Influence of feeding by nitrogen mineral and integrated organomineral fertilizers on the yield and quality of hard wheat

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Abstract. The problem of nutrition of the world's population has become even more acute and complex, due to the increase in the population. In solving this problem, a special role belongs to cereals and winter durum wheat in particular. The soil and climate conditions of the Crimea are quite favourable for growing this crop. The purpose of the research is to study the mutual influence of fertilizing with nitrogen fertilizers in the form of ammonium nitrate and complex organomineral fertilizers on the yield and quality of durum wheat. Field experiments were conducted in 2016-2018 in the Foothill-steppe zone of Crimea. It was found that the highest yield of winter durum wheat (52.3 C / ha) with a gluten content of 28.70% and protein of 15.56% is formed when n 60+60 is applied. The most effective complex organomineral fertilizers are Aminokat, Microkart, Atlante, foliar treatment of which contributes to the production of grain yield of 38.65-39.85 C / ha with high-quality indicators: gluten content 22.85-25.12%, protein content 12.52-13.20%.

1. Introduction
Durum wheat (Triticum durum) takes the second place in the world after soft wheat in cultivated areas and is a valuable food crop, and its grain is an indispensable raw material in the production of pasta [1]. All over the world there is a tendency to increase consumption of durum wheat products. Pasta, bread and all other cereal products are the main group of healthy, balanced and nutritious foods.

The soil and climatic conditions of the Crimean Peninsula are quite favorable for the realization of the genetic potential of hard winter wheat varieties [2]. In Crimea, fertile soils and high heat supply of the vegetation period are well combined with relatively mild winters. Such natural conditions contribute to a good wintering of plants and the formation of grain with high proteinity and vitreousness. According to the calculations of A.V. Ryumshin, in the structure of sown areas, hard winter wheat in the Crimea can occupy 80–100 thousand ha, when placed in clean and occupied fallows. However, at present, only some Crimean farms cultivate durum wheat, and the Crimean pasta factory produces about 20 products exclusively on raw materials from soft wheat varieties [3]. Such products are significantly inferior in quality to those of durum wheat: they have a gray color, boil and stick together during cooking, forming a lot of sediment.
Currently, in connection with the entry of the Republic of Crimea into the legal field of Russia, the study of new varieties of durum winter wheat for the peninsula, included in the State Register of Selection Achievements Allowed for Growing in the VI (North Caucasus) Region, is an urgent and sought-after production. Of great practical importance is the ability of Triticum durum to enhance the accumulation of protein in grain under the influence of nitrogen fertilizers [4 p. 87]. It has been established that, at the same doses of nitrogen, durum wheat usually produces higher quality grain than soft wheat. It follows that to obtain a certain protein content, durum wheat will require less nitrogen fertilizer than soft wheat.

The use of organic fertilizers is another way of managing the plant, with the aim of influencing the yield and quality of the resulting product [5-6]. The latest such studies on winter soft wheat in Crimea were conducted in 2016–2018. [7]. In the experiments of Remeslo E.V. it has been convincingly shown that the use of organic fertilizers—Atlante, Mikrokat zernovoy, and Aminokat—contributed to an increase in grain yield of 0.23–0.33 t/ha (4.6–6.6%) compared to control due to an increase in the number of grains in the head by 7.7–9.9% and the weight of grains by 14.0–16.8%, and the content of protein and gluten by 5.5 and 1.6%.

The root system of winter durum wheat, although it branches well and penetrates deeply into the soil, has a low assimilative ability and poorly uses nutrients from the soil. Therefore, winter wheat is responsive to the application of organic and mineral fertilizers both directly into the soil and through foliar treatments [8].

High-quality durum wheat grain should have a number of positive characteristics [9–11], most often they include protein and gluten content, vitreousness, nature, ash content, sometimes they pay attention to the amount of yellow pigments (carotenoids), the quality parameters of semolina and low lipoxidase content.

Procurers of durum wheat food grains in Russia evaluate its quality in accordance with GOST R 52554-2006 [12], which divides wheat grain into classes according to such indicators as natural mass, vitreousness, protein, gluten content and quality.

The aim of our research was to study the mutual influence of fertilizing with nitrogen fertilizers in the form of ammonium nitrate and complex organic mineral fertilizers on the yield and quality of durum wheat in the Crimea.

2. Materials and research methods

Field studies were conducted in 2016–2018 in the foothill-steppe zone of Crimea on the experimental field of the Academy of Bioresources and Nature Management “V.I. Vernadsky Crimean Federal University” using the generally accepted technology for the cultivation of winter durum wheat with the bastard fallow predecessor (vetch-oat mixture). The experiments were laid in 4-fold repetition with a randomized arrangement of plots with an area of 72 m². The seeding rate of winter durum wheat in the experiment was 5 million/ha.

The subject of research was Amazon durum wheat variety.

The soils of the experimental site were represented by southern micellar-carbonate weakly humus chernozem on quaternary yellow-brown loesslike light clays. The content in the arable layer of nitrate nitrogen was 29.5 mg/dm³ (according to the Grandval-Lyazh method, GOST 26488–91), the content of labile forms of phosphorus was 1.45 mg/dm³, the content of exchange potassium was 22.5 mg/dm³ (according to Machigin method modified by TsINAO, 26205–91). The humus content in the arable layer (according to Tyurin) is 2.11%.

The climate of the research area is characterized as arid, moderately hot, with relatively mild winters with short-term severe cooling and with inconsistent snow cover. The hydrothermal coefficient is 0.7.

Agrometeorological conditions for temperature and humidity in years 2016 and 2017 were favorable for the germination and vegetation of winter durum wheat. The cessation of autumn winter vegetation was noted on December 11 in 2015 and on November 18 in 2016. The weather conditions
of the vegetation period 2017–2018 were, on the contrary, unfavorable in the second half of the growing season due to atmospheric drought against the background of abnormal heat. The air temperature in March and April exceeded the annual average by 1.9–6.6 °C, and the absence of precipitation and a decrease in relative air humidity of 20–30% led to inhibition of wheat plants.

The hydrothermal coefficient in the vegetation period of 2016 amounted to 1.20; in 2017 it was 1.14 and 0.84 in 2018.

Nitrogen fertilizer (ammonium nitrate) was introduced in the fall under pre-sowing cultivation and in early spring on frozen soil in equal doses of the active substance: N0+0 (control), N20+20, N40+40, N60+60.

Foliar treatment of plants was carried out at the shooting stage and the beginning of head formation of winter durum wheat with complex organomineral fertilizers Nutrivant+, Atlanta, Mikrokat and Aminokat using a backpack sprayer using recommended doses (3 kg/ha of Nutrivant, 1 l/ha of Atlanta, Aminokat and Mikrokat) [13]. The consumption of the working solution was 300 l/ha. The variant with spraying with water served as the control.

During the vegetation of plants, the necessary counts and observations were carried out according to the methodology of the State Committee for the Testing of New Varieties of Agricultural Plants [14]. Statistical processing of experimental data was carried out by the dispersion method [15].

3. Results and its discussion

The minimum wheat grain yield in the experiment was obtained in 2018 without the use of fertilizers and preparations (control) and amounted to 11.4 c/ha, and the maximum yield was in 2016 for the variant with the addition of N60+60 and treatment with 62.9 c/ha of Aminokat (Table 1).

Table 1. The effect of nitrogen fertilizers and complex organic-mineral fertilizers on the yield of winter durum wheat, c/ha

| Nitrogen Nutrition Level (Factor A) | Foliar treatment (Factor B) | Year (Factor C) | Average |
|------------------------------------|-----------------------------|-----------------|--------|
|                                    |                             | 2016   | 2017   | 2018   | Factor A | Factor B |
| N0                                 | Control                     | 18.7   | 17.9   | 11.4   | 28.37    |          |
|                                    | Nutrivant+                  | 22.8   | 21.3   | 15.6   | 35.85    |          |
|                                    | Atlanta                     | 21.7   | 20.4   | 14.6   | 18.48    | 38.65    |
|                                    | Mikrokat                    | 21.5   | 20.1   | 12.7   | 38.60    |          |
|                                    | Aminokat                    | 22.9   | 21.6   | 14.0   | 39.85    |          |
|                                    | Control                      | 24.7   | 23.1   | 18.2   |          |          |
|                                    | Nutrivant+                  | 32.6   | 30.8   | 23.0   |          |          |
| N20+20                             | Atlante                      | 36.2   | 34.5   | 29.2   | 29.80    |          |
|                                    | Mikrokat                    | 34.3   | 32.7   | 23.3   |          |          |
|                                    | Aminokat                    | 40.7   | 35.4   | 28.3   |          |          |
|                                    | Control                      | 32.9   | 31.5   | 26.5   |          |          |
|                                    | Nutrivant+                  | 48.3   | 45.8   | 39.4   |          |          |
| N40+40                             | Atlante                      | 52.4   | 50.6   | 40.7   | 44.48    |          |
|                                    | Mikrokat                    | 54.6   | 52.9   | 44.3   |          |          |
|                                    | Aminokat                    | 53.2   | 51.9   | 42.2   |          |          |
|                                    | Control                      | 51.8   | 49.6   | 34.2   |          |          |
|                                    | Nutrivant+                  | 53.6   | 52.3   | 44.7   |          |          |
| N60+60                             | Atlante                      | 58.1   | 55.9   | 49.5   |          | 52.30    |
|                                    | Mikrokat                    | 62.1   | 59.7   | 45.0   |          |          |
|                                    | Aminokat                    | 62.9   | 61.7   | 43.4   |          |          |
|                                    | Average C                    | 53.73  | 51.31  | 40.01  |          |          |

Note: LSD05 factor A = 2.52 c/ha; LSD05 factor B = 1.61 c/ha;
LSD$_{05}$ factor C = 0.80 c/ha; LSD$_{05}$ interaction AB = 4.10 c/ha; LSD$_{05}$ interaction AS = 1.69 c/ha; LSD$_{05}$ interaction of the aircraft = 2.71 c/ha; LSD$_{05}$ interaction ABC = 4.83 c/ha.

Of the controlled factors affecting crop yields, the most significant was the level of nitrogen nutrition (factor A); the share of influence was 48.6% than the treatment with drugs (factor B) was 2.1%. The interaction of these factors (AB) accounts for 19.7%. The dependence of the grain yield of winter durum wheat on the weather conditions of the year (factor C) was 6.6%. The share of the influence of the studied agricultural practices and conditions of the year (triple interaction of factors) amounted to 7.8%, the level of nitrogen nutrition and conditions of the year (AS) was 8.7%, drug treatment and weather conditions (BC) reached 6.5%.

Thus, the direct action of factor A (fertilizing with nitrogen fertilizers) and the interaction of agricultural practices, i.e. factors AB had a greater share of influence than the conditions of the year, and this influence, being reliable, had a huge impact on the formation of significant increases between the tested experimental variants, and indicates the need for nitrogen fertilizer regardless of the conditions of the year.

Yield quality is an integral indicator reflecting the impact of a complex of factors on the intake, assimilation and metabolism of nutrients in specific soil and climatic conditions. In our experiment, when determining the dependence of the gluten content on the applied agrotechnical methods, it was found that the level of nitrogen nutrition (factor A) was also the most significant: its influence amounted to 58.0%. The share of factor B was insignificant (only 0.2%), that of factor C was 13.2%.

The data in Table 2 clearly show a significant increase in gluten content depending on the dose of ammonium nitrate: while in the control variant the average value was 17.82%, a gradual increase in the dose of fertilizers led to an improvement in grain quality, and the highest rate was recorded for variant N$_{60+60}$ (28.7% which is 10.88% higher than for the control variant).

The gluten content after the application of organic fertilizers significantly increased according to the options with the agents Atlante, Mikrokarts and Aminokat.

**Table 2.** Effect of nitrogen fertilizers and complex organic fertilizers on gluten content in winter durum wheat grain, %

| Nitrogen Nutrition Level (Factor A) | Foliar treatment (Factor B) | Year (Factor C) | Average |
|-----------------------------------|-----------------------------|----------------|---------|
|                                   |                             | 2016  | 2017  | 2018  | Factor A | Factor B |
| N$_0$                            | Control                     | 17.9  | 16.7  | 14.3  | 17.82    | 21.07    |
|                                  | Nutrivant+                  | 18.7  | 18.9  | 16.7  | 22.52    | 25.52    |
|                                  | Atlante                     | 18.4  | 17.9  | 16.2  | 22.85    | 25.85    |
|                                  | Mikrokart                   | 19.1  | 18.9  | 17.5  | 24.27    | 27.27    |
|                                  | Aminokat                    | 19.6  | 19.3  | 17.2  | 25.12    | 28.12    |
| N$_{20+20}$                      | Control                     | 19.1  | 18.9  | 17.2  | 20.20    |          |
|                                  | Nutrivant+                  | 20.1  | 19.7  | 18.4  |          |          |
|                                  | Atlante                     | 20.3  | 20.1  | 19.3  |          |          |
|                                  | Mikrokart                   | 21.9  | 21.6  | 20.7  |          |          |
|                                  | Aminokat                    | 22.6  | 22.1  | 21    |          |          |
| N$_{40+40}$                      | Control                     | 23.1  | 23.4  | 21    | 25.93    |          |
|                                  | Nutrivant+                  | 25.2  | 24.8  | 23.2  |          |          |
|                                  | Atlante                     | 26.4  | 26.1  | 24.3  |          |          |
|                                  | Mikrokart                   | 28.3  | 28.5  | 25.7  |          |          |
|                                  | Aminokat                    | 30.7  | 30.4  | 28.3  |          |          |
| N$_{60+60}$                      | Control                     | 28.9  | 28.6  | 23.8  | 28.70    |          |
|                                  | Nutrivant+                  | 29.3  | 29.6  | 25.7  |          |          |
|                                  | Atlante                     | 29.4  | 29.1  | 26.7  |          |          |
|                                  | Mikrokart                   | 30.5  | 29.9  | 28.7  |          |          |
|                                  | Aminokat                    | 31.3  | 30.7  | 28.3  |          |          |
With the introduction of nitrogen fertilizers, the protein content in the grain of winter durum wheat was also expected to increase (Table 3). Its greatest amount was noted in the variant with the introduction of 15.56% of \( N_{60+60} \), which is 4.8% higher than in the control. The share of the influence of factor A in this case was 79.2%, that of factor B was 1.3% and that of factor C was 16.1%.

It should be noted that a significant increase in protein during foliar treatment of plants with complex organomineral fertilizers was only in the variant with the Aminokat preparation (13.20% which is 0.73% higher than the control).

### Table 3. Effect of nitrogen fertilizers and complex organic fertilizers on the protein content in winter durum wheat grain, %

| Nitrogen Nutrition Level (Factor A) | Foliar treatment (Factor B) | Year (Factor C) | Average C |
|------------------------------------|-----------------------------|----------------|-----------|
|                                    |                             | 2016 | 2017 | 2018 | Factor A | Factor B |
| Control                            |                             | 10.9 | 10.7 | 9.6 | 24.04    |          |
| Nutrivant+                         |                             | 11.5 | 11   | 10.2 | 23.76    |          |
| Atlante                            |                             | 11.3 | 10.9 | 9.3 | 21.71    |          |
| Mikrokat                           |                             | 11.7 | 11.2 | 9.8 |          | 24.04    |
| Aminokat                           |                             | 11.9 | 11.6 | 9.8 |          | 23.76    |
| Control                            |                             | 11.3 | 11.6 | 9.2 |          | 21.71    |
| Nutrivant+                         |                             | 11.8 | 11.2 | 9.7 |          |          |
| Atlante                            |                             | 11.4 | 11.1 | 9.6 | 24.04    |
| Mikrokat                           |                             | 11.6 | 10.9 | 10.2 |          |
| Aminokat                           |                             | 12.1 | 11.8 | 10.9 |          |
| Control                            |                             | 14.1 | 13.9 | 12.5 |          |
| Nutrivant+                         |                             | 14.7 | 14.4 | 12.9 |          |
| Atlante                            |                             | 14.5 | 14.8 | 11.8 | 24.04    |
| Mikrokat                           |                             | 14.3 | 14.1 | 13.3 |          |
| Aminokat                           |                             | 14.7 | 14.2 | 13.1 |          |
| Control                            |                             | 16.2 | 15.8 | 13.9 |          |
| Nutrivant+                         |                             | 16.5 | 16.2 | 14.4 |          |
| Atlante                            |                             | 16.7 | 16.5 | 12.4 | 24.04    |
| Mikrokat                           |                             | 16.9 | 16.3 | 13.3 |          |
| Aminokat                           |                             | 17.2 | 16.9 | 14.2 |          |
| Average C                          |                             | 13.56| 13.25| 11.5 |          |

### 4. Conclusions

In the conditions of the Piedmont-steppe zone of Crimea, a high dependence of the grain yield and its quality—the gluten and protein content—on the level of nitrogen nutrition of winter durum wheat plants was established. The share of this factor in this case was 48.6%, 58.0% and 72.9%, respectively.
On average for 2016–2018 the optimal dose of nitrogen fertilizers is N\textsubscript{90-60}, at which the highest yield of 52.3 c/ha (increase of 33.82 c/ha) with a gluten content of 28.70% and protein content of 15.56% is formed.

The use of Aminokat, Mikrokart, Atlante preparations for foliar treatment of plants is recommended, which allows to obtain grain yields in the range of 38.65–39.85 c/ha with high grain quality indicators (22.85–25.12% of gluten, 12.52–13.20% of protein).

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