The influence of crop predecessor and chemicalization levels on grain quality and spring wheat productivity

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Abstract. The research purpose is to assess the influence of predecessor and chemization levels on grain quality and spring wheat productivity. The research was conducted in 2018-2019 in the forest-steppe zone of the Irkutsk region on gray forest soil on the experimental field of the Irkutsk Scientific Research Institute of Agriculture. The two-factor experiment scheme included predecessors: pure steam; annual grasses (pea-oat mixture) and corn, as well as chemization levels: without fertilizers; mineral fertilizer N\textsubscript{45}P\textsubscript{45}K\textsubscript{45} (diammophosca and ammonium nitrate); mineral fertilizer N\textsubscript{45}P\textsubscript{45}K\textsubscript{45} and herbicides. The highest productivity of spring wheat grain of 2.62-2.82 t / ha was obtained by pure steam. Compared with its predecessor, corn productivity growth was 0.38-0.76 t / ha, compared with annual grasses – 0.65-0.99 t/ha. The increase from fertilizers is reliable and its value is higher for non-fallow predecessors for corn 0.36-0.38 t / ha, for annual grasses 0.33-0.34 t / ha. The grain productivity was 62-93% dependent on the predecessor and 3-28% on the chemization level. The placement of wheat in pure steam increased the grain nature by 35-40 g, the glassiness content by 1.6-2.2%, and the gluten content by 3.4-6.0% compared to non-steam predecessors. The share of the influence of the predecessor on the grain quality is 67-92%, the share of the influence of the chemization level is 3-10% and the interaction of factors accounts for 2-8%. The application of mineral fertilizers increases the gross grain harvest, but reduces the profitability compared to the non-winded background for all predecessors.

1. Introduction

In the Irkutsk region, spring wheat is the main strategic crop that largely determines the economy of agricultural enterprises. In 2019, the area of crop cultivation in the region was more than 242 thousand hectares, of which the Iren’ variety accounted for 43.5% (105.6 thousand ha), for the Buryat spinous variety 22.1% (53.6 thousand ha), the Selega variety 8.5% (20.7 thousand ha). The share of other varieties does not exceed 5%.

The productivity and quality of spring wheat grain depend on the specific growing conditions in which the genetic potential of varieties is realized and the real level of these characteristics is formed. This is confirmed by research in different regions of the Russian Federation [1, 2, 3, 4, 5] and scientific works in the conditions of the Irkutsk region [6, 7].

The most important reserve for increasing the productivity and stability of grain production in modern agriculture is the most complete realization of the potential productivity of cultivated varieties.
The variety plays an important role in increasing productivity and improving product quality. In modern conditions, the variety should be considered as not so much an element of culture cultivation technology, but as its most important basic basis [8].

Modern varieties should not only be high-yielding, giving high-quality products, but also resistant to adverse environmental factors, that is, highly adapted. The choice of the Buryat spinous variety for the experiment is due to the fact that it takes the second place by area among the varieties cultivated in the region, is drought-resistant and a good filler.

Among the agrotechnical techniques, an important role in improving the grain quality and productivity of spring wheat belongs to its predecessors. In most cases, the only predecessor largely determines the level of soil moisture and mineral nutrition elements, the species composition and number of weeds, pests and pathogens. Grain with high quality indicators and good productivity of spring wheat are formed only with normal plant development during the entire vegetation period. The share of the influence of predecessors in the yield can be 15-35% [9]. In areas with insufficient and unstable moisture, including the Irkutsk region, the most reliable predecessor of spring wheat is currently considered to be pure steam, where about 50% of this crop is sown [10].

However, in many farms of the region, due to the absence of a large share of fallow in the structure of arable land, a significant part of wheat crops is placed on non-fallow predecessors (perennial and annual grasses, row crops, rapeseed, cereals, etc.). In this case, in addition to moisture accumulation, the task is to ensure the nutrition of plants to obtain high-quality grain.

When developing technology for the production of grain with high quality indicators, including food, many questions arise related to mineral nutrition [11, 12]. Scientific-based mineral nutrition of spring soft wheat remains relevant in the conditions of modern technologies, which, other things being equal, will pay off with an increase in the productivity from the applied fertilizers. In a market economy, it is necessary to study and establish an acceptable level of mineral nutrition for each wheat variety [13].

The purpose of this work was to assess the influence of predecessors and chemization levels on the quality of grain and productivity of spring wheat in the forest steppe of the Irkutsk region.

2. Conditions, materials and methods

The research was conducted in 2018-2019 in the forest-steppe zone of the Irkutsk region on gray forest soil on the experimental field of the Federal State Budgetary Scientific Institution “Irkutsk Scientific Research Institute of Agriculture”. The soil is loamy with humus content in the layer of 0-30 cm to about 5%; total nitrogen 0.22%; total phosphorus 0.23%; pH 5.5; the amount of absorbed bases 21-25 mEq /100 g; hydrolytic acidity 7.3-8.0 mEq /100 g; degree of saturation with bases 73-83%; availability of phosphorus and potassium is average. The area of the experimental plot is 50 m². The experience has been repeated three times. Spring wheat is the Buryat spinous variety.

The scheme of the experiment is the next. Factor A is the predecessors: steam in a three-field crop rotation steam-wheat-oats; annual grasses (pea-oat mix) and corn in a four-field crop rotation pea-oat mix-wheat -corn-wheat. Factor B is chemization level: without fertilizers; mineral fertilizer N45P45K45 (diammofoska and ammonium nitrate); mineral fertilizer N45P45K45 and herbicides.

Tillage in pure steam included plowing by 23-25 cm in the first decade of June, two layer-by-layer cultivations by 8-10 cm and 10-12 cm in the first and third decades of July, non-fallow loosening by 16-18 cm in the second decade of August. Corn and annual grasses were harvested in the second decade of August, after which they plowed 20-22 cm. In the third decade of April, early spring harrowing was carried out with tooth harrows, before sowing the field was cultivated to the depth of 6-8 cm with the PAV-4 cultivator. Spring wheat was sown in the second decade of may in an ordinary way with a seeding rate of 7 million germinated grains per ha. After sowing, the field was rolled up. Harvesting was carried out by a combine "Terrion". Statistical processing of experimental data was carried out by the method of dispersion analysis. The amount of gluten was determined according to GOST 27839-2013, glassiness according to GOST 10987-76, protein according to GOST 10846-91, starch according to GOST 10845-98.
The weather conditions of the growing season varied in terms of temperature and precipitation over the years of the study. For the growing season of 2018 (from May to August), 220.1 mm of precipitation fell, which is 26% lower than the annual average. In May, 16.1 mm of precipitation fell, or 50% of the monthly norm. The deficit of precipitation was observed in June, their amount was 27 mm or 43.2% of the average annual value. The deficit occurred during the period of tillering and earning of plants and had a significant impact on productivity and especially on non-fallow predecessors. The average daily temperatures of the growing season were 2.8°C higher than the average annual values. The sum of active air temperatures above 10°C was 2042°C. Thus, it can be noted that by amount and distribution of precipitation, the conditions in 2018 were unfavorable for the formation of high productivity and good for the formation of high-quality grain.

For the growing season of 2019 227.6 mm of precipitation fell, which is close to 2018 and below the average annual norm by 23.8%. They were distributed unevenly over separate periods of vegetation, as in 2018. Thus, May was characterized by a lack of precipitation (30% of the norm) and a low temperature of 1.7°C below the average annual temperature. The increase in average daily temperatures and precipitation (52.9 mm in the third decade) was registered in June. In the first and second decades of this month, there was a deficit (77% and 35% of the norm, respectively). In July, 99.3 mm fell, or 90% of the average annual norm. In August, the amount of precipitation was 48.5 mm, or 51% of the norm. The average daily air temperature during the growing season exceeded the average long-term indicators by 2.4°C. A fairly high air temperature was observed from the second decade of June to the second decade of August, on average for this period it was 19.0°C, which is 18% higher than the average annual data. The sum of active air temperatures above 10°C was 2048°C. Thus, it can be noted that by precipitation against the background of high temperatures, the conditions of 2019 were more favorable for the formation of high-quality grain and productivity than the conditions of 2018.

3. Research results and discussion

Analysis of table 1 data showed that the productivity of wheat for net steam was 1.95 t / ha in 2018 and 3.28 t / ha in 2019.

The productivity of wheat when placed on corn and annual grasses was significantly lower, in 2018 by 0.55-0.7 t / ha on a windless background and by 0.33-0.56 t / ha on the background of mineral fertilizers at a dose of N45P45K45 kg of active substance per one ha. In 2019, the difference in productivity between steam and non-steam predecessors was even greater (0.81-1.41 t / ha on a wind background and 0.69-1.04 t / ha on a fertilizer background). It is also worth noting that fertilization reduced the difference in productivity between predecessors. A significant difference in productivity in the years of research can be explained by the conditions of moisture in the initial growing season in these years. A close positive correlation (r=0.75±0.05) was found between the moisture conditions of the first half of the growing season (May – June) and the productivity. On average, over two years, the highest productivity was obtained for a net pair of 2.62-2.82 t / ha. Placement of wheat on corn led to a decrease in productivity by 0.38-0.4 t / ha on the background of fertilizers and herbicides and by 0.76 t / ha on the non-winded background. The lowest productivity was obtained for the predecessor annual grasses 1.63-1.97 t / ha, which is lower compared to pure steam at 0.65-0.99 t / ha.

Fertilization provided a reliable significant increase in productivity for all predecessors. For pure steam, it was 0.14-0.2 t / ha, for corn-0.36-0.38 t / ha, for annual grasses-0.33-0.34 t / ha. No significant effect of herbicides on wheat productivity in the years of research has been established.

| Predecessor, factor A | Chemization level, factor B | 2018 | 2019 | On average for 2 years | Increase (decrease) |
|-----------------------|-----------------------------|------|------|-----------------------|--------------------|
| pure steam (control)  | no fertilizers (control)    | 1.95 | 3.28 | 2.62                  | -                  |
|                       | N45P45K45                   | 2.21 | 3.31 | 2.76                  | 0.14               |

Table 1. Spring wheat productivity for 2018-2019, t / ha.
Analyzing the share of influence of factors on the productivity value, it is worth noting that the largest percentage of 61.9-93.4% falls on the predecessor and 2.9-27.8% on the chemization level. Thus, the greatest impact on the productivity in the years of research had a predecessor (86.8% on average for two years).

Nature is one of the indicators of wheat grain quality. According to the results of the analysis of table 2 data, it can be seen that the predecessor pure steam allowed to obtain high-grain grains on both fertilized and non-fertilized backgrounds - 785-805 g / l. Corn predecessor and annual grasses formed a grain with a smaller natural weight of 745-785 g, but within the basic quality conditions.

The introduction of mineral fertilizers for all predecessors led to significant increase in the nature of grain by 15-20 g for pure steam, 31-35 g for corn and 29-30 g for annual grasses.

With an increase in the content of starch in the grain, the glassiness content decreases and vice versa. Depending on the predecessor and the chemicalization level, the glassiness content of wheat grain ranged from 36.9 to 39.7%. A significantly higher value of glassiness content was found in wheat grain obtained from the predecessor pure steam 39.1-39.7%, which is 2.0-2.2% more than for corn and 1.6-1.8% more than for annual grasses. The effect of chemization level on the glassiness content is insignificant, and in some cases it is not proven.

Gluten is water-insoluble proteins of gluten and gliadins. An important economic indicator of the industry, the selling price of grain, depends on the quantity and quality of gluten. The accumulation of gluten in grain depending on the predecessor and mineral fertilizers in the forest-steppe of the Irkutsk region can be judged by the data in table 2.

In the control variant for pure steam, the Buryat spinous wheat variety formed a grain with a gluten content of 30.6% on average over two years. For corn and annual grasses, the gluten content is significantly lower and ranges from 24.6-27.2%. The effect of mineral fertilizers on increasing gluten is established by the predecessors of corn and annual grasses. Growth was 1.9-2.1% and 1.5-1.9%, respectively. For pure steam, the chemization level did not affect the gluten content of the grain.

**Table 2.** Quality indicators of spring wheat grain (on average for 2018-2019).
Similar differences between the variants were found in the protein content of the grain. The highest content of its predecessor pure steam 15.5-15.6%, for corn and annual grasses is significantly lower (13.5-14.4%).

The results of variance analysis of data show that the greatest influence on the quality of wheat grain had a predecessor factor. The share of its influence, depending on the indicator, is 67.8-92.7%, while the chemization level is from 3.0 to 10.2%, and the interaction of factors accounts for from 1.4 to 8.1%.

Table 3 shows the results of economic evaluation of spring wheat cultivation, taking into account the yield depending on the predecessor, the level of chemization and the price of grain sales depending on quality indicators.

Production costs per 1 ha were calculated based on technological maps. Analysis of the results showed that the largest expenditures were made when cultivating wheat for pure steam against the background of fertilizers and herbicides 21.9-22.9 thousand rubles per 1 ha. The use of mineral fertilizers at a dose of N₄₅P₄₅K₄₅ kg of active substance per one ha increased production costs for all predecessors by an average of 9.2 thousand rubles per ha, and the additional use of herbicide increased by another 1 thousand rubles per hectare. Despite the fact that the use of fertilizers led to an increase in the quality of wheat grain and grain was sold at a higher price, the lowest level of profitability for all predecessors was obtained for backgrounds with the use of fertilizers and herbicides. The main reason for this is the low increase in grain productivity from the applied fertilizers. The lowest cost of spring wheat grain at 4.87 thousand rubles per ton and the highest level of profitability of 126% were obtained when cultivating wheat using pure wind steam.

Table 3. Economic efficiency of spring wheat cultivation.

| Predecessor, factor A | Chemization level, factor B | Indicator | productivity, t/ha | sale price 1 t, RUB | costs per 1 ha, RUB | the cost of grain, RUB/t | profitability, % |
|-----------------------|-----------------------------|-----------|-------------------|---------------------|---------------------|----------------------|-----------------|
| pure steam (control)  | no fertilizers              |           | 2.62              | 11000               | 12767               | 4870                 | 126             |
|                       | N₄₅P₄₅K₄₅                  |           | 2.76              | 11000               | 21958               | 7790                 | 41              |

The smallest significant difference 0.05:

- for factor A: 9, 0.72, 0.13, 0.06, 0.21
- for factor B: 5, 0.50, 0.16, 0.06, 0.27


|                        | N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> and herbicides | 2.82 | 11000 | 22979 | 8330 | 32 |
|------------------------|----------------------------------------------------------|------|-------|-------|------|----|
| corn                   | no fertilizers                                           | 1.86 | 8000  | 8866  | 4770 | 68 |
|                        | N<sub>45</sub>P<sub>45</sub>K<sub>45</sub>               | 2.24 | 10000 | 18153 | 8100 | 23 |
|                        | N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> and herbicides | 2.22 | 10000 | 19159 | 8650 | 16 |
| annual grass           | no fertilizers                                           | 1.63 | 8000  | 8745  | 5370 | 49 |
|                        | N<sub>45</sub>P<sub>45</sub>K<sub>45</sub>               | 1.96 | 10000 | 18005 | 9190 | 9  |
|                        | N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> and herbicides | 1.97 | 10000 | 19063 | 9680 | 3  |

4. Conclusion

The highest productivity of spring wheat grain in the conditions of the forest-steppe zone of the Irkutsk region is provided by the predecessor pure steam. The productivity growth in comparison with corn is 0.38-0.76 t / ha, annual grasses 0.65-0.99 t / ha. The increase from fertilizers is significantly higher for non-fallow predecessors, for corn 0.36-0.38 t / ha, for annual grasses 0.33-0.34 t / ha. 62-93% productivity depends on the predecessor and only 3-28% on the chemization level.

Pure steam increases the grain nature by 35-40 g, glassiness content by 1.6-2.2%, and gluten content by 3.4-6.0% compared to non-steam predecessors. The share of the influence of the predecessor on the quality of grain is 67-92%, the level of chemization accounts for 3-10% and the interaction of factors 2-8%.

The production of wheat grain is cost-effective for all predecessors and at all levels of chemization. The application of mineral fertilizers increases the gross grain harvest, but reduces the profitability compared to the non-winded background for all predecessors.

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