to 34.7 \%, or by 33.4 \%.

Kernel hardness was more dependent on a cultivar than on a level of chemicalization. The greatest hardness of grain was obtained from Yunata – 54.7-58.1 \% depending a chemicalization level, and the least – from Tulunskaya 11 – 37.2-38.5 \%. A true rise in grain hardness from applying the chemical aids was marked in the varieties Iren and Buryatskaya ostistaya on the background of fertilizers, in Yunata – on all the backgrounds. The application of the chemical aids for Tulunskaya 11 and Novosibirskaya 15 did not lead to increasing kernel hardness.

Natural weight is one of the characteristics of wheat grain quality. According to the results of data analysis, it is clear that grain with the highest test weight was obtained from the cultivars Tulunskaya 11, Iren and Buryatskaya ostistaya 763.1-783.1 g depending a chemicalization level. The varieties Pamyati Yudina, Yunata and Novosibirskaya 15 were inferior to them. A reliable increase of test weight of grain from applying the chemical aids was noted in Tulunskaya 11 on the background of fertilizers and fertilizers with herbicides, in Buryatskaya ostistaya – on all the backgrounds, in Pamyati Yudina – on the background of herbicides and fertilizers. The application of the chemical aids for Iren and Novosibirskaya 15 did not result in a true rise in grain test weight.

Evaluating the extent of influencing factors on grain quality indicators of the studied wheat varieties, it should be noted that the share of varietal effect is much greater than the impact of chemicals. Thus, the share of cultivar effect in protein content is 75.2 \%, in gluten content – 71.2 \%, in kernel hardness – 85.4 \%, in grain test weight – 87.4 \%. The low share of chemicalization factor influence can be explained by arid conditions in the years of studies when fertilizers were not fully used by plants.
Table 2. Grain quality indicators of spring wheat varieties at different levels of chemicalization.

| Cultivar          | Chemicalization level | Indicator     | protein, % | gluten, % | hardness, % | test weight, g |
|-------------------|-----------------------|---------------|------------|-----------|-------------|----------------|
| Tulunskaya 11     | control               | 15.3          | 26.0       | 38.5      | 769.6       |
|                   | herbicides            | 16.2          | 28.2       | 37.2      | 769.3       |
|                   | N_{60}P_{60}K_{60}    | 15.9          | 34.7       | 37.8      | 780.2       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 17.8 | 36.7 | 38.5 | 777.6 |
| Iren              | control               | 16.0          | 29.5       | 44.0      | 770.2       |
|                   | herbicides            | 16.7          | 32.2       | 43.6      | 770.9       |
|                   | N_{60}P_{60}K_{60}    | 16.8          | 35.4       | 52.1      | 774.4       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 18.6 | 40.8 | 44.8 | 763.1 |
| Buryatskaya       | control               | 14.2          | 26.5       | 41.3      | 770.6       |
| ostistayya        | herbicides            | 15.5          | 32.7       | 42.1      | 780.7       |
|                   | N_{60}P_{60}K_{60}    | 15.0          | 31.5       | 45.2      | 783.1       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 16.1 | 32.7 | 42.0 | 777.9 |
| Pamyati Yudina    | control               | 15.8          | 30.0       | 42.0      | 758.5       |
|                   | herbicides            | 16.4          | 33.3       | 44.9      | 763.1       |
|                   | N_{60}P_{60}K_{60}    | 16.6          | 38.6       | 42.7      | 764.8       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 17.9 | 39.6 | 45.2 | 753.5 |
| Yunata            | control               | 14.6          | 27.7       | 54.7      | 753.6       |
|                   | herbicides            | 15.5          | 31.4       | 57.2      | 747.3       |
|                   | N_{60}P_{60}K_{60}    | 15.7          | 34.6       | 58.1      | 750.0       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 16.5 | 38.2 | 57.0 | 740.7 |
| Novosibirskaya    | control               | 16.4          | 36.1       | 41.6      | 751.2       |
| 15                | herbicides            | 17.0          | 38.2       | 40.9      | 749.4       |
|                   | N_{60}P_{60}K_{60}    | 17.2          | 39.9       | 38.1      | 752.8       |
|                   | N_{60}P_{60}K_{60}+ herbicides | 18.0 | 38.1 | 41.9 | 755.4 |
| HCP_{65}          | cultivar              | 0.34          | 0.42       | 0.71      | 5           |
|                   | chemicalization level | 0.36          | 0.51       | 0.85      | 6           |

4. Conclusion

Adverse weather conditions for the years of the research having resulted in the form of drought during germination and tillering stages when cultivating spring wheat varieties revealed different degrees of the response of the studied cultivars to the use of chemical aids, which directly depended on genetic potential of a particular variety. The field trials showed that the cultivar *Buryatskaya ostistayya* proved to be the most productive at different levels of chemicalization and provided the grain output 2.70–3.29 t/ha. However, according to the main indicators of grain quality, protein and gluten content, it is inferior to other varieties. In protein content, the cultivars *Novosibirskaya 15* and *Iren* were the best, having provided the grain harvest at different levels of chemicalization with the protein content 16.0–18.6 %. The greatest gluten amount 36.1–39.9 % was found in grain of the varieties *Novosibirskaya 15* and *Iren*, on the background of fertilizers and herbicides – *Iren* (40.8 %). In terms of kernel hardness, the best values related to *Yunata* – 54.7–58.1 %. The share of cultivar as a factor influencing the protein content in grain was 75.2 %; the gluten amount – 71.2 %; the kernel hardness – 85.4 %; the test weight of grain – 87.4 %. The low share of the influence of the chemicalization factor on the quality indicators of grain can be explained by arid conditions in the years of the research.
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