Formation of grain quality of spring soft wheat varieties depending on agrotechnical methods

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Abstract. The article deals with the issues of improving the grain quality of spring soft wheat using various varieties, fore crops and nitrogen fertilizers. It was found in experiments with spring soft wheat, carried out on gray forest heavy loamy soil, that the quality indicators of grain, dough and bakery assessments were most strongly influenced by varietal characteristics, weather conditions and placement according to optimal fore crops. Voronezhskaya 10 turned out to be a more productive variety, which formed grain that met the requirements of the standard for strong wheat, both in different years and according to different fore crops. The most valuable fore crops for obtaining high quality grain turned out to be complete fallow and clover. The best forecrop for Priokskaya was clover, the worst one was complete fallow. L-503 had low values of flour strength for clover and higher ones for winter crops, especially for the unfertilized variant. The effect of fertilizers on flour strength was mixed. In a case of Voronezhskaya 10, the flour strength decreased for pure fertilized fallow and fertilized winter crops. In a case of Priokskaya, a small positive effect was observed for all fertilized variants. When fertilized, L-503 reduced the flour strength for winter crops and rapeseed. The effect of fertilizers was mixed and small. In a case of Voronezhskaya 10, the overall bakery score from fertilizers decreased when placed on complete fallow, and increased for clover, rapeseed, and especially peas. In a case of Priokskaya, the positive effect of fertilizers was when placed after clover. It was revealed that the introduction of \(N_{60}\) for pre-sowing cultivation did not affect the technological qualities of the grain, because most of the nitrogen was used by plants for the formation of vegetative mass.

1. Introduction

The modern bakery industry in Russia makes high demands on the quality of wheat [1]. Due to the wide variety of soil and climatic conditions and varietal composition of wheat, milling enterprises in some regions of the country constantly need high-quality wheat capable of improving wheat batches that are weak in terms of baking. There is a particular shortage of high-quality baking wheat in areas where the production of strong wheat is impossible due to soil and climatic conditions [2, 3].

The size of the yield is influenced by many factors, among which the largest and most significant ones are: soil fertility, climatic conditions, the level of agricultural technology and the plant itself, which forms the yield [4, 5, 6]. The most powerful and complex influence is exerted by the plant. It is determined by its properties inherent in the genotype of the variety, which manifest themselves at every stage of growth and development. The genetic potential of the variety is formed from the variety of these properties [7, 8].
The purpose of the study is to study the influence of various fore crops and nitrogen fertilizers on the technological qualities of grain of spring soft wheat varieties in the conditions of the Central region of Russia.

2. Materials and methods
The research was carried out at an experimental agro-technological station, being a part of educational and scientific innovation center "Agrotechnopark" FSBEI HE RSATU in 2018-2019. The soil of the experimental plot was gray forest heavy loamy, the humus content was 2.6-2.8 %, P$_2$O$_5$ (according to Kirsanov) was 13.5-14.2 %, K$_2$O (according to Maslova) was 20.5-22.0 mg/100 g of soil, pH was 5.6-6.0. Three studied varieties of spring soft wheat included Voronezhskaya 10, Priokskaya and L-503. The experimental design to study nitrogen nutrition of spring wheat included the following variants: 1 - without fertilizers; 2 - N$_{60}$. Fertilizing background was created by introducing 60 kg rate of appl. of nitrogen in the form of ammonium nitrate after early spring harrowing of the site. The fore crops in the experiments were: complete fallow, clover for 2 years of use, rapeseed, peas, winter cereals. Sowing was carried out with a CH-16 seeder at the optimal time. The total area of the plot was 70 m$^2$ and the registration plot was 60 m$^2$. The arrangement of the plots was systematic, the replication was fourfold.

Evaluation of technological parameters of grain was carried out by standard methods [9]. Statistical processing of the experimental material was carried out by the dispersion analysis using computer program "Straz" [10].

3. Results and discussion
Determination of grain vitreousness in years of different weather conditions (Table 1) showed that in drier 2018, it was generally higher than that in 2019. The difference for variants was 4-6 and even 9 %

There was a difference between varieties. L-503 had the glassiest grain and Priokskaya had the least glassy one. This trend was typical for both 2018 and 2019. The varieties reacted differently to nitrogen fertilization. In 2018, there was a weak tendency for a decrease in vitreousness: in L-503 in variants for rapeseed, peas, winter crops, in Voronezhskaya 10 and Priokskaya in variant with winter crops. In 2019, being wet, there were more variants with a positive effect of fertilizers, especially at Priokskaya.

In 2018, Voronezhskaya 10 reacted very poorly to its fore crops. The reaction of Priokskaya was different. For complete fertilized fallow, the vitreousness reached 54 %, and for rapeseed and winter crops it dropped to 49 %. L-503 had high vitreousness for complete fallow and clover and low for peas and winter crops.

In 2019, the reaction to fore crops was more differentiated. Complete fallow distinguished itself in all varieties. In a case of Voronezhskaya 10, clover was not inferior to complete fallow. In a case of Priokskaya and L-503, the vitreousness in clover was lower. The vitreousness of peas in L-503 decreased less than in Voronezhskaya 10 and especially in comparison with Priokskaya. The lowest vitreousness was when placing spring wheat varieties after winter ones.

When characterizing the weight of 1,000 kernels, one should pay attention to the varietal difference. In 2018, L-503 was the most large-kernelled variety and Priokskaya was the small-kernelled one.

Nitrogen fertilizers had some positive effect on the weight of 1,000 kernels in 4 out of 5 variants of Voronezhskaya 10, in 1 variant of L-503 and in 3 variants of Priokskaya.

The largest kernel of L-503 was formed against complete fallow without fertilizers and when fertilized and unfertilized peas. A larger kernel of Voronezhskaya 10 was formed when it was placed after peas and fertilized winter crops. The kernel size of Priokskaya was more noticeably influenced by fertilized complete fallow and fertilized clover.

The kernel size is largely determined by varietal characteristics, especially ear grain content and the degree of productive tillering. The studied varieties, especially Priokskaya and L-503, were hereditarily contrasting in these features.
In more favorable weather conditions in 2019, the varietal differences remained the same: Priokskaya was small-kernelled and L-503 was large-kernelled.

Voronezhskaya 10 had a larger kernel for all forecrops in the fertilized variants. Priokskaya had little difference between fertilized and unfertilized variants. The differences between fertilized and unfertilized variants for L-503 were also insignificant. There was no noticeable difference between forecrops. All this can be explained by the same conditions for tillering and preservation of plants for harvesting. In average weather conditions, the potential of the more intense varieties was not realized.

Table 1. Physical properties of grain of spring soft wheat varieties

| Variety         | Forecrop        | Fertilizers, kg/ha rate of appl. | Vitreousness, % | Weight of 1,000 kernels, g |
|-----------------|-----------------|----------------------------------|-----------------|---------------------------|
| Voronezhskaya 10| Complete fallow | no/fert.                         | 2018 2019       | 2018 2019                 |
|                 |                 | N<sub>60</sub>                   | 50              | 50                        | 29.7 31.1    |
|                 | Clover          | no/fert.                         | 52              | 50                        | 28.6 31.6    |
|                 | Rape            | no/fert.                         | 50              | 49                        | 27.0 29.6    |
|                 | Peas            | no/fert.                         | 52              | 49                        | 30.0 29.8    |
|                 | Winter crops    | no/fert.                         | 51              | 39                        | 28.5 31.4    |
|                 |                 | N<sub>60</sub>                   | 50              | 45                        | 31.1 31.8    |
| Priokskaya      | Complete fallow | no/fert.                         | 53              | 51                        | 26.5 26.6    |
|                 |                 | N<sub>60</sub>                   | 54              | 51                        | 28.6 26.2    |
|                 | Clover          | no/fert.                         | 50              | 50                        | 27.6 26.6    |
|                 | Rape            | no/fert.                         | 49              | 47                        | 25.8 25.8    |
|                 | Peas            | no/fert.                         | 52              | 43                        | 26.4 26.9    |
|                 | Winter crops    | no/fert.                         | 49              | 38                        | 27.2 27.3    |
|                 |                 | N<sub>60</sub>                   | 52              | 43                        | 25.2 27.6    |
| L-503           | Complete fallow | no/fert.                         | 52              | 50                        | 36.4 33.1    |
|                 |                 | N<sub>60</sub>                   | 54              | 51                        | 32.3 32.4    |
|                 | Clover          | no/fert.                         | 51              | 49                        | 31.0 33.0    |
|                 | Rape            | no/fert.                         | 52              | 48                        | 29.1 32.3    |
|                 | Peas            | no/fert.                         | 51              | -                         | 35.4 33.1    |
|                 | Winter crops    | no/fert.                         | 51              | 41                        | 32.6 32.3    |
|                 |                 | N<sub>60</sub>                   | 50              | 44                        | 30.0 31.4    |

The protein content in the grain was primarily determined by weather conditions. In 2018, being drier, there was noticeably more protein than in 2019. Priokskaya as a whole differed from other varieties in a higher protein content and insignificant variation of this indicator according to the variants of the experiment.
L-503 had lower indicators of protein content and increased variability in variants (from 16.8 to 13.9 %). Voronezhskaya 10 was characterized by average indicators.

The crude gluten content correlated very closely with the protein content ($r=0.73 \pm 0.16$). So, in 2018, the content of raw gluten in some variants of the experiment reached 37.7-38.8 %, which was much higher than the indicators of 2019, being cooler and more humid.

Attention should be paid to noticeable varietal differences in the content of wet gluten. The highest and most stable indicators were when Priokskaya.

L-503 was inferior to Priokskaya both in terms of raw gluten and its stability of the experimental variants. Voronezhskaya 10 was significantly inferior to L-503. There were great differences between fore crops. The highest rates for all varieties were when they were placed in a complete fallow. They were less noticeable in L-503, rather large in Voronezhskaya 10 when clover without fertilizers. Rape as a forecrop took the third place. Winter crops turned out to be the worst forecrop. The difference between the best fertilized and the worst fertilized was 9.2 % for Voronezhskaya 10, 4.7 % for Priokskaya and 6.4 % for L-503. This difference in unfertilized variants was, respectively, 5.8, 4.3, 6.8 %.

Fertilizers in most variants of the experiment increased the content of wet gluten, with the exception of the variant of Voronezhskaya 10 for winter crops, where a decrease in gluten was obtained by 0.7 %. The highest increase was obtained for peas, where the difference in favor of the fertilized variant was 5.8 %. The introduction of nitrogen against clover contributed to an increase in the content of wet gluten in a case of Voronezhskaya 10 by 1.8 %, Priokskaya - by 3.0 % and L-503 - by 2.5 %.

Gluten formed in the grain must have high technological indicators, which are generally identified on the IDK device in units of the scale of the device. Gluten must be both firm and elastic. Overly strong gluten is just as undesirable as overly weak one. Good gluten should have between 50 and 70 units.

Voronezhskaya 10 had strong gluten and Priokskaya had weak gluten. Fertilizers had little effect on quality indicators in 2018. They made gluten weaker only in some cases (when Priokskaya for clover; when L-503 for clover, peas, and rape). There were interesting data on the reaction of varieties to their fore crops. If Voronezhskaya 10 formed gluten of group 1 against complete fallow and clover, then L-503 gave gluten close to group 1 against rape, peas and unfertilized winter crops.

The strength of flour depends, first of all, on the hereditary characteristics of the variety, weather and agrotechnical conditions.

In 2018, the highest indicators, close to the requirements of the standard for strong wheat, were in Voronezhskaya 10 and very low ones were in Priokskaya. L-503, occupying an intermediate position in flour strength, was nevertheless closer to Priokskaya than to Voronezhskaya 10. According to the variants of the experiment, Voronezhskaya 10 gave stable results. The difference between the best and worst variants was 75 units. When Priokskaya, this difference reached 139 units, i.e. almost twice as much as in Voronezhskaya 10. In L-503, the differences between the variants against the background of low values of the flour strength amounted to 59 units. The flour strength of Voronezhskaya 10 decreased against complete fertilized fallow and fertilized winter crops.

Priokskaya had a slight positive effect in all fertilized variants.

When applying fertilizers, L-503 reduced the strength of flour for winter crops and rape.

Voronezhskaya 10 reacted poorly to its fore crops. The strength of the flour decreased only against complete fertilized fallow and fertilized winter crops. For the rest of the variants, similar indicators were obtained.

Data on baking qualities are presented in Table 2.
| Variety | Forecrop          | Fertilizers | Bread volume, ml | OXO, units |
|---------|-------------------|-------------|------------------|------------|
|         |                   |             | 2018  | 2019  | 2018  | 2019  |
| Voronezhskaya 10 | Complete fallow   | no/fert.    | 1,000 | 1,190 | 4.4  | 4.9  |
|         |                   | N60         | 950   | 1,200 | 3.6  | 4.6  |
|         |                   | Clover      | 1,040 | 920   | 4.0  | 3.5  |
|         |                   | N60         | 1,100 | 1,120 | 4.3  | 4.2  |
|         |                   | Rape        | 1,050 | 920   | 4.0  | 3.8  |
|         |                   | N60         | 1,090 | 940   | 4.3  | 3.8  |
|         |                   | Peas        | 820   | 910   | 3.0  | 3.1  |
|         |                   | N60         | 950   | 910   | 3.7  | 3.2  |
|         |                   | Winter crops| no/fert. | 1,050 | 850 | 4.0 | 3.1 |
|         |                   |             | N60   | 910   | 3.9  | 3.4  |
| Priokskaya | Complete fallow   | no/fert.    | 850   | 1,080 | 2.9  | 4.1  |
|         |                   | N60         | 950   | 1,100 | 3.1  | 4.3  |
|         |                   | Clover      | 960   | 900   | 3.3  | 3.2  |
|         |                   | N60         | 990   | 960   | 3.9  | 3.3  |
|         |                   | Rape        | 870   | 900   | 3.0  | 3.6  |
|         |                   | N60         | 900   | 920   | 3.1  | 3.7  |
|         |                   | Peas        | 790   | 900   | 2.9  | 3.1  |
|         |                   | N60         | 810   | 840   | 3.0  | 3.4  |
|         |                   | Winter crops| no/fert. | 780   | 860 | 3.0 | 3.0 |
|         |                   |             | N60   | 820   | 1,100 | 3.1 | 3.2 |
| L-503   | Complete fallow   | no/fert.    | 740   | 1,160 | 2.9  | 4.3  |
|         |                   | N60         | 790   | 940   | 2.8  | 4.4  |
|         |                   | Clover      | 850   | 980   | 3.2  | 3.6  |
|         |                   | N60         | 900   | 900   | 2.8  | 3.6  |
|         |                   | Rape        | 800   | 900   | 3.9  | 3.5  |
|         |                   | N60         | 890   | -     | 3.0  | 3.6  |
|         |                   | Peas        | 910   | -     | 3.5  | -     |
|         |                   | N60         | 960   | 840   | 3.8  | -     |
|         |                   | Winter crops| no/fert. | 950   | 860 | 3.6 | 3.0 |
|         |                   |             | N60   | 980   | 3.8  | 3.2  |

Analyzing the data presented in the table on the volume of bread from 100 g of flour, it should be noted that the influence of weather conditions is not very strong. Compared to the chemical properties,
which vary greatly over the years of research, the volume of bread changed little. The varietal differences were more significant. In 2018, Voronezhskaya 10 stood out in terms of bread volume. Priokskaya and L-503 were almost the same with a slight advantage of L-503.

Fertilizers in most variants of the experiment had a positive effect on the volume of bread, with the exception of Voronezhskaya 10, placed for winter crops. The stronger reaction for nitrogen fertilization was in a case of Voronezhskaya 10 against peas, Priokskaya against complete fallow, L-503 against rape.

A higher volume of bread from Voronezhskaya 10 was when it was against complete fallow, clover and rape, from Priokskaya – against complete fallow and clover, from L-503 – against peas and rape.

In 2019, varietal differences were smoothed out. The best indicators were against complete fallow, the lowest ones were against winter crops. Clover as a forecrop had no advantages over other forecrops.

The best forecrop for Priokskaya was clover, the worst one was complete fallow. In L-503, low values for the strength of flour were obtained for clover and higher ones for winter crops, especially in the unfertilized variant.

4. Conclusion
The quality indicators of grain, dough and bakery assessments were most strongly influenced by varietal characteristics, weather conditions and placement according to optimal fore crops. The best variety turned out to be Voronezhskaya 10, which formed grain that met the requirements of the standard for strong wheat, both in different years and according to different fore crops. Complete fallow and clover have proven to be the most valuable fore crops for obtaining high quality grain. The introduction of N<sub>60</sub> for pre-sowing cultivation did not affect the technological qualities of the grain, because most of the nitrogen was used by plants for the formation of vegetative mass.

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