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EXAMINATION OF THE EFFECT OF COMPLEX NUTRIENT SUPPLY ON YIELD AND QUALITY OF WINTER WHEAT

KOMPLEX TÁPANYAGUTÁNPÓTLÁS HATÁSÁNAK VIZSGÁLATA AZ ŐSZI BÚZA TERMÉSÉRE ÉS MINŐSÉGÉRE

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Abstract

The climate of our country is suitable for wheat cultivation everywhere, but there is variation from one region to another. Nowadays, the greatest risk in wheat production is posed by extreme weather conditions, but next to them the other key issue of successful growth is the correct nutrient supply.

In the present work, the results of the nutrient supply experiment conducted in 2017 and 2022 at the Research Institute of Kompolt of the predecessor institution of MATE are presented. The experiment was set up on small plots, in 4 replications, with Latin square arrangement. In the experiment the effect of NPK doses were examined on the growth of the plants and on the yield in four treatments (three levels of nutrient supply plus control treatment). Each plot was divided into two parts, and one part of each treatment was supplemented with foliar fertilization. The main goal of our experiment is to determine the optimal amount and content of fertilizer, which can give the highest yield in different crop years among the given ecological conditions. We measured the plant height at full maturity, the amount of the yield and the different quality parameters. We found that the highest yield was given by treatment of "growing area specific" fertilizer supplemented with foliar fertilizer.

Keywords: *winter wheat, nutrient supply, yield, quality, crop year*
JEL kód: *Q19*

Összefoglalás

Hazánk éghajlata mindenütt megfelel a búza termesztésére, azonban tájankénti változatosság figyelhető meg. A búza termesztése során napjainkban a legnagyobb kockázatot az extrém időjárási körülmények jelentik, emellett a sikeres termelés másik meghatározó tényezője a helyes tápanyagellátás.

Jelen munkánkban a MATE jogelőd intézményének Kompolti Kutatóintézetében a 2017-es, valamint a 2022-es évben beállított tápanyagellátási kísérlet eredményeit dolgoztuk fel. A kísérlet beállítása kisparcellán, 4 ismétlésben, latin négyzet elrendezésben történt. A kísérletben 4 kezelésben (3 műtrágyázási szint + kontroll kezelés) vizsgáltuk az NPK adagok hatását a növények fejlődésére és a termésképzésre. A parcellákat két részre választottuk, majd az egyik rész esetében a kezeléseket lombtrágya kezeléssel egészítettük ki. Célunk, hogy adott ökológiai adottságok mellett meghatározható legyen az optimális összetételű, hatóanyagtartalmú és mennyiségű műtrágya, amellyel a különböző évjáratok mellett a legmagasabb hozam érhető el.

Mértük a növénymagasságot a teljes érés idején, a termés mennyiségét, valamint a különböző minőségi paraméterek alakulását. Eredményeink alapján megállapítottuk, hogy a legmagasabb termést a lombtrágyával kiegészített „tájspecifikus" kezelés esetén kaptuk.
Kulcsszavak: *őszi búza, tápanyagellátás, hozam, minőség, évjárat*

Introduction

The winter wheat is one of our most important crops. Meeting domestic needs is not a problem in Hungary, but there can be significant differences in production efficiency if technology is not adapted to ecological conditions (VARGA and HOFFMANN, 2024a). The climate of our country is suitable for wheat cultivation everywhere, but there is some regional variation (MAGDA and MARSELEK, 2000, KISS et al., 2016). Nowadays, the greatest risk in wheat production is posed by extreme weather conditions, but next to them other key issue of successful growth is the correct nutrient supply (PEPÓ, 2007, PETRÓCZI, 2008). In the intensive cultivation technology, the most important technological factor for the yield and quality of the wheat can be the nutrient supply, accounting for up to 30% (PEPÓ, 2019b).

However, more than 40 years ago Ralph and Ridgman (1981) found that crops cannot respond well to fertilizer in soils under insufficient moisture. SAEED et al. (2012) also confirmed that the nutrient requirement depends on soil fertility, climate conditions, cultivar characteristics, and yields. The balanced use of macro- and micronutrients has basic role in crop nutrition for increased yield and quality. KOVÁCS (1999) found, that especially the intensive wheat varieties respond to nutrient deficiencies with a decline in yield and quality.

In the case of wheat, quality is a complex, multidimensional concept, as it is determined by many characteristics (KAJDI, 2011).

The millability can be inferred from the formation of the thousand-grain weight, as larger wheat grains are richer in flour.

The crude protein content of wheat is calculated by multiplying the total protein and non-protein nitrogen content of the crop by 5.7 (LÁSZTITY 1981). It is determined by digestion using the Kjeldahl or Dumas method, or it can also be determined using a rapid infrared analyzer (KAJDI, 2011). The protein content of medium-quality wheat is between 11.5 and 13.0% on a dry matter content (JOLÁNKAI – SZABÓ 2005, KAJDI 2011).

The wet gluten content of wheat flour consists of water-insoluble proteins (glutenins and gliadins) remaining after the soluble components have been washed out. Its value is generally between 20 and 40+%.

The Zeleny index or sedimentation value provides information about the quality of gluten, as gluten proteins swell in an acidic medium and the increase in volume expressed in ml, can be used to determine the quality of the flour. A value above 30 ml is favorable, while a value above 45 ml indicates improver quality (ZELENY, 1947; KAJDI, 2011).

The W-index expresses the strength of the dough; for medium-quality wheat, its value ranges between 180 and 250 (JOLÁNKAI – SZABÓ 2005).

Wheat is a nutrient-demanding crop that appreciates fertilisation, so optimal nutrient supply is a crucial agrotechnical element for it. It requires macro- (N, P, K), meso- (Ca, Mg, S) and micro-nutrients (Cu, Fe, Zn, B, Mo, Mn, etc.) for yield formation, with different uptake and physiological roles (PEPÓ, 2019a).

Nitrogen is the determinant raw material for the growth of the plant, as favours the conversion of carbohydrates into proteins, which promotes the formation of protoplasm (YASIN, 2015, ÁRENDÁS, 2019). Nitrogen is the essential component of the proteins (including the different enzymes), amino acids, nucleic acids and photosynthetic pigment (BUNGARD et al., 1999). Furthermore, it increases the number of tillers, and the mature heads, but excessive nitrogen application can lead to risk of lodging, disease and reduced winter hardiness (MEENA et al., 2020). SINGH et al. (2011) also found, that application of nitrogen increases the plant height, the 1000-grain weight and also the number of productive tillers, which results in higher grain yield. In its absence, the development of plant is stunted, and it turns light green (PEPÓ 2019a). Nitrogen uptake is very moderate in autumn but increases in early spring until the period of grain saturation (March-June) (PEPÓ, 2019b). It is beneficial if the wheat receives enough nitrogen in autumn to cover its needs in the autumn-winter period, thus avoiding a shortage in early spring. The first top-dressing should take place at the time of tillering (VARGA and HOFFMANN, 2024b) and at ear emergence, applying 40-60 kg N ha^{-1}, which can be divided into two portions to enable a late foliar spray, which can increase the protein content of the grain and therefore providing a flour with better baking quality.

Phosphorus is an indispensable requirement of numerous physiological functions, as the energy accumulation, photosynthesis, respiration, cell differentiation and the synthesis of ATP and ADP. It is also required for initiation of primordial leaves and florets (ANWAR, 2016). Phosphorus apparently stimulates young root development, flowering and fruiting, seed formation and the crop maturation (YASIN, 2015). Phosphorus uptake is already significant in autumn and continues at a steady rate in spring until ripening (PEPÓ, 2019b).

Potassium is required by wheat in autumn for the formation of carbohydrates, which are essential for safe overwintering. In spring, wheat takes up large amounts of potassium from March to May for the formation of vegetative mass, and at the very end of the growing season potassium is already being released in the crop (PEPÓ, 2019b).

Among the macronutrients, phosphorus and potassium are recommended to be applied in autumn, before sowing, while nitrogen is applied in divided doses, depending on the amount. In autumn, one third of the total amount of nitrogen is given out as a base fertiliser, and the remainder is given out in spring, as a top dressing in 2 or 3 instalments (PEPÓ, 2019a, VARGA and HOFFMANN, 2024b).

Micronutrients improve the good, strong and consistent growth of plants, therefore produce higher yields (MEENA et al., 2020). They are necessary for healthy plant populations and proper development. Based on their experiments, VARGA and HOFFMANN (2024a) found that in the case of latent deficiencies, when they have not yet caused visible symptoms, yields can be reduced by as much as 10-15%. To replenish the micronutrients, at least two foliar fertilizations are recommended, at the end of the tillering period and in the middle of the stem elongation. Foliar fertilization is an essential, quick and effective solution in production, especially at the critical developmental stages of wheat for providing nutrients through the leaves, to correct nutritional deficiencies, increase assimilation, plant growth, plant mass, quality and yield (BĂRDAŞ et al., 2024).

Based on his experiments KÁDÁR (2006) found, that the NP treatment increased the thousand-grain weight and average yield of wheat by 30%, compared to the results of the control plots without fertilizer treatment. PETRÓCZI (2015) confirmed with the results of his long-term experiment that the level of fertilization determines the amount of yield that can be achieved, with 180+60+60 NPK active ingredient, he was able to achieve a yield above the national average. PEPÓ (2004) found that, compared to the yield, good quality required higher NPK doses, with abundant nutrient supply (N300/150+PK treatment), the wet gluten content in average of the varieties fell into the improver quality category, which also was confirmed by ZECEVIC et al. (2010).

Experiments conducted in the region have particular importance in determining the optimal nutrient dosages, as local conditions can significantly influence the uptake and utilization of nutrients. KOVÁCS (1999) in his experiments found, that fertilizer treatments that give the highest crop surpluses do not always represent the most efficient use of fertilizer, as their return on investment must also be considered. In addition, excessive use of synthtic fertilizer not only leads to poorer crop quality and susceptibility to disease, but also damages the environment (SINGH et al., 2024).

The main goal of our experiment is to determine the optimal content and amount of the fertilizer, which can give the highest yield in different crop years among the given ecological conditions.

Materials and methods

In the present work, the results of the nutrient supply experiment conducted in 2017 and 2022 at the Research Institute of Kompolt, the predecessor institution of MATE were processed.

Kompolt is located on the north-western edge of the Great Plain, on the southern slopes of the Mátra, at an altitude of 125 m above sea level. The region has a moderately hot but extreme drought-prone landscape, being one of the most precipitation-poor regions in Hungary (HOLLÓ et al., 2009). In the predominant soil types, the groundwater level is very deep at 11-12 m, and the high content of dead water increases the soil salinity (BÉLTEKI et al., 2017, AMBRUS et al., 2020).

The soil type of the experimental area is chernozem brown forest soil. Thickness of the humus layer varies between 0.5 and 0.8 m. The soil pH is acidic, the N content is medium, the ammonium-lactate (AL) soluble P content is low, and the K content is satisfactory. The zinc, copper and manganese content was determined with Ethylenediaminetetraacetic acid extraction. The results of the soil analysis made in 2015 can be found at table 1.

Table 1. The results of soil analysis of the experiment (2015)

Designation	Value
pH (KCl)	4.60
pH (H_2O)	5.86
Humus (%)	2.47
Plasticity according to Arany (K_A)	43
Salinity (%)	0.07
AL-P_2O_5 (mg kg^{-1})	122
AL-K_2O (mg kg^{-1})	232
Mg (KCl) (mg kg^{-1})	408
AL-Na (mg kg^{-1})	13.20
Zn (EDTA) (mg kg^{-1})	1.66
Cu (EDTA) (mg kg^{-1})	4.07
Mn (EDTA) (mg kg^{-1})	166
S (KCl) (mg kg^{-1})	31.7

Source: own work, based on the data of Fleischmann Rudolf Research Institute

The amount of the precipitation and the temperature during the growing period were continuously recorded on daily basis, which were later averaged and aggregated for monthly periods.

The experiment was conducted on small plots, in four replications with Latin square arrangement on 90 m^2 gross, 60 m^2 net plots. The wheat variety used in the experiment was Mv Kolompos. The experimental field was cultivated with commonly used agrotechnics.

The effect of NPK doses were examined at four fertilization levels (three levels of nutrient supply plus control treatment) on plant growth, yield and quality. In the case of Environmentally friendly treatment, the fertilizer dose was determined taking economic considerations into account. It represents a lower amount, which is expected to be sufficient for the plant and does not significantly burden the environment. Growing area-specific treatment is the highest level of adaptation to the region, adjusted to soil and climate conditions, which aims to achieve maximum crop yields based on decades of experience. The Balanced level represents the middle grade between the environmentally friendly and landscape-specific levels. Each plot was divided into two parts, and one part of each treatment was supplemented with foliar fertilization. The treatments applied are shown in table 2. The foliar fertiliser was applied two times, the first dosage at the beginning of stem elongation, and the second dosage at the stage of heading.

Table 2. Fertilization treatments of the nutrient supply experiment, amount of nutrients

Treatment	Nutrient (kg ha^{-1})			Base dressing (kg ha^{-1})	Top dressing (kg ha^{-1})	Foliar fertilization (l ha^{-1})
	N	P_2O_5	K_2O			
Ø (control)	-	-	-	-	-	2 X 4 Cereals foliar fertiliser
Environmentally friendly	132	22	0	90 (NP 15:25)	407 (CAN)	
Balanced level	145	44	0	176 (NP 15:25)	441 (CAN)	
Growing area-specific	154	60	30	300 (NPK 10:20:10)	414 (Sulphur urea)	

Source: own work, based on the data of Fleischmann Rudolf Research Institute

In the present work, we examined plant height, yield and quality of wheat in 2017 and 2022.

Statistical analysis of data was made in Microsoft Excel 2013 and IBM SPSS Statistics 20 program. The analysis was conducted by analysis of variance and $LSD_{5\%}$ was calculated to evaluate the yield and quality results obtained during the experiment. Before the analysis of variance, we made Levene-test, which showed that the data were homogeneous except for plant height in the 2017 growing season and Zeleny index in the 2022 growing season, so the analysis of variance could be performed. Statistically verifiable differences between treatments were also checked by Tukey's-b test. Tukey's-b test was used to determine treatments with the same effect. Examination of connection between the growth, the yield and the quality of wheat was conducted by Pearson’s correlation. A BoxPlot was used to describe the distribution of the data.

Results

The meteorological data (Figures 1, 2) show that the 2017 growing season was more favourable for wheat development than the 2022 growing season.

In 2016/2017 the amount of precipitation in the vegetation period was 469.6 mm, it was higher than the average of 50 years with 113.8 mm and the average of the monthly temperature (8.5 °C) was lower with 0.1 °C. In autumn, sufficient rainfall was available for germination and emergence and the rainfall in January-February replenished the soil with sufficient water. From April to harvest, wheat also received above average, consistent water supply. Totally, we can say, the natural water supply gratified the water requirement of wheat. Temperatures were below the 50-year average in autumn-winter and above the 50-year average in spring-summer.

In the 2021/22 growing season, the amount of the precipitation was only 242 mm. The wheat had sufficient water for germination and emergence in autumn, followed by a very dry January and February. March and April had rainfall values in line with the multi-year average, which favoured the spring development of wheat. From May to harvest, however, there was a very dry, droughty period, with amounts at half to one third of the average, combined with temperatures well above average. The high temperatures further increased the negative impact of the drought.

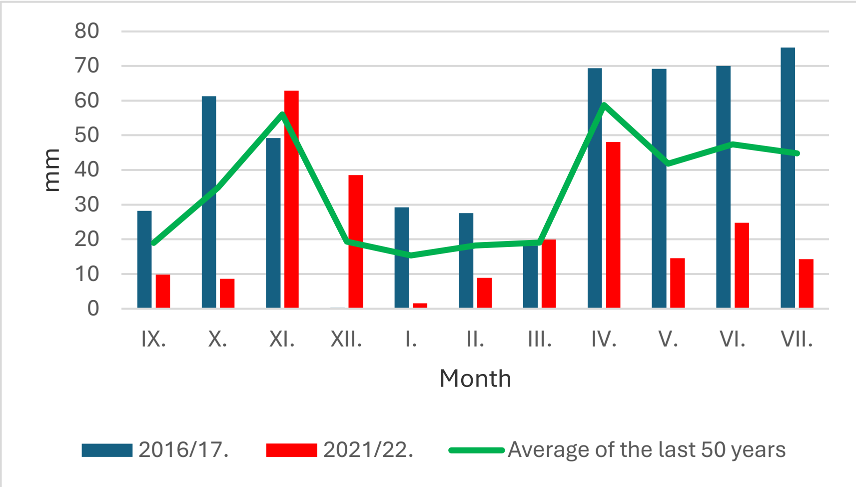

Figure 1. Precipitation (mm) in the examined crop years (Kompolt)

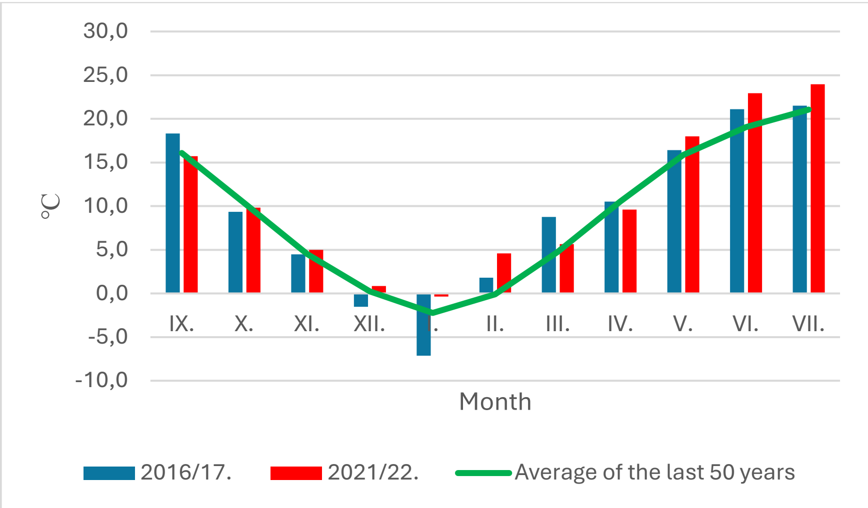

Figure 2. Temperature (˚C) in the examined crop years (Kompolt)

In 2017 the different fertilization treatments caused significant difference in each feature compared to the control plots (Table 3). The effect of the smallest "environmentally friendly" dosage of nutrient has already meant nearly 70 % increase in yield compared to the control treatment. The growing area-specific treatment with foliar fertiliser further raised the amount of the yield to 5.31 t ha^{-1}, which was the highest in the experiment in 2017. This treatment gave the most favourable results for all parameters observed. Foliar fertilization resulted in improvements in all examined parameters for all treatments. However, the quality of wheat was poorer this year, with wet gluten content indicating that it was only suitable for animal feed. Statistically significant differences in plant height, average yield, and W-index can be observed among the treatment results, which were confirmed by the Tukey's-b test (Table 4). The statistically significant differences were only between the control and the other treatments. Higher doses of fertilizer yielded better results, but these were not significant.

Table 3. The results of the nutrient supply experiment (2017)

	Plant height (cm)	**Yield (t ha^{-1})**	**Moisture content at harvest (%)**	**Thousand seed weight (g)**	**Crude protein content (%)**	**Wet gluten content (%)**	**Zeleny-index (ml)**	**W-index**
Ø (Control)	64.85	2.56	12.40	48	11.38	21.83	41.33	193.36
Control + Foliar fertiliser	74.50	2.81	11.90	51.75	11.80	22.48	43.65	220.93
Environmentally friendly	78.51	4.27	12.08	49.50	11.90	22.95	43.23	248.37
Environmentally friendly + Foliar fertiliser	80.44	5.02	11.00	50.25	12.80	25.30	48.98	290.48
Balanced level	78.01	4.25	11.65	46.50	12.08	23.18	44.35	245.50
Balanced level + Foliar fertiliser	80.73	5.23	12.40	52.25	13.35	26.70	53.15	306.60
Growing area-specific	78.31	4.42	11.85	50.75	12.55	25.05	48.28	276.30
Growing area-specific + Foliar fertiliser	81.13	5.31	11.35	52.25	13.75	28.00	54.63	334.60
Average	**77.06**	**4.23**	**11.83**	**50.16**	**12.45**	**24.44**	**47.20**	**264.52**
LSD$_{5\%}$	**4.97**	**0.65**	**-**	**-**	-	-	-	50.57

Table 4. The results of Tukey's-b test (2017)

	Treatment	N	Subset for alpha = 0.05					
			Plant height (cm)		**Yield (t ha^{-1})**		**W-index**	
			1	2	1	2	1	2
Tukey B[a]	Control	8	69.67		2.68		207.14	
	Balanced level	8		79.36		4.64		269.42
	Environmentally friendly	8		79.47		4.73		276.05
	Growing area specific	8		79.71		4.86		305.45
Means for groups in homogeneous subsets are displayed.								
a. Uses Harmonic Mean Sample Size = 8.000.								

In 2022, the yield reduction caused by low precipitation during the growing season is not reflected in the results of the experiment (Table 5). The highest plant height and the yield was measured in case of the growing area-specific treatment with application of foliar fertiliser. Owing to the warm and dry weather conditions around the ripening, the moisture content was significantly lower compared to the previous examined year. The smaller amount of the precipitation and the higher temperature also caused better quality. With the exception of moisture content, statistically significant differences were observed between the effects of the treatments for all other examined parameters (Table 6, 7). The Tukey's-b test showed significant difference between the control and the other treatments in case of plant height, yield and the quality parameters, however, the thousand seed weight did not have significant difference in control, environmentally friendly and balanced level treatments. Only the growing area-specific treatment could cause higher difference.

Table 5. The results of the nutrient supply experiment (2022)

	Plant height (cm)	**Yield (t ha^{-1})**	**Moisture content at harvest (%)**	**Thousand seed weight (g)**	**Crude protein content (%)**	**Wet gluten content (%)**	**Zeleny-index (ml)**	**W-index**
Ø (Control)	62.05	2.35	8.45	48.93	10.80	24.40	38.65	159.70
Control + Foliar fertiliser	63.10	2.89	8.45	49.90	11.10	25.40	41.05	168.20
Environmentally friendly	76.50	4.42	8.20	43.98	14.10	34.30	63.58	227.68
Environmentally friendly + Foliar fertiliser	76.60	4.80	8.30	45.85	14.90	36.60	65.23	247.68
Balanced level	77.20	4.38	8.22	43.68	14.00	33.60	62.35	223.60
Balanced level + Foliar fertiliser	77.40	4.81	8.33	47.08	15.30	39.30	66.25	257.33
Growing area-specific	75.80	4.76	8.30	44.18	14.10	34.00	64.33	222.20
Growing area-specific + Foliar fertiliser	77.95	5.44	8.20	47.30	15.40	39.40	67.13	253.40
Average	**77.06**	**4.23**	**8.31**	**46.36**	**13.71**	**33.38**	**47.20**	**264.52**
$LSD_{5\%}$	**3.40**	**0.67**	**-**	**1.66**	0.67	2.45	4.12	16.10

Table 6. The results of Tukey's-b test I. (2022)

	Treatment	N	Subset for alpha = 0.05						
			Plant height (cm)		**Yield (t ha^{-1})**		**Moisture content (%)**	**Thousand seed weight (g)**	
			1	2	1	2	1	1	2
Tukey B[a]	Control	8	62.57		2.62		8.25	44.91	
	Balanced level	8		76.55		4.59	8.25	45.37	
	Environmentally friendly	8		76.87		4.61	8.27	45.74	
	Growing area specific	8		77.30		5.10	8.45		49.41
Means for groups in homogeneous subsets are displayed.									
a. Uses Harmonic Mean Sample Size = 8.000.									

Table 7. The results of Tukey's-b test II. (2022)

	Treatment	N	Subset for alpha = 0.05							
			Crude protein content (%)		**Wet gluten content (%)**		**Zeleny-index (ml)**		**W-index**	
			1	2	1	2	1	2	1	2
Tukey B[a]	Control	8	10.94		24.85		39.85		163.95	
	Balanced level	8		14.46		35.41		64.30		237.67
	Environmentally friendly	8		14.64		36.40		64.40		237.80
	Growing area specific	8		14.75		36.71		65.72		240.46
Means for groups in homogeneous subsets are displayed.										
a. Uses Harmonic Mean Sample Size = 8.000.										

The effect of foliar fertilization had a positive effect on the yield of wheat in all treatments. Except for the control treatment in 2017, the use of foliar fertilizer resulted in more homogeneous crop yields, while treatments without foliar fertilizer caused greater variation in the data (Figure 3-4). Comparing the results of the two examined years, it can be concluded that in the 2022 crop year, the data showed less variation in yields for all treatments.

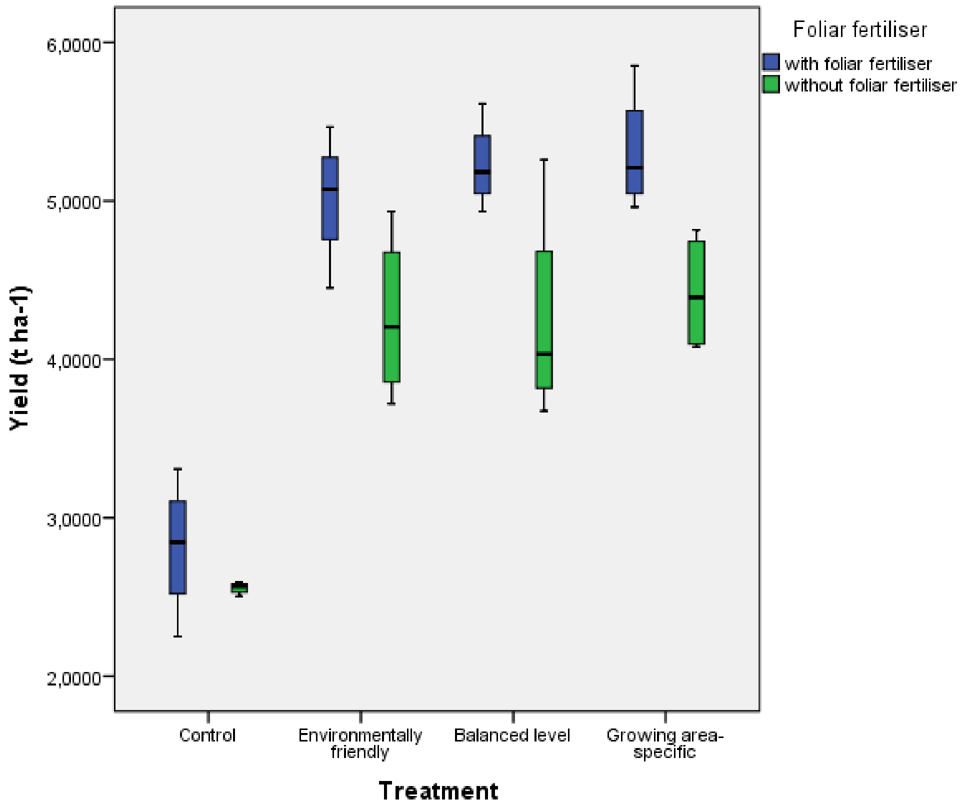

Figure 3. The effect of the foliar fertilization on the yield of wheat (2017)

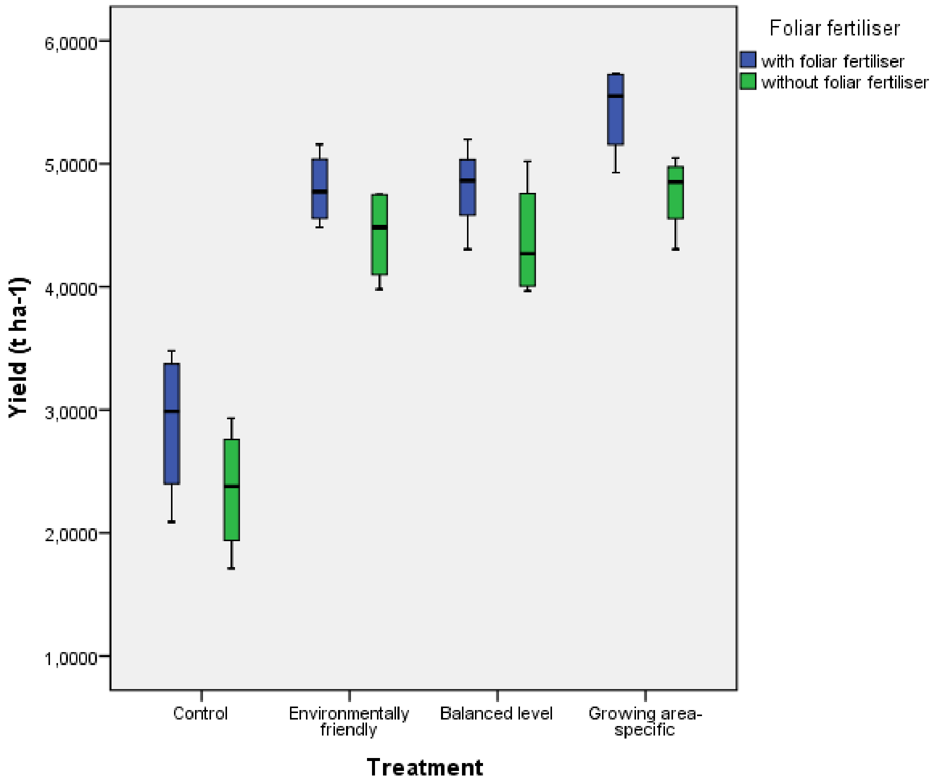

Figure 4. The effect of the foliar fertilisation on the yield of wheat (2022)

The connection between the parameters was examined by Pearson's correlation, which can determine the strength and direction of the correlation (SAJTOS – MITEV, 2007).

Table 8. The correlation coefficients between the examined parameters

	Correlation coefficient (r)						
	Plant height (cm)	**Yield (t ha^{-1})**	**Thousand seed weight (g)**	**Crude protein (%)**	**Wet gluten content (%)**	**Zeleny-index (ml)**	**W-index**
Plant height (cm)	1	0.801^{**}	0.066	0.558^{**}	0.304^{*}	0.471^{**}	0.716^{**}
Yield (t ha^{-1})	0.801^{**}	1	-0.067	0.675^{**}	0.517^{**}	0.610^{**}	0.692^{**}
Thousand seed weight (g)	0.066	-0.067	1	-0.297^{*}	-0.447^{**}	-0.414^{**}	0.330^{**}
Crude protein (%)	0.558^{**}	0.675^{**}	-0.297^{*}	1	0.919^{**}	0.973^{**}	0.545^{**}
Wet gluten content (%)	0.304^{*}	0.517^{**}	-0.447^{**}	0.919^{**}	1	0.944^{**}	0.233
Zeleny-index (ml)	0.471^{**}	0.610^{**}	-0.414^{**}	0.973^{**}	0.944^{**}	1	0.426^{**}
W-index	0.716^{**}	0.692^{**}	0.330^{**}	0.545^{**}	0.233	0.426^{**}	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The statistical evaluation showed a positive correlation of varying strength between the plant height and the other parameters examined, but very strong, significant, positive correlation (0.801) was found between the plant height and the yield. In the studied years between the yield and all the quality parameters a medium positive interaction was found. The closest correlation was between the crude protein content and the Zeleny-index (0.973), followed by the wet gluten content and the Zeleny-index (0.944) as well as the crude protein content and the wet gluten content (0.919). However, correlation analysis showed no relationship between yield and thousand seed weight and indicated a very weak negative correlation (-0.067) for the period under review (Table 8).

Conclusions

Owing to technological advances, the average yield of the wheat is steadily increasing, reaching a national average of 5.4 t ha^{-1} in 2017 (http1). Climatic conditions, including weather patterns during the crop year, have significant impact on the yield and quality of winter wheat. In 2022, due to the extreme drought, the average yield of major arable crops, including wheat, was low (4.4 t/ha) (http2). In our experiment, average yields were similar to the national average, exceeding it in 2022 with the highest fertiliser application rates.

In the experiment the growing area specific treatment with foliar fertiliser gave the highest yield and the best quality. According to our results we can confirm that the optimal nutrient supply, which is adapted to the conditions of the growing area, has a determinative role in the yield of winter wheat. The higher precipitation with lower temperature has positive effect on the amount of the yield, while the higher temperature in the vegetation period of the wheat has positive influence on the quality indicators.

The foliar fertilisation had a positive effect on the development of wheat and resulted higher yields and better quality. Our results confirm the findings of VARGA-HOFFMANN (2024a), that foliar fertilisation is a yield-increasing, cost-effective and highly efficient income-generating technological element with low input costs. Furthermore, our experimental results confirm that the use of foliar fertilization can mitigate the yield-reducing effects of unfavourable, droughty weather conditions.

We recommend applying spring fertilizer in liquid form, which can be absorbed by the plant even in dry soil.

Further examinations are needed because proper conclusion can be drawn only from the results of several years, which making further examinations is essential.

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