Variation of gluten amount in wheat grain under the influence of weather conditions

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Abstract. The purpose of the work was to find out the role of temperature factor and precipitation during the growing season in the formation of gluten amount in the grain of spring soft wheat in the southern forest-steppe of the Krasnoyarsk territory. Varieties of soft spring wheat were evaluated by the gluten content; the scale of the trait variability was established. The role of the temperature factor was analyzed, the influence of moisture availability during the growing season and its contribution to the change in the gluten amount in soft spring wheat was considered. The experience was conducted by the method of competitive testing at the Karatuz state variety site in 2008-2017. The varieties «Novosibirskaya 15», «Vetluzhanka», «Omskaya 33» and «Kantegirskaya 89» were studied. The results were processed using mathematical statistics. It was found that the variation in the gluten content of the studied samples over the analyzed period was low and the indicator was stable. The gluten amount increased under the influence of high temperatures and precipitation in July. August precipitation had a negative effect on increasing the gluten content.

1. Introduction
Spring soft wheat is the main food crop in the Krasnoyarsk territory. The resulting grain is used for baking. In modern conditions the role in technological qualities of the resulting grain is especially important in connection with the transition to import substitution with high-quality grain. In Eastern Siberia breeders are faced with the task of creating soft spring wheat varieties of local selection, characterized by high milling and baking qualities [1].

The formation of the spring wheat crop and its quality in the forest-steppe of the Krasnoyarsk territory is influenced by a complex set of weather conditions [2]. Processing of long-term data on the gluten content will reveal the nature of its variability under the influence of environmental conditions, determine the stability of the trait and determine ways to improve newly bred varieties.

The aim of the work was to assess the role of temperature factor and conditions of moisture supply during the growing season in the amount formation of spring wheat gluten in the southern forest-steppe of the Krasnoyarsk territory.

Tasks set during the research were:
1. To evaluate varieties of soft spring wheat in the southern forest-steppe of the Krasnoyarsk territory for gluten content and establish the scale of the trait variability.
2. To identify the role of temperature factor in the analyzed indicator formation in the studied culture.
3. To consider the influence of moisture content during the growing season and its contribution to the change in the gluten amount in wheat grains.

2. Methods and results
In 2008-2017 the experience was conducted on the method of competitive testing at the Karatuz state varietal site in order to perform the tasks set for the study to evaluate soft spring wheat varieties based on the gluten content grown in the forest-steppe of the Krasnoyarsk territory, and to identify the role of meteorological conditions in the formation of the analyzed indicator [3]. The soil cover was represented by xeric chernozem. The repeatability in the experiment was 4 times, the area of the plot was 25 m² [4]. In this work the varieties «Novosibirskaya 15», «Vetluzhanka», «Omskaya 33» and «Kantegirskaya 89» were studied. The gluten content was determined by the method of the state standard 27839-2013 [5]. As a result of the research the materials of the competitive variety testing were processed by mathematical statistics using the StatSoft ® STATISTICA 6.0 package [6].

It is well known that the gluten content in wheat and the physical properties that characterize its quality can vary very widely. The gluten content usually correlates well with the protein amount in the grain, which is understandable, since gluten is mainly a protein substance. The exception is those cases when under the influence of certain effects of gluten, the protein changes its physical and chemical properties dramatically and therefore loses the ability to form a fused hydrated mass of raw gluten to a greater or lesser extent, which leads to a decrease in the yield of washed gluten with a sufficient content of total protein in the grain. An example is wheat damaged by bugs, early frosts, sprouted on the root, or damaged by improper processing and storage methods (over-dried, self-heating grain, etc.).

For wheat with gluten of good and medium quality the content of the latter in the grain is determined by the same factors as the content of total protein. Varietal characteristics of wheat, meteorological conditions of vegetation and features of the ripening period, agricultural activities — soil preparation, crop rotation, fertilization, irrigation, and so on, all this affects the gluten content in the same direction as the protein content in the grain.

The highest gluten content in assessing it during the study period had variety «Novosibirskaya 15»-33.7% (table. 1). The range of the trait variation in this sample was low: from 31.9 % to 34.5 %, with a variation of only 2 %. This variety was followed by «Vetluzhanka» and «Kantegirskaya 89» with gluten content of 32.6 %. In the last place among the analyzed samples was the variety «Omskaya 33», the average gluten content for the study period was 31 %, the range of the trait variability indicated that the gluten content in its grain was 28.4% in 2009.

| Varieties           | lim       | M±m      | V, %  |
|---------------------|-----------|----------|-------|
| «Vetluzhanka»        | 31.8-33.3 | 32.6±1.1 | 1.8   |
| «Omskaya 33»        | 28.4-33.5 | 31.3±1.3 | 4.5   |
| «Kantegirskaya 89»  | 30.9-33.4 | 32.6±1.0 | 2.4   |
| «Novosibirskaya 15» | 31.9-34.5 | 33.7±0.9 | 2.4   |

According to the requirements for the gluten content in high-quality wheat grain, it must be at least 28 %. According to our data, all varieties formed grain with the quality corresponding to this parameter during the study period (figure 1). The variation of the indicator was low – from 1.8 to 4.5 %, which indicated the stability of the trait in the studied varieties in this zone.
According to table 2, the average monthly temperatures in May and June did not significantly affect the gluten amount in the studied spring wheat varieties in the southern forest-steppe zone. The only variety that responded to an increase in heat in June was «Novosibirskaya 15» (the correlation coefficient was 0.458), with an increase in the temperature of this period, the gluten content increased. This type of relationship can be explained by the fact that the variety is early and at the end of June it forms flower organs and inflorescences, and the increase in heat supply at this time affects these processes positively.

Table 2. The role of temperature factor in the formation of gluten content in spring wheat grain in the conditions of the Karatuz state varietal site, 2008-2017.

| Varieties         | May   | June  | July  | August | September |
|-------------------|-------|-------|-------|--------|-----------|
| «Vetluzhanka»     | 0.111 | -0.229| 0.564 | 0.045  | -0.243    |
| «Omskaya 33»      | -0.154| -0.184| 0.645 | 0.047  | -0.083    |
| «Novosibirskaya 15» | -0.058| 0.458 | 0.395 | 0.269  | -0.333    |
| «Kantegirskaya 89» | -0.211| -0.199| 0.410 | 0.167  | -0.351    |

At m² 0.245 – 0.255

The most significant correlation of gluten content in grain with an increase in temperatures was observed in July. All varieties responded positively to the increase in heat in the second summer month, as evidenced by the correlation coefficients (r varied from 0.395 in the variety «Novosibirskaya 15» to 0.645 in the variety «Omskaya 33»). This is due to the fact that during this period the processes of formation in all inflorescence organs, pollination and fertilization, and the formation of the grain are completed, which depend on sufficient heat supply positively. In August and September the nature of these relationships weakens, and the correlation coefficients decrease.

Having considered the nature and strength of the relationship between the gluten content and the moisture availability of the growing season, we found that the most significant effect on the studied quality attribute in spring wheat of the studied varieties is provided by precipitation in July and August (table 3).

Table 3. The role of water availability in the gluten formation of spring wheat grain in the conditions of the Karatuz state varietal site, 2008-2017.

| Varieties         | Months |
|-------------------|--------|
|                   | May    | June   | July   | August | September |

Figure 1. Gluten content in soft spring wheat grain at the Karatuz state varietal site, % (2008-2017).
July precipitation had a positive effect on the formation of gluten amount. The most responsive was the variety «Vetluzhanka» - its correlation coefficient reached 0.425, followed by the variety «Kantegirskaya 89» with a correlation coefficient of 0.392. The precipitation that fell during this period had a positive effect on the output and flowering of spring wheat, as well as on the further development of plants, that is the increase in moisture availability during the critical period of this crop had a favorable effect on the quality of grain.

In August the picture was opposite, excessive moisture during this period led to a decrease in the gluten content, obtained negative correlation can be explained by the leaching of micro- and macroelements, deterioration of the gas regime in the soil, reduced microbial activity. Plants can be exposed to root and leaf rot [7]. All these factors affected the index of gluten content in the grain of soft spring wheat in the studied zoned varieties negatively. Moisture availability in May, June and September did not affect the gluten content in the grain of the studied varieties significantly.

Based on the research, the following conclusions are formulated:

1. The average gluten content of the studied wheat varieties in the southern forest-steppe zone of the Krasnoyarsk territory over the years of research ranged from 31.3 % to 33.7 % with a variation of 1.8 % to 4.5 %. The maximum gluten amount in this zone formed the variety «Novosibirskaya 15» -33.7 %.

2. The gluten content increased with increasing temperatures and precipitation in July, r changed from 0.355 in the variety «Novosibirskaya 15» to 0.645 in «Omskaya 33». The negative effect on the gluten amount was characterized by precipitation in August; the variability of correlation coefficients was from -0.109 in the variety «Novosibirskaya 15» to -0.533 in the variety «Vetluzhanka».

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| Variety             | r   | r   | r   | r   |
|---------------------|-----|-----|-----|-----|
| «Vetluzhanka»        | -0.230 | -0.078 | 0.425 | -0.533 | -0.230 |
| «Omskaya 33»        | -0.155 | 0.017 | 0.359 | -0.626 | -0.079 |
| «Novosibirskaya 15» | -0.240 | -0.217 | 0.374 | -0.355 | -0.296 |
| «Kantegirskaya 89»  | -0.013 | 0.179 | 0.392- | -0.381 | -0.217 |

At m° 0.095 – 0.250