Winter wheat varieties responsiveness to soil and foliar fertilization

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Abstract. Common winter wheat (Triticum aestivum L.) makes up more than half of the cereals grown in the European Union and in Bulgaria. For two years (2021-2022) a field experiment was carried out at the experimental plain of the Department of Plant Production at the Technical University of Varna. Two varieties of winter common wheat were grown, a selection of the Dobrudja Agricultural Institute - General Toshevo. The trial pattern included a variant without fertilization (control - Fert 0), a variant with combined foliar feeding and soil fertilization (Fert SF) and a variant with soil fertilization alone (Fert S). The effect of the way of fertilizing on the productivity and quality of winter common wheat was investigated. Grain yield (GY) and its structural elements - spike length (LMS), number of grains per spike (NGS) and grain weight per spike (WGS), weight per 1000 grains (TGW) and hectoliter weight (TestW) were determined. Biochemical analysis of the wheat grain was performed and the content of protein (Pr), starch (St) and ash substances (Ash) was determined. Fertilization has a strong effect on productivity and grain quality in winter common wheat (both alone and in combination with growing conditions). The method of fertilization has an effect on the productivity of winter common wheat - feeding with foliar fertilizers during the spring vegetation (in the tillering and booting phases) increases grain yield as a result of increasing each of the productivity components. The method of fertilization does not have a significant impact on the quality indicators of winter common wheat, with the exception of the hectoliter mass, whose values are proven to be higher during soil nutrition. The two studied Bulgarian varieties, Sladuna and Nikodim, differ from each other in their efficiency in relation to the way of feeding in the spring.

1 Introduction

It is estimated that by 2050 the world population will reach about 9 billion, requiring up to 70% more food (Jiang et al, 2023).

Common winter wheat (Triticum aestivum L.) occupies a major place in the cereal group. Global consumption of cereals in 2023-2024 is expected to reach 2,823 million tons

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– an increase of 1.1% from the previous year, which is mainly due to increased consumption of maize and wheat for food [28, 3, 10]. Increasing the productivity and quality potential of winter common wheat is a major task in its cultivation technology. Fertilization, as an element of wheat agrotechnics, is a powerful factor in reaching its genetic potential. Optimizing mineral nutrition is the main prerequisite for high and stable yields. Nitrogen deficiency is one of the main factors affecting the yield and quality of wheat. The application of mineral fertilization increases the productivity of agricultural crops, but it is also associated with some disadvantages - a lower coefficient of use of fertilizers, acidification or salinization of the soil, etc. [19, 23, 18, 5, 11].

In agriculture, as an agrotechnical measure, foliar fertilization is applied as foliar feeding of agricultural crops. Foliar fertilizers fall directly on the leaf mass and have some advantages: improved absorption and utilization of nutrients, rapid correction of nutrient deficiency, complete and targeted satisfaction of plant nutritional needs, less loss. [6, 8, 15]. The nutrients applied to the leaves improve the uptake of nutrients from the soil, because they are absorbed faster, with lower energy consumption and directly initiate the corresponding exchange processes in the plants. All nutrients can enter through the leaves, but foliar feeding cannot replace soil fertilization. It is its complement [9, 10, 20].

The aim of the study was to investigate the impact of different fertilization methods on the productivity and quality of winter common wheat; to determine the agronomic efficiency of the grain yield in the wheat varieties studied.

2 Material and methods

The research was conducted during the period 2021-2022 at the educational and experimental field of the Department of Plant Production at the Technical University of Varna. The experiment was carried out in three replications with the size of the experimental area of 12 m2 and the sowing rate of 600 germinated seeds /m2. During the years of the research, the varieties were sown in the optimal agrotechnical term for the region. Two varieties of common winter wheat were grown - Sladuna and Nikodim, a selection of the Dobrudja Agricultural Institute - General Toshevo. The treatment of the area consists of a double disking after the predecessor sunflower. The following fertilizing variants were studied:

- Variant 1 (Fert 0) – control variant without fertilization
- Variant 2 (Fert SF) (Soil+Foliar) – variant with pre-sowing soil fertilization and two-time foliar feeding during spring vegetation – soil and foliar fertilization applied
- Variant 3 (Fert S) (Soil) – variant with pre-sowing and two-time soil feeding during the spring vegetation – only soil fertilization was applied

Ammonium nitrate with 34.4% nitrogen content was used for soil fertilization, and Burall foliar fertilizers (NPK (5.5 3.5 5.0) 4.7 SO3) were used for foliar feeding. Feeding during the spring vegetation was carried out by tillering (Z25-29) and booting (Z31-39) phases [25].

The formed yield of grain in kg/da (GY) and its structural elements were determined - length of spike in cm (LMS), number of grains in spike (NGS) and weight of grain in spike in g (WGS), weight of 1000 grains in g (TGW), hectoliter mass in kg (TestW). A biochemical analysis of the wheat grain was carried out in the Agroecological Laboratory of the Technical University - Varna and the percentage content of protein (Pr), starch (St) and ash substances (Ash) was determined. For this purpose, a NIR analyzer was used (Model: DA7200 NIR, Manufacturer: Perten Instruments AB, Sweden).

The agronomic efficiency (AE) of grain yield was calculated as a ratio: AE = (GYt – GY0) / Fert, where: GYt – grain yield from the fertilized treatment (kg/da); GY0 – grain

yield from the non-fertilized variant (kg/da); Fert – nitrogen fertilizer rate (kg/da); Statistical processing of the data was carried out using SPSS 19 software and Microsoft Excel.

3 Results and discussion

Climate affects the growth and development of crops differently during different stages of growth. Rainfall and temperature are important climatic factors that determine the growth, development and yield of crops. Precipitation during the growing season is the dominant and favorable factor for wheat yields [13, 24].

During the study period, rainfall totals for the entire growing season were 645.25 l/m² for 2020-2021 and 525 l/m² for 2021-2022 (Figure 1). The greatest influence on the development of wheat is exerted by the precipitation that has fallen after its germination and during the twining phase. Spring, when wheat plants are in the spindle phase, is the most critical period for the formation of grain yield. The sum of the rainfall for the period from October to March forms the moisture reserve in the soil. This amount was higher by 55.25 l/m² in the first year of the study (386.25 l/m²) than the amount for the second year studied (331 l/m²). This has helped plant development at the start of the spring growing season. During the spring vegetation, when wheat is in the spindle phase (month of April), the rainfall was 58.25 l/m² for 2021 and 81.75 l/m² for 2022. These conditions were favorable for the formation of productivity.

Regarding the temperature regime at the beginning of the growing season in the autumn-winter months, the second year is characterized by lower temperatures. The difference in the value recorded in the month of December is particularly large: the positive 5.90 C in 2020 and the negative -0.70 C in 2021. In the spring period, the month of April is warmer by 3.20 C in 2022, i.e. warming started earlier. The measured temperature values also differ in the month of July, when the wheat is harvested: 27.20C in the first year 2021 and 23.90C in the second year 2022.

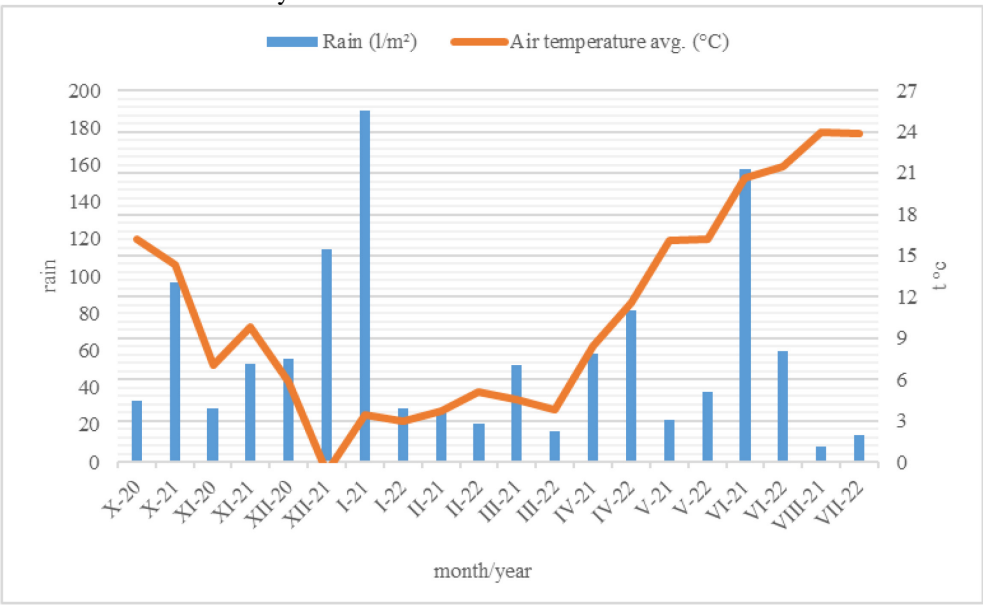

Fig. 1. Weather conditions during the study period

Wheat yield varies over the years due to the influence of management practices and climatic conditions. Increases in wheat productivity are achieved by technological improvements, such as the introduction of new varieties and increased nitrogen application and other management variants [2, 27].

Fertilization is one of the basic agrotechnical field management practices, it can increase yields [26]. Good fertilization practices such as different ways of application, timing and rates are important to increase the productivity of wheat [13]. Nitrogen management plays an important role in improving the yield and quality of winter wheat [4].

The performed statistical analysis determines the separate action of the investigated factors and their interaction for some of the signs (Table 1). The year (A) and fertilization (B) have the strongest influence on the formation of grain yield. Fertilization is a factor that significantly affects the signs except for ash content. The effect of this factor is complicated by interaction with the conditions of the year in a predominant part of the signs. The mass of 1000 grains is a varietal trait and the genotype itself has the strongest effect on it. The conditions of the year most significantly affect the hectoliter mass and the content of ash substances.

Table 1. Anova (significance) of investigated factors for all the traits

	A	**B**	**C**	**AxB**	**AxC**	**BxC**	**AxBxC**
GY	0.001	0.009	0.808	0.309	0.303	0.398	0.327
LMS	0.002	0.011	0.006	0.025	0.111	0.006	0.002
NGS	0.017	0.000	0.001	0.000	0.004	0.028	0.044
WGS	0.077	0.007	0.155	0.088	0.369	0.020	0.000
TGW	0.000	0.014	0.000	0.364	0.000	0.050	0.085
TesW	0.000	0.000	0.000	0.000	0.015	0.500	0.354
Pr	0.000	0.000	0.000	0.000	0.000	0.000	0.000
St	0.000	0.012	0.000	0.000	0.000	0.000	0.013
Ash	0.001	0.340	0.098	0.810	0.388	0.027	0.811

A-Year, B-Fertilization, C-Variety

The values of spike length (LMS), number of grains in spike (NGS), protein (Pr) and starch (St) content were reliably affected by the interaction of all combinations of main factors. Varietal characteristics in combination with fertilization are decisive for all the studied signs.

According to the different fertilization nutrition, the studied indicators showed distinctly different values (Table 2). Quite naturally, in the variants where the wheat is not fertilized (Fert 0), the values of the studied indicators are the lowest. In the fertilizer variants, where foliar feeding of the wheat was carried out (Fert SF), the values of the studied indicators were the highest. The most distinct are the differences in the indicators of hectoliter mass (TestW) and number of grains in spike (NGS).

The protein content is an index that determines the quality of the grain. Wheat grain protein content and yield structural elements are the result of the influence of genetic factors and environmental factors [2, 7, 22, 1]. The application of foliar fertilizers containing nitrogen is an effective way to increase the protein content and quality of wheat grains [14, 21]. Application of fertilization, whether soil or foliar, increased grain protein content in this field experiment as well.

Foliar nutrition of wheat during the spring vegetation (in the bracing and spindle phases) improves its yield and quality as opposed to independent soil nutrition with ammonium nitrate.

Table 2. Means and differences of the indexes according to fertilization.

Fertilization Indexes	Fert 0	Fert SF	Fert S
GY	581.524 a	759.216 b	628.378 a
LMS	9.38 ab	9.71 b	9.09 a
NGS	47 b	52 c	44 a
WGS	2.106 b	2.190 b	1.935 a
TGW	37.31 a	39.04 b	37.90 a
TestW	77.97 a	79.59 b	80.35 c
Pr	11.89 a	13.17 b	13.22 b
St	65.76 a	66.25 b	66.52 b
Ash	1.697 a	1.716 a	1.728 a

The same letter shows not significant difference between the values by columns

The use of efficiency indicators makes it possible to evaluate not only the agronomic and economic efficiency, but also the use of the elements introduced with the fertilizers and the expected changes in the soil stock [17]. Agronomic efficiency reflects the responsiveness of agricultural crops to applied fertilizers and indicates the actual uptake of nutrients [12, 16]. This indicator characterizes the ability of plants to increase yield as a result of fertilization and for wheat it depends to the greatest extent on nitrogen fertilization and climatic conditions [5]. In the present study, the additional grain yield per kilogram of fertilizer nitrogen varied significantly depending on the method of fertilization (Figure 2). Higher values of agronomic efficiency (AE) in both investigated wheat varieties were obtained when foliar fertilization was applied as top dressing during the spring vegetation. Under these conditions, the AE of the Sladuna variety is 11 kg grain/kg N, while that of Nikodim is 21 kg grain/kg N. Regardless of the method of fertilization (foliar or soil), the Nikodim variety increases its productivity compared to the variant without fertilization. The Sladuna variety, however, shows greater responsiveness to the application of foliar fertilization, compared to the variant of only soil fertilization.

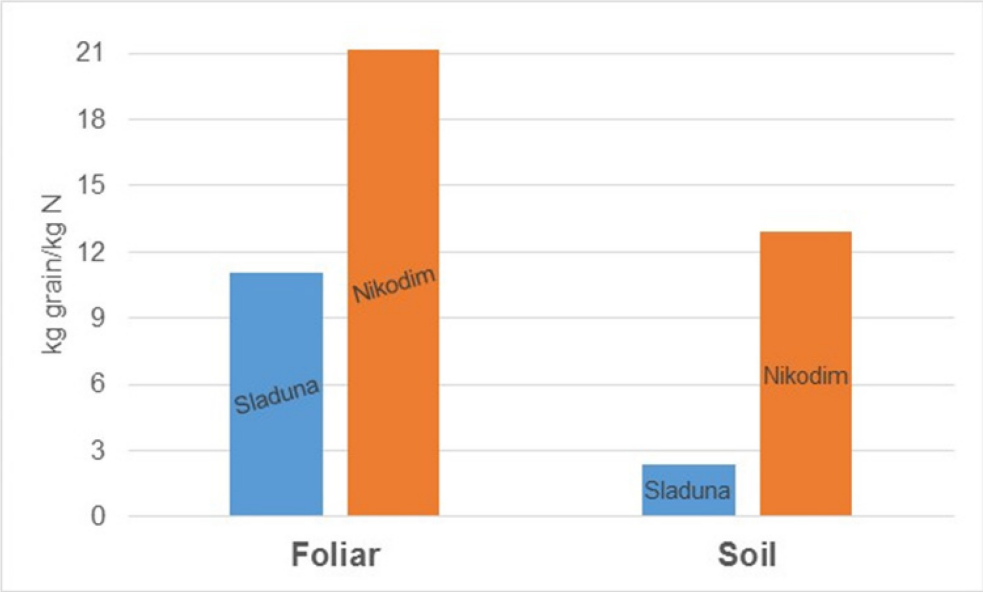

Fig. 2. Agronomic efficiency (AE) of varieties for in terms of grain yield

4 Conclusion

Fertilization has a strong effect on productivity and grain quality in winter common wheat (both alone and in combination with growing conditions).

The method of fertilization has an effect on the productivity of winter common wheat - feeding with foliar fertilizers during the spring vegetation (in the tillering and booting phases) increases grain yield as a result of increasing each of the productivity components.

The method of fertilization does not have a significant impact on the quality indicators of winter common wheat, with the exception of the hectoliter mass, whose values are proven to be higher during soil nutrition.

The two studied Bulgarian varieties of winter common wheat, Sladuna and Nikodim, differ from each other in their efficiency in relation to the way of feeding in the spring.

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