INFLUENCE OF SOME AGROTECHNICAL FACTORS ON THE PRODUCTIVITY AND QUALITY OF WINTER COMMON WHEAT (*TRITICUM AESTIVUM* L.) IN THE VARNA REGION

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Abstract

For three years (2021-2023) winter common wheat was grown at the educational and experimental field of the Department of Plant Production at the Technical University – Varna. The experiment was carried out by the split plot method with the size of the experimental area of 10 m^2 in two replicates with a seeding rate of 600 germinating seeds/m^2. Three levels of nutrition were included in the study: variants without fertilization (To), variants with soil and foliar fertilization (Tls) and variants with only soil fertilization (Ts). Soil fertilization was carried out with ammonium nitrate, and foliar feeding was carried out twice during the spring vegetation of wheat in the booting and heading phases. Grain yield (Yields), weight per 1000 grains (TGW) and some structural elements of yield were determined. Some quality indicators were also studied: moisture, protein, starch and ash content. Under the conditions of a short-term monoculture (for a period of three years), the independent effect of the conditions of the year is most strongly expressed on the formation of the grain yield, and the applied fertilization has the greatest influence on the protein content of the wheat grain. The combination of weather conditions in the first two years of the study was more favorable and wheat formed a higher productivity. The lower amounts of precipitation, their uneven distribution and higher temperatures during the growing season of the third studied year led to a decrease in the formed yield of grain. The combined application of soil fertilization and foliar feeding during the spring vegetation is most favorable for the formation of maximum productivity and high protein content in wheat.

Key words: ***year, fertilization, wheat, yields, protein***

INTRODUCTION

Wheat is one of the most ancient and widely cultivated cereals. It has a key role in feeding the world's population and constitutes about 20% of the total amount of calories and proteins of food worldwide ((Shiferaw et al., 2013). In the last five years (2019/2020 – 2023/24) the areas, on which it is grown in the European Union averages about 24 million hectares. The average production is about 135 million tons and the average yield is 5.5 tons per hectare (USDA).

In Bulgaria in 2023, the harvested areas with wheat are about 1221 thousand hectares, the production is about 6624 thousand tons and a reported average yield of 5.4 tons per hectare (Agrostatistics).

The productivity and quality of wheat are formed under the influence of applied agricultural techniques and environmental conditions. Fertilization is an essential and dynamic part of its cultivation that can be influenced while the conditions of the year are uncontrollable but predictable. The effectiveness of applied fertilization is closely related to seasonal conditions and affects, both alone and in interaction, the formation of yield and grain protein content (Blandino et al., 2020; Nsafon et al., 2020; Hu et al., 2021; Wu et al., 2022; Giordano et al., 2023; Zhang et al., 2023; Alaru et al., 2024).

A large part of research worldwide is aimed at determining optimal fertilizer rates under specific conditions of the region in order to achieve maximum productivity of wheat. Coordinating fertilization with forecasted rainfall is a challenge for modern agriculture (Cao et al., 2017; Manschadi & Soltani, 2021; Wang et al., 2023; Burton et al., 2024; Li et al., 2024). Current agriculture is developing in a changing climate, characterized by rising temperatures and frequent occurrence of extreme weather conditions such as droughts or floods (Lecerf et al., 2019; Le Gouis et al., 2020; Giordano et al., 2024; Nandan et al., 2024).

The purpose of the present research is to study the influence of the conditions of the year and the applied fertilization on the formation of the yield and some quality indicators of winter common wheat in a short-term monoculture grown in the Varna region.

MATERIAL AND METHODS

An experiment was conducted at the educational and experimental field of the Department of Plant Production at the Technical University - Varna. For three years (2021-2023), common winter wheat (*Triticum aestivum* L.) was grown under short-term monoculture conditions. The experiment was carried out using the split plot method with the size of the experimental area of 10 m^2 in two replications with a seeding rate of 600 germinating seeds/m^2. Soil treatment includes milling the area and subsequent shaping of the paths and test plots. In all three years, sowing was carried out at the end of October and harvesting - at the beginning of July. Three levels of nutrition were included in the study: variants without fertilization (To), variants with soil fertilization and foliar fertilization (Tls) and variants with only soil fertilization (Ts). Soil fertilization was carried out with ammonium nitrate (34.4% N) with a fertilizer rate of 12 kg/da (active substance). Foliar fertilization was carried out twice during the spring vegetation of wheat in the booting and heading/flowering phases (Zadoks et al., 1974). The obtained grain yield in t/ha (Yields), weight per of 1000 grains in g (TGW) and some of the structural elements of the yield - length of one spike in cm (LS) and weight of grain in one spike in g (WGS). Some quality indicators in % were also studied: moisture, protein, starch and ash content. Statistical data processing was done using Microsoft Excel and SPSS 19.

RESULTS AND DISCUSSION

The years during which the research was carried out differ in terms of weather conditions: amount and distribution of precipitation (Table 1) and temperature regime (Figure 1). Decisive for the development of wheat are the precipitations in autumn (in the phases of emergence and tillering) and during the spring critical period. The amount of precipitation that fell for the period October-March (X–III) forms the autumn-winter reserve of moisture in the soil. The most favorable in this regard is the autumn of 2020 (the first year), when the weather conditions proved to be the best for the friendly germination and initial development of the plants (99.17 mm above the three-year average value). In the third year (2022), sowing at the end of October was carried out under extremely dry conditions, and plant emergence and crop formation was observed as late as December. The deviation from the calculated average autumn-winter moisture supply is 142.83 mm. These dry conditions sharply set this last year apart from the previous two. During the spring critical period (IV–V), when the plants are in the booting and heading-flowering phases, a low amount of precipitation was recorded in the first year 2021 (23.42 mm less than the calculated average). During this part of the wheat growing season, the amount of precipitation in the second (2022) and third (2023) years is higher. In the month of June, when the grain is milk

development phase, the rainfall in the 2022 and 2023 harvest year are less compared to 2021.

In general, during the growing season of wheat in the studied years, the distribution of precipitation is uneven. Their sum for the autumn-winter months determines 2020-2021. and 2021-2022 as more favorable for the initial development of plants. The drought in the spring critical period of 2021. adversely affected wheat productivity compared to 2022. The third year of the study (2022-2023) is distinguished by the lowest amount of precipitation – 302 mm, which inevitably had an impact on the formation of wheat productivity.

Table 1. Distribution of rainfalls during the investigated period.

Years / Month	Mean 2021 – 2023	2020 – 2021	Deviation
X – III	287,08	386,25	99,17
IV – V	104,42	81,00	-23,42
VI	87,50	157,75	70,25
Veg.period	479,00	625,00	146,00
Years / Month	**Mean 2021 – 2023**	**2021 – 2022**	**Deviation**
X – III	287,08	330,75	43,67
IV – V	104,42	119,50	15,08
VI	87,50	59,75	-27,75
Veg.period	479,00	510,00	31,00
Years / Month	**Mean 2021 – 2023**	**2022 – 2023**	**Deviation**
X – III	287,08	144,25	-142,83
IV – V	104,42	112,75	8,33
VI	87,50	45,00	-42,50
Veg.period	479,00	302,00	-177,00

The years during which the study was conducted also differ in terms of the temperature regime (Figure 1). The average day-night temperatures measured in all three studied years were positive, except for December 2021 (-3.8^{0}C). For the same vegetation period (2021-2022), the lowest temperatures are also in the months of January (2.8^{0}C) and March (3.8^{0}C). It is likely that these typical winter conditions favored the development of wheat in the second year 2021-2022. During the spring growing season (April), the differences are also distinct. The highest temperatures of 11.6^{0}C recorded in 2022 combined with the highest amount of rainfall (81.75 mm) also had a positive impact on plants during this critical spring period.

In general, the average daily air temperature for the entire growing season of wheat in the first year 2020-2021 and the second year 2021-2022 has close values, 9.8^{0}C and 9.4^{0}C, respectively. The third year of the study 2022-2023 stands out as the warmest (11^{0}C).

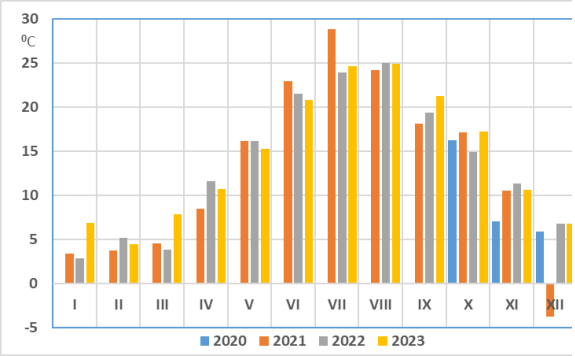

Figure 1. Average midday air temperatures (^{0}C) during the investigated period.

A multifactorial analysis was made to determine the independent and combined impact of the agrotechnical factors, conditions of the year and applied fertilization on the studied indicators (Table 2).

Table 2. Multifactor Analysis of Variance, (type III Sum of Squares).

Traits / Source of variation		Yields	LS	WGS	TGW
Year (A)	F Sig	29,94 **0,000**	1,69 0,238	11,03 **0,004**	0,28 0,763
Fertilization (B)	F Sig	4,78 **0,038**	0,54 0,601	1,69 0,238	0,51 0,619
A x B	F Sig	2,06 0,070	0,89 0,509	1,32 0,334	0,14 0,962
		Moisture	**Protein**	**Starch**	**Ash**
Year (A)	F Sig	16,94 **0,001**	1,45 0,284	3,20 0,089	4,32 **0,048**
Fertilization (B)	F Sig	0,22 0,804	35,72 **0,000**	14,54 **0,002**	4,41 **0,046**
A x B	F Sig	1,21 0,372	10,22 **0,002**	18,08 **0,000**	1,34 0,328

The independent effect of season conditions is most pronounced and statistically proven on the formation of grain yield (Yields), grain weight in one spike (WGS) and moisture content. Fertilization as an independent factor has the greatest influence on the protein content of the wheat grain and the mass of 1000 grains (TGW), although statistically unreliable. The combined interaction of the two factors is most clearly expressed in the accumulation of protein and starch in wheat and, although weaker, in grain yield.

The investigated indicators with their average values depending on the weather conditions of the years and the level of applied fertilization fall into different groups (Table 3). The differences in the obtained average grain yields according to the environmental conditions are most pronounced. They divide this indicator into three statistically proven groups. The conditions during the studied years distributed most of the studied signs into two reliable groups - grain weight in one class (WGS), moisture content, starch and ash substances. Compared to this factor, the differences in spike length (LS), mass of 1000 grains (TGW) and protein content are the smallest. According to the obtained average values of the investigated indicators, the weather conditions in the second year (2021-2022) turned out to be the most favorable for the development of wheat.

The level of applied fertilization divides the investigated indicators mainly into two separate groups. The smallest differences are in spike length (LS) and moisture content. Naturally, the lowest average values were obtained in the variants without application of fertilization (To). The combination of soil fertilization with foliar fertilization (Tls) during the spring vegetation is most favorable for the development of wheat. From the variants with the application of independent soil fertilization (Ts), average values close to the null variants (To) were obtained. Compared to this factor, the differences in the obtained yields and the protein content of the wheat grain are the most distinct.

Table 3. Mean values of the investigated traits.

Traits	Yields	LS	WGS	TGW
		Year		
2020-2021	5,917 b	9.02 a	2,009 b	40,09 a
2021-2022	7,229 c	9.65 a	2,130 b	41,01 a
2022-2023	3,628 a	9.22 a	1,431 a	40,45 a
		Fertilization		
T_O	4,846 a	9.24 a	1,743 a	40,06 a
T_{LS}	6,301 b	9.50 a	2,021 b	41,23 b
T_S	5,628 ab	9.15 a	1,805 a	40,27 a
Traits	**Moisture**	**Protein**	**Starch**	**Ash**
		Year		
2020-2021	13,02 b	12,83 a	66,92 b	1,729ab
2021-2022	12,33 a	13,27 a	66,64ab	1,676 a
2022-2023	12,29 a	12,70 a	65,26 a	1,751 b
		Fertilization		
T_O	12,50 a	11,23 a	68,04 b	1,675 a
T_{LS}	12,59 a	13,97 b	64,26 a	1,751 b
T_S	12,55 a	13,59 b	66,52 b	1,730ab

* Values with the same letter are not differ significantly

The differences between the years of cultivation and the level of fertilization are the reason for obtaining a different grain yield (Figure 2). Its average values for these two factors are compared with the average yield for the experiment (5.591 t/ha). The combination of weather conditions during the first two years of the study was more favorable for the growth and development of the plants, as a result of which they formed a higher productivity. The resulting average yield in 2021 exceeds the average by 5.8%, and in 2022 – with 29.3%. Lower amounts of precipitation, their uneven distribution and higher temperatures during the growing season of the third studied year (2022-2023) have led to a decrease in the formed grain yield by 35.1% below the calculated average. Water scarcity during critical stages of wheat development has resulted in reduced yield under Chinese conditions as well (Noor et al., 2022, 2023). Rising temperatures, water deficit, insufficient nitrogen in the soil and their interactions limit grain yield also under the

conditions of the Mediterranean region (Elia et al., 2018; Cossani & Sadras, 2021).

In the variants where fertilization was not applied, the obtained yields were 13.3% below the average for the experiment. It should be noted that this is a relatively high yield with a value of 4.85 t/ha under conditions of short-term monoculture and natural soil fertility. Foliar feeding during the spring vegetation of wheat, combined with soil fertilization, increased its productivity by 12.7% above the average yield. Independent soil fertilization with a moderate nitrogen fertilizer rate resulted in an increase in yield by about 1% above the experimental average.

Foliar feeding during the spring vegetation of wheat as a supplement to soil fertilization leads to an increase in its productivity and quality (Solanki et al., 2020; Ferrari et al., 2021; Zhang et al., 2022; Bărdaş et al., 2024; Bongiovani et al., 2024).

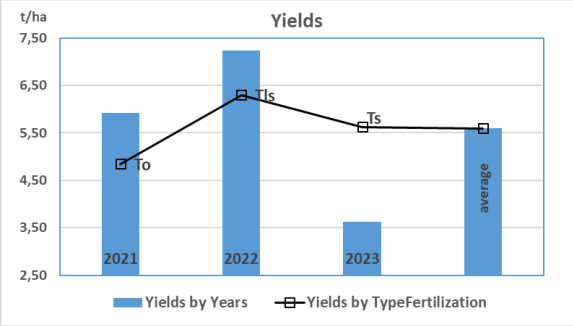

Figure 2. Effect of Year and Fertilization on average grain yield.

CONCLUSIONS

Under the conditions of a short-term monoculture (for a period of three years), the independent effect of the conditions of the year is most strongly expressed on the formation of the grain yield, and the applied fertilization has the greatest influence on the protein content of the wheat grain.

The combination of weather conditions in the first two years of the study was more favorable and wheat formed a higher productivity. The lower amounts of the fallen amounts of precipitation, their uneven distribution and higher temperatures during the vegetation of the third studied year led to a decrease in the formed yield of grain.

The combined application of soil fertilization and foliar feeding during the spring vegetation is most favorable for the formation of maximum productivity and high protein content in wheat.

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