Meteorological conditions, mineral fertilizers and lime aftereffect influence on the barley grain yield and quality in the Irkutsk region

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Abstract. The results of studies of the meteorological conditions, mineral and calcareous fertilizers impact on the barley Biom yield and quality in the Irkutsk region in 2018-2019 in a crop rotation: corn, barley + clover, clover, wheat are presented. The experimental plot soil is grey forest loamy. Corn was the precursor; mineral fertilizers were applied at a dose of N30P30K30. In the growing periods of 2018 and 2019, which are characterized as dry, the barley yield was 1.53-2.01 t/ha and 1.86-2.42 t/ha, respectively depending on the type of experiment. In 2019, raise from mineral fertilizers application increased by 12-22% comparing without adding lime, with the lime aftereffect - by 8-19% and were the largest when applying complex fertilizer. The lime aftereffect of the 1st year did not affect the gain in yield. The yield value depended to a greater extent on the depth of precipitation both for the entire growing season and for the seedlings-tillering period; the average correlation dependence between these indicators was established over two years, the correlation coefficient was 0.69 and 0.62, respectively. Grain nature increased by 1-2% with the use of nitrogen-potassium fertilizers, and the weight of 1000 grains - by 4% in the variants with the introduction of nitrogen-phosphorus, nitrogen-potassium, and complex fertilizers for both backgrounds. The lime aftereffect increased the weight of 1000 grains by 2-5%. An increase in the amount of protein in grain by 6-8% was facilitated by nitrogen-phosphorus and complex fertilizers.

1. Introduction
In 2018-2019 barley crops in the Irkutsk region occupied 85-88% of the sown area in the structure of grain crops. Barley (Hordeum vulgare L.) in our region is cultivated as a valuable fodder crop and can grow in a wide range of environmental conditions [1-2]. Among grain crops, barley is the least demanding of weather conditions, however, sharp deviations of these conditions from the optimum can significantly affect its productivity [3].

Currently, climatic changes around the world are accompanied by an increase in average daily air temperature and more frequent annual droughts, which adversely affects the growth and development of crops, and subsequently a decrease in crop production [4-8] and its quality [9].

Studies conducted in the crop rotation showed the mineral fertilizers and lime effectiveness on barley yield in 2001-2012 [10-11] and on average for 2013-2018 [12]. Barley grain quality in crop rotation has not been previously studied.
The purpose of the study was to investigate the meteorological conditions, mineral fertilizers, and aftereffect of lime influence on the yield and quality of barley grain in crop rotation.

2. Materials and methods

The study was carried out at the experimental field of the Federal state scientific institution "Irkutsk scientific research Institute of agriculture" in crop rotation: corn, barley+clover, clover, wheat in 2018-2019. The object of study – grade spring barley Biome. Initial soil characteristics: acidic grey forest heavy loam, with a humus content of 3.7...4.0 %; total nitrogen – 0.25 %; PHs – 3.9...4.4; Hr – 10.1...11.9 meq/100 g of soil, degree of base saturation 68.4...72.1 %, labile phosphorus content (according to Kirsanov) – 100...120, exchangeable potassium – 80...100 mg/kg of soil. The two-factor scheme of the experiment included the following options: lime – no lime, lime 0.5 g/kg (5.7 t/ha); fertilizer – no fertilizer, NP, PK, NK, NPK. Fertilizers were put for sowing barley in a dose N30P30K30.

As a meliorant limestone flour with the contents of CaCO3 85 % was used, which was added at the rate of 0.5 Ng (5.7 t/ha) for maize (hybrid Katerina SV) once in 4 years.

Barley and undersow clover were sown on the good predecessor, the corn, after early-spring harrowing, followed by rolling in 2018 - May 8, in 2019 - May 12 with a seeding rate of barley – 6.5 million, clover – 4 million germinating grains per 1 ha. Sowing was performed with a planter SNP - 1.6. Crop tending included treatment with insecticides if necessary. Harvest cleaning and registration were done at each working plot by direct combining with "Sampo 500". The area of cultivated plots - 122.5 m², registration plot - 80.5 m². Plot tier - 4-fold, an arrangement of single-row plots, consistent. Indicators of barley grain quality were determined in agrochemical laboratory of FBSI "Irkutsk scientific research institute of agriculture": a kind of grain according to GOST R 54895-2012 [13], mass of 1000 seeds according to GOST 12042-80 [14] and in the laboratory of Irkutsk State Agrarian University FY-12 (protein content, crude fiber, phosphorus). Statistical processing of results of research performed using the software package Snedekor [15].

3. Results

Meteorological conditions during the years of research differed from long-term average. According to the Pivovarikha meteorological station and the Federal SBSI “Irkutsk Research Institute of Agriculture”, the amount of precipitation during the vegetation periods of 2018 and 2019 fell below the long-run annual norm by 69.5 mm (20%) and 51.4 mm (15%), respectively. Shortage of precipitation in May and June 2018 amounted to 47 % and 57%, in May 2019 - 73%, which negatively affected the growth of barley (table 1).

Table 1. Meteorological conditions of growth season 2018-2019.

| Month | Ten-day period | Vegetation period | Average daily temperature, °C | Precipitation depth, mm | Hydrothermal index |
|-------|----------------|-------------------|-------------------------------|-------------------------|-------------------|
| 2018  |                |                   |                               |                         |                   |
| May   | I              | Dropping          | 8.3                           | 6.7                     | 1.90              |
|       | II             |                   | 8.8                           | 1.0                     | 0.26              |
|       | III            | Seedlings         | 14.8                          | 8.4                     | 0.64              |
|       | May, average   |                   | 10.6                          | 16.1                    | 0.79              |
| June  | I              |                   | 16.6                          | 5.5                     | 0.33              |
|       | II             | Tillering         | 19.9                          | 8.3                     | 0.42              |
|       | III            |                   | 23.0                          | 13.2                    | 0.58              |
| June, average |               |                   | 19.8                          | 27.0                    | 0.45              |
| July  | I              | Booting           | 17.1                          | 42.8                    | 2.50              |
|       | II             |                   | 19.4                          | 15.4                    | 0.79              |
|       | III            |                   | 18.4                          | 18.9                    | 0.93              |
| July, average |               |                   | 18.3                          | 77.1                    | 1.40              |
| August| I              | Earing            | 17.9                          | 22.6                    | 1.30              |
|       | II             |                   | 19.0                          | 1.3                     | 0.07              |
|       | III            | Full maturity     | 18.2                          | 76.0                    | 3.80              |
In 2018 barley experienced an acute lack of moisture in the development phases: seedlings and tillering (hydrothermal index was 0.33 and 0.58, respectively). In 2019, during the same periods, barley was better provided with water (hydrothermal index at seedlings - 0.97 and at tillering - 2.78). The humidification conditions at the period of booting and earing in these two years of the study were approximately the same.

According to the temperature regime, the vegetation periods of 2018-2019 were hot: the average daily air temperature was 15.3 °C and 14.9 °C, respectively, with an average annual temperature of 12.5 °C. In general, the agricultural climatic conditions of 2018-2019 were unfavourable for the growth and development of barley.

In 2018, the barley yield against the background without lime amounted to –1.53-1.80 t / ha, and against the background of lime aftereffect - 1.74-2.01 t / ha and was the highest in the variant with the addition of N30P30K30 (table 2).

Table 2. Barley grain yield depending on mineral fertilizers and lime aftereffect in 2018 and 2019 r., t/ha.

| Variant | background without lime | Yield, t/ha | Increment with fertilizers aftereffect 0,5 g.k. | with lime aftereffect |
|---------|------------------------|-------------|-----------------------------------------------|----------------------|
|         | backgroun-d-without     | background  | average                                       | background-lime      | aftereffect          |
|         | background aftereffect  |              |                                               | aftereffect          |                      |
|         |                        |              |                                               | 0,5 g.k.             |                      |
|         |                        |              |                                               | 0,5 g.k.             |                      |
| Without fertilizers | 1.53 | 1.74 | 1.64 | - | - | 0.21 |
| N_{30}P_{30} | 1.57 | 1.97 | 1.77 | 0.14 | 0.23 | 0.30 |
| P_{30}K_{30} | 1.63 | 1.80 | 1.72 | 0.10 | 0.06 | 0.17 |
| N_{30}K_{30} | 1.72 | 1.91 | 1.82 | 0.19 | 0.17 | 0.19 |
| N_{30}P_{30}K_{30} | 1.80 | 2.01 | 1.91 | 0.27 | 0.27 | 0.21 |
| Average | 1.65 | 1.89 | 1.77 | - | - | - |
| HCP_{0.5} shared = 1.21; HCP_{0.5} lime = 0.54; HCP_{0.5} fertilizers = 0.86 | | | | | |
| Without fertilizers | 1.86 | 2.04 | 1.95 | - | - | 0.18 |
| N_{30}P_{30} | 2.10 | 2.20 | 2.15 | 0.23 | 0.16 | 0.10 |
| P_{30}K_{30} | 2.25 | 2.37 | 2.31 | 0.39 | 0.33 | 0.12 |

Table 1 shows that...
The spring-summer drought adversely affected barley productivity. The resulting increases from the application of mineral fertilizers and lime aftereffect in 2018 were unreliable. When conducting a correlation analysis of data in 2018, a strong dependence of the yield on the amount of precipitation both for the entire growing season and during the sprouting-tillering period ($r = 0.80$) and the average dependence of the yield on the average daily air temperature ($r = 0.66$). Similar results on the positive association between precipitation of the growing season and barley yield were obtained by the researchers from Scotland [16].

Mineral fertilization in 2019 made it possible to obtain barley grain productivity increases against a natural background of 0.23-0.40 t / ha (12-22%), and on a limed one, 0.16-0.38 t / ha (8-19%). The largest grain yield for both backgrounds was in the NPK variant, the smallest in the NP variant. When comparing paired combinations of variants, their effectiveness turned out to be approximately the same with the manifestation of some advantage of RK over NK. The aftereffect of the first year of lime in 2019 did not affect the increase in barley grain yield. The average correlation dependence of productivity on rainfall over the entire growing season ($r = 0.59$) and average daily air temperature ($r = 0.55$) was established.

The influence of mineral fertilizers and the aftereffect of the 1st year of lime on barley grain quality indicators is presented in table 3.

**Table 3.** The effect of mineral fertilizers and the aftereffect of the 1st year of lime on the quality of barley grain, 2019.

| Experiment variant | Grain unit g/l | Difference of control of lime | Weight 1000 grains, g | Difference of control of lime | Protein, % | Difference of control of lime | Crude fiber, % | Difference of control of lime |
|--------------------|----------------|-------------------------------|-----------------------|-------------------------------|------------|-------------------------------|---------------|-------------------------------|
| Control            | 631.6          | –                             | 46.6                  | –                             | 13.0       | –                             | 3.09          | –                             |
|                    | 626.5          | –                             | 47.6                  | –                             | 13.0       | –                             | 3.20          | –                             |
| NP                 | 625.0          | –                             | 47.0                  | 0.4                           | 13.9       | 0.9                           | 3.07          | –                             |
|                    | 626.4          | 0.8                           | 49.5                  | 1.9                           | 13.8       | 0.8                           | 3.01          | –                             |
| PK                 | 633.6          | 2.0                           | 47.3                  | 0.7                           | 12.5       | 0.5                           | 3.03          | –                             |
|                    | 626.4          | 0.8                           | 48.5                  | 0.9                           | 13.6       | 0.6                           | 3.42          | 0.22                          |
|                     |                |                               |                       |                               |            |                               |               |                               |
| NK                 | 641.4          | 9.8                           | 47.5                  | 0.9                           | 13.3       | 0.3                           | 2.99          | –                             |
|                    | 633.1          | 7.5                           | 49.6                  | 2.0                           | 13.3       | 0.3                           | 3.09          | –                             |
|                     |                |                               |                       |                               |            |                               |               |                               |
| NPK                | 635.5          | 3.9                           | 48.4                  | 1.8                           | 13.4       | 0.4                           | 3.14          | 0.05                          |
|                    | 625.4          | –                             | 49.7                  | 2.1                           | 14.0       | 1.0                           | 2.97          | –                             |

HCP<sub>sh</sub> 8.6  1.8  0.5  0.4
HCP<sub>lime</sub> 3.8  0.8  0.2  0.2
HCP<sub>lime</sub> 6.0  1.3  0.4  0.3

Numerator – background without lime
Denominator – background with lime 0.5 ng
An accurate increase in the natural weight of barley grain was provided by the NK variant, where the difference with the control was 9.8 g / l (2%) against the unlimed background and 7.5 g / l (1%) against the lime aftereffect background. The lime aftereffect of the 1st year did not affect the value of the full-grain weight of barley. The application of mineral fertilizers contributed to an increase in the weight of 1000 grains against the lime aftereffect background in the NP, NK and NPK variants for both backgrounds by 4%. Due to the lime aftereffect, this indicator increased by 1-2.5 g (2-5%) and was the largest in the NP variant.

The protein roughage in barley grain averaged 13.2% and 13.5% on natural and limed backgrounds, respectively. The smallest amount was observed in the control. When using nitrogen - phosphorus and agricultural triad, the protein roughage in the grain increased by 6-8%. The greatest increase in this indicator was noted in the NPK variant against the background of lime aftereffect. Crude fiber was not dependent on mineral fertilizers. The maximum value of this indicator was noted in the RK variant of the lime aftereffect of the 1st year, where the increase in control was 13%.

The average correlation between the grain weight and the amount of precipitation during the growing season (r = 0.53) and the hydrothermal index value (r = 0.52) was established. The weight of 1000 grains and the amount of protein in the grain depended on the barley grain yield, the correlation coefficient was 0.60 and 0.32, respectively. An average inverse correlation dependence Between the content of crude fiber and yield was established (r = -0.43).

4. Conclusion

In 2018 and 2019 the barley grain yield was formed due to meteorological conditions of vegetation periods, especially due to the availability of moisture during the sprouting period. The use of mineral fertilizers in 2019 against a natural background increased the amount of grain harvest by 12-22%, and against the lime aftereffect background - by 8-19%. The largest grain yield for both backgrounds was in the variant with complex mineral fertilizers (NPK). The use of nitrogen-potassium fertilizers on both backgrounds contributed to an increase in the natural weight of barley grain and did not depend on the 1st year lime aftereffect. The NP, NK and NPK application increased the weight of 1000 grains by 4%, and the lime aftereffect by 2.5%. The maximum amount of protein in the grain was noted in the NPK variant against the lime aftereffect background. Crude fiber was not dependent on mineral fertilizers.

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