Impact of mineral fertilizers on winter wheat quality using No-Till technology

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Abstract. The paper presents the study of the influence of ammophos, potassium magnesia and ammonium nitrate on the content of protein, gluten and grain unit of winter wheat using No-Till technology in the edaphoclimatic conditions of the southern zone of Rostov Region. It was shown that the application of mineral fertilizers to the surface soil layer during winter wheat cultivation using No-Till technology improves the grain quality. The highest grain quality parameters (protein content – 13.4% and gluten content – 25.3%, grain unit – 780.0 g/l) were obtained when ammophos and potassium magnesia were jointly added prior to sowing at a depth of 10 cm with double dressing of ammonium nitrate in the tillering and booting phases. High direct dependence of protein content in winter wheat grain on the accumulation of nitrate nitrogen in soil in the booting phase was revealed in all test layers: 0–10 (r = 0.85), 10–20 (r = 0.72), 0–30 cm (r = 0.76). The gluten content in the grain and its grain unit significantly depended on the mobility of phosphorus in the surface soil layer – 0–10 cm (r = 0.66 and 0.52, respectively). Along with the quality improvement of winter wheat grain, the rational use of mineral fertilizers in the No-Till system increases its yield. There is a direct positive relationship between grain protein content and winter wheat yield (r = 0.93).

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1 Introduction

Russian grain is a strategic export product and positions Russia in the international arena as one of the guarantors of global food security [17]. Grain production is the basis of crop production and the entire agricultural sector in the vast majority of agricultural zones of the world [1]. Currently, Rostov Region is the leader among other regions of the country in gross grain yield, and the largest producer of winter wheat. However, it is impossible to increase yield and improve the quality of winter wheat in conditions of intensive farming without the use of resource-saving technologies for its cultivation, including No-Till technology. One of the elements of these technologies is the rational use of mineral fertilizers, which is the main factor that increases the yield and improves the quality of crops while maintaining soil fertility [10, 18, 20]. The problem of optimizing the mineral nutrition of crops with the introduction of resource-saving technologies is relevant and at the same time the least studied in the edaphoclimatic conditions of the European part of southern Russia.

2 Materials and Methods

The studies were conducted from 2016 to 2018 within field tests [9] in the territory of Kirov ZAO, Peschanokopsky District, located in the southern natural and climatic zone of Rostov Region.

The climate pattern of this zone includes scarcity of precipitation, hot summer, low relative humidity in summer. Annual precipitation amounts to 410-460 mm, hydrothermal index = 0.7–0.76, average annual temperature – 8.7–9.5°C [15]. The agrometeorological conditions were different over the years of study, which made it possible to objectively assess the impact of mineral fertilizers on the quality of winter wheat.

Soil – ordinary calcareous medium-phase heavy loamy chernozem. According to the World Research Base, the studied soils belong to Calcic Chernozems [23]. Ordinary calcareous chernozems are among the best arable soils in the region, favorable for the cultivation of all field crops. The agrochemical characteristics of the arable soil layer of the test site are as follows: content of nitrate nitrogen and mobile sulfur – low, content of mobile phosphorus and magnesium – average; exchange potassium – high.

Test crop – winter wheat (Triticum aestivum L.), Grom variety. This variety is characterized by high winter hardiness, good drought resistance, therefore, it is widely cultivated not only in the Central Chernozem Region, but also in the North Caucasus and Lower Volga regions characterized by unstable and insufficient moisture. Predecessor: flax Linum L.

Experimental design: 1. Control (without fertilizers); 2. N12P52 in the sowing phase + N30 in the tillering phase + N70 in the booting phase; 3. K32Mg12S20 in the sowing phase + N30 in the tillering phase + N70 in the booting phase; 4. N12P52 + K32Mg12S20 in the sowing phase + N30 in the tillering phase + N70 in the booting phase; 5. N12P52 + K32Mg12S20 in the sowing phase to a depth of 10 cm + N30 in the tillering phase + N70 in the booting phase.

The following fertilizers were used: ammophos (N12P52), potassium magnesia (K32Mg12S20), ammonium nitrate (N34). The test was repeated four times. The total area of the plot – 110 m^2. MTZ 1523 tractor and Semeato TDNG 420 seeder (Brazil) were used for sowing. Seed application rate – 5 million pieces of viable seeds per 1 hectare, seeding depth – 4 cm. The yield was taken into account by the ACROS 585 combine to achieve the full ripeness of winter wheat grain. Sampling of winter wheat grain and their preparation for analysis were performed using generally accepted methods [13]. The gluten content in the grain was determined according to GOST 13586.1-68 [3], protein – according to GOST 10846-91 [5], grain unit – according to GOST 10840-64 [4]. The main quality indicators were evaluated in accordance with GOST 9353-2016 [6].

Correlation and dispersion analyses were performed using STATISTICA 13.

3 Results

The protein content of winter wheat with the application of mineral fertilizers varied in 2016 – from 11.5 to 14.1%; in 2017 – from 13.5 to 13.7%; in 2018 – from 12.0 to 12.4%. The gluten content changed in 2016 – from 14.7 to 21.1%; in 2017 – from 28.9 to 29.5%, in 2019 – from 24.6 to 25.5%. The grain unit according to the test variants varied in 2016 – from 691.3 to 742.8 g/l; in 2017 – from 795.5 to 811.8 g/l; in 2018 – from 788.5 to 800.0 g/l (Figures 1, 3, 5).

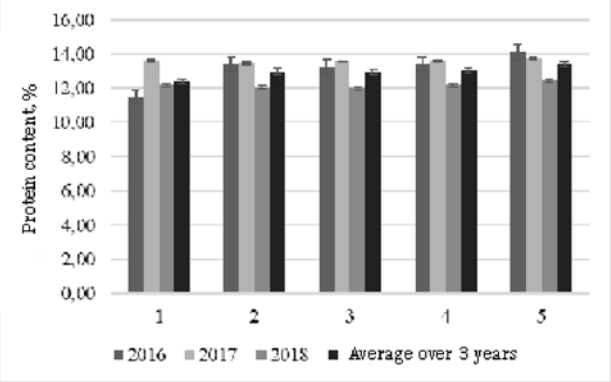

Fig. 1. Protein content of winter wheat with the application of fertilizers in No-Till system, %.

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On average, over the years of the study the content of protein, gluten and grain unit of winter wheat in the control variant made 12.4%, 23.1%, 760.7 g/l, respectively. The application of mineral fertilizers improves the quality of grain. The presowing application of ammophos with double dressing of ammonium nitrate increases the protein content to 13.0%, which is 4.0% more in relation to the control sample. The addition of potassium magnesia with ammonium nitrate also increases the protein content by 4.0% compared to the control sample (Figure 2).

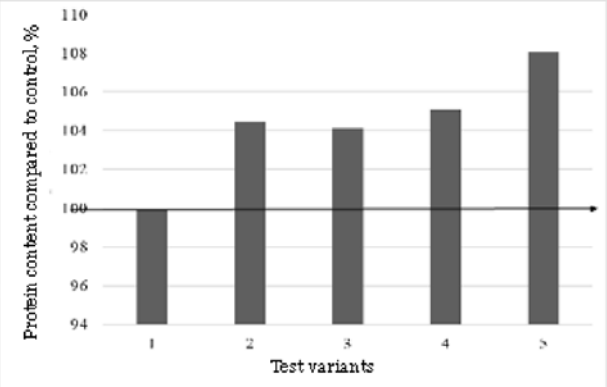


Fig. 2. Change in protein content of winter wheat with the application of mineral fertilizers in relation to control sample, average over 3 year.

The protein content in the grain with the combined use of ammophos and potassium magnesia is almost the same as with the introduction of ammophos alone.

The maximum protein content (13.4%) was revealed in variant N12P52 + K32Mg12S20 (to a depth of 10 cm) + N30 in the tillering phase + N70 in the booting phase. The increase in protein content was 8.0% relative to the control.

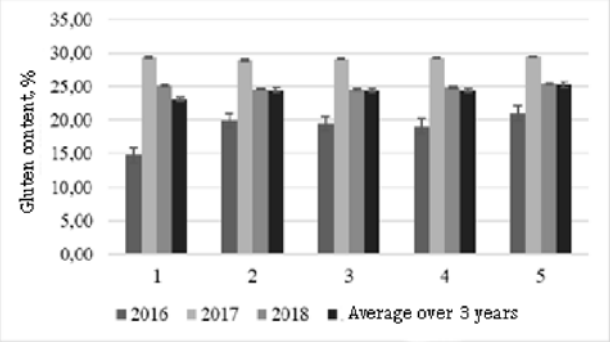


Fig. 3. Gluten content of winter wheat with fertilizer treatment within the No-Till system.

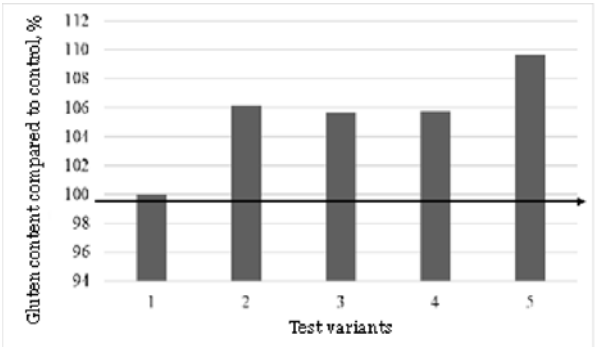


Fig. 4. Change in gluten content of winter wheat with the application of mineral fertilizers in relation to control sample, average over 3 years.

A similar pattern was established according to the effect of fertilizers on gluten content of winter wheat (Figure 3). Over three years of studies, the increase in gluten both with the separate application of ammophos and potassium magnesia, and when used together to the sowing depth was 6.0% compared with the control sample. The introduction of ammophos and potassium magnesia to a depth of 10 cm against the background of double dressing with ammonium nitrate increases the gluten content to the highest value – 25.3., which is 10.0% more than in the control version (Figure 4).

The analysis of variance showed that the established increase in protein and gluten content of winter wheat with the application of the studied mineral fertilizers is significant and reliable (Figure 5).

The grain unit is less than the content of protein and gluten, and changes when mineral fertilizers are applied. On average, there is a slight increase in the fertilizer variants – 2.0% to 3.0% compared to the control sample.

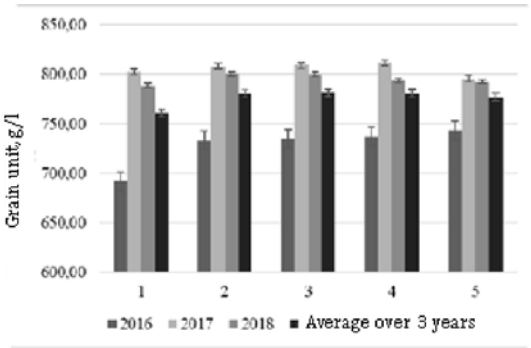


Fig. 5. Winter wheat grain unit with the application of fertilizers within No-Till system, g/l.

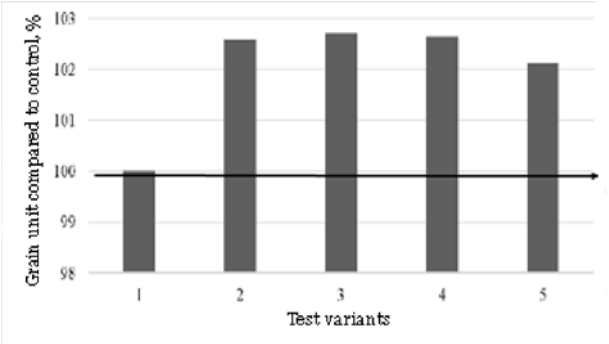
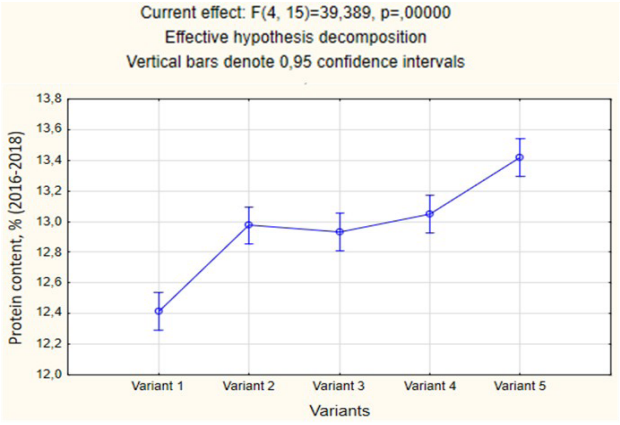


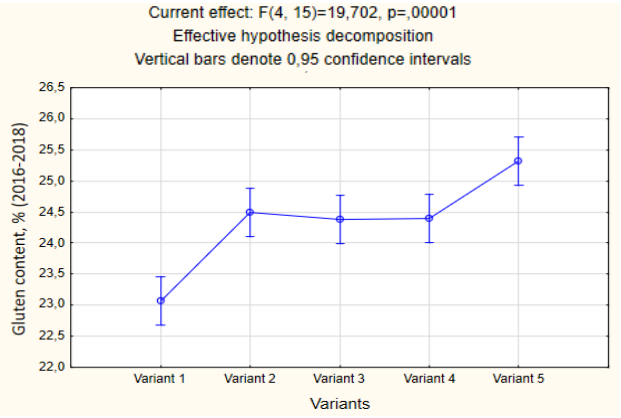
Fig. 6. Change in the grain unit of winter wheat with the application of mineral fertilizers in relation to control sample, average over 3 years.

4 Discussion

The term "wheat quality" includes more than two dozen features that characterize the composition of grain, as well as the baking properties of flour. Among them the protein content serves a determining indicator of the quality of winter wheat grain. This indicator is an inherited feature and depends to a greater extent on the variety, but under the influence of agrotechnical factors its fluctuations may reach 8.0% or more [16]. Fertilizers are the main factor in regulating the nutritional regime of the soil, thus improving its biological and physical properties, which ensures the production of high-quality and stable crops [7, 10, 12]. The correlation analysis revealed a significant dependence of winter wheat grain quality on effective fertility of ordinary calcareous chernozem (Figure 5).



(a)



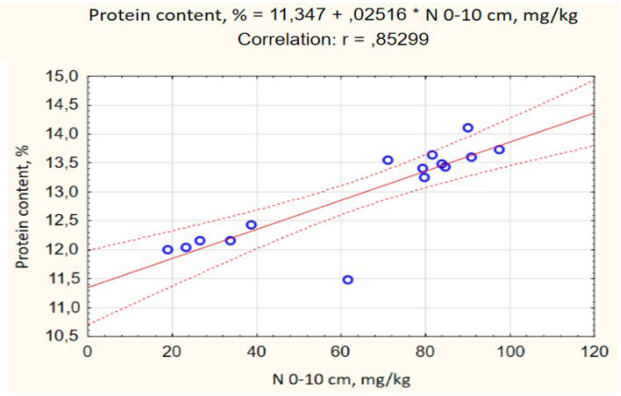
(b)

Fig. 7. Influence of mineral fertilizers on the content of protein (a) and gluten (b) in winter wheat grain

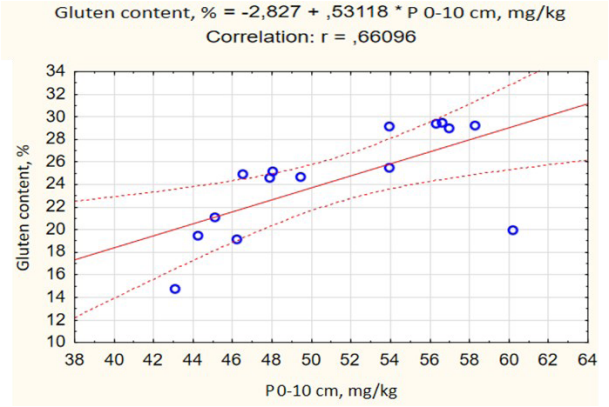
The direct dependence of the protein content of winter wheat on the amount of nitrate nitrogen in the soil in the booting phase was established. The high correlation coefficient between the above parameters is typical for all the studied soil layers: 0–10 (r = 0.85), 10–20 (r = 0.72), 0–30 cm (r = 0.76). The gluten content and the grain unit of winter wheat significantly depended on the mobility of phosphorus in the surface soil layer – 0–10 cm (r = 0.66 and 0.52, respectively).

The findings are supported by research data stating that nitrogen fertilizers play a major role in improving winter wheat quality in the arid zone of the North Caucasus. The application of nitrogen at a dose of N30 in the tillering and booting phases increases the protein content in the grain by 2–3%, crude gluten – by 4–5%.

According to [16], the protein content should be at the level of 11.0–17.0%. If the protein content increases more than 17.0–19.0% or decreases by less than 11.0%, bread quality deteriorates [19, 22].



(a)



(b)

Fig. 8. Dependence of protein (a) and gluten (b) content in grain on soil fertility indicators.

In our experiments (on average over three years) the content of protein and gluten in the grain was not high (<13.5% and <28.0%, respectively), which is probably associated with precipitation during the grain-filling period. According to these indicators, grain belongs to the third class in accordance with the requirements of GOST 9353-2016.

According to [8, 22], edaphoclimatic conditions significantly affect the protein content of winter wheat grain. Temperature and moisture from heading to yellowing periods have the greatest influence on gluten content [11]. According to the obtained data, in 2017 grain filling was observed in hot, dry weather, so the content of protein and gluten in the grain in all test variants was higher than in 2016 and 2018.

The impact of mineral fertilizers on winter wheat grain quality was found to depend on weather conditions during the years of study. In 2016 the content of protein, gluten and grain unit at the control sample was less, and the efficiency of mineral fertilizers was higher compared to 2017 and 2018. A similar dependence was revealed on the yield of winter wheat. At the same time, high positive relationship (r = 0.93) was established between the protein content in winter wheat grain and its yield (Figure 9).

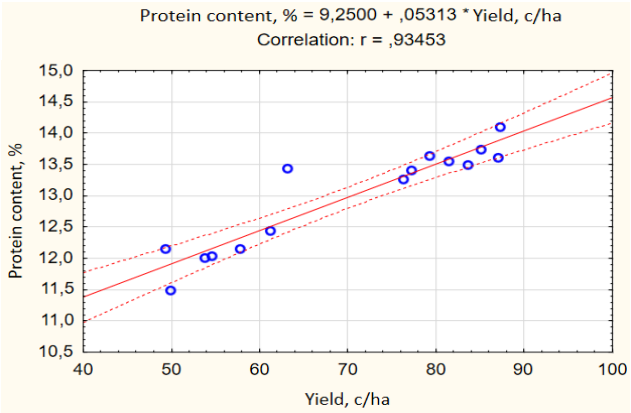


Fig. 9. Dependence of protein content in grain on winter wheat yield.

The protein content of wheat grain is significantly correlated with the accumulation of nitrogen in plants. In order to obtain stable high-quality winter wheat yields in the studied area, the nitrogen content in the top of plants in the booting phase should be at least 3.0% [2]. Protein content in winter wheat grain depends not only on the degree of nitrogen deficiency, but also on its correlation with manganese, phosphorus and iron. Earlier it was proved [21] that the use of No-Till technology stabilizes the nitrogen state of the soil of winter wheat agrocenoses. Therefore, with an average supply of soil with phosphorus and manganese against the background of double dressing with ammonium nitrate in the first half of the vegetation, the intensity of nitrogen absorption by plants was quite high. This contributed not only to the increase in protein content of winter wheat grain, but also in its yield. The obtained data are confirmed by studies conducted in various edaphoclimatic conditions [14]. It was shown that in a certain range of doses of nitrogen fertilizers, the correlation coefficients of grain yield – protein content, are usually significantly positive. The increase of the dose of N-fertilizer above a certain value can lead to the reduction in yields.

5 Conclusion

In conditions of insufficient humidification, the rational use of mineral fertilizers in ordinary calcareous chernozems when cultivating winter wheat using zero technology increases the quality of winter wheat For the studied variety of winter wheat (Grom), the most effective joint application of ammophos (N12P52) and potassium magnesia (K32Mg12S20) before sowing to a depth of 10 cm with double dressing with ammonium nitrate in the tillering (N30) and booting (N70) phases. A significant effect of potassium magnesia on the content of protein, gluten and grain unit was revealed, which indicates the need to use mineral fertilizers containing sulfur and magnesium when cultivating winter wheat. The grain obtained in the test sample corresponds to class 3. To improve the quality of winter wheat grain calcareous soils, it is necessary to optimize the mineral nutrition of the culture not only with macro-, but also with microelements.

Acknowledgments

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