chemistry proceedings

Extended Abstract

Yeld and quality of winter wheat (*Triticum aestivum* L.) depending on multi-component foliar fertilization

Wacław Jarecki [1], Maria Czernicka [2]*

[1] Department of Crop Production, University of Rzeszow, Zelwerowicza 4, Rzeszow 35-601, Poland; jarecki@ur.edu.pl
[2] Department of Bioenergetics, Food Analysis and Microbiology, Institute of Food Technology and Nutrition, College of Natural Sciences, University of Rzeszow, 35-601 Rzeszow, Poland; mczernicka@ur.edu.pl;
* Correspondence: wjarecki@ur.edu.pl (W.J.); mczernicka@ur.edu.pl (M.C)

Abstract: Winter wheat is a popular cultivated grain. To produce high and good quality yields, it requires proper fertilization. In a field experiment, the reactions of winter wheat, cv. RGT Kilimanjaro with multicomponent foliar fertilization were assessed. The tested factor were foliar fertilizers used in various combinations: (A) - Control, (B) - YaraVita Gramitrel, (C) - YaraVita Kombiphos, (D) - YaraVita Thiotrac, (E) - YaraVita Gramitrel + YaraVita Kombiphos, (F) - YaraVita Gramitrel + YaraVita Thiotrac, (G) - YaraVita Kombiphos + YaraVita Thiotrac, (H) - YaraVita Gramitrel + YaraVita Kombiphos + YaraVita Thiotrac. It was shown that the variable weather conditions in the years of research had a modifying effect on the yields. The best results were achieved by applying three times foliar fertilization (variant H). The obtained increase in grain yield in relation to control (A) amounted to 0.62 $t \cdot ha^{-1}$. The innovation of the experiment is the possibility of limiting the dose of soil fertilizers in the cultivation of winter wheat without reducing the size and quality of the grain yield. This has an important ecological and economic aspect. The combinations of foliar fertilizers used contain quickly digestible micro- (Mn, Zn, Cu) and macronutrients (N, P, K, Mg, S). Compared to the control, the content of protein and microelements in the grain increased and the fibers decreased. Plant field measurements showed that index SPAD (Soil Plant Analysis Development) and LAI (Leaf Area Index) readings increased after foliar fertilization, but the index MTA (Mean Tip Angle) was decreased compared to the control. In the case of the stomata conductivity of leaves (Gs), it was proved that the applied fertilization in variant H resulted in a reduction of measurements in relation to the control.

Keywords: common wheat, foliar fertilization, macronutrients, micronutrients, yield components, yield, chemical composition

Citation: Jarecki, W.; Czernicka, M. Yeld and quality of winter wheat (Triticum aestivum L.) depending on Multi-component Foliar Fertilization . *Chem. Proc.* **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Published: date

1. Introduction

Winter wheat covers a large sown area and yields high grain yields compared to other cereals. Černý et al. [1] emphasize the great needs of this species for both macronutrients and micronutrients. They proved that mineral fertilization significantly increased the wheat yield, especially in soils with lower nutrient abundance. Fageria et al. [2] conclude that essential nutrients for crops are applied to the soil to be taken up by the root system. It is also possible to use macronutrients and microelements in the form of foliar fertilizers. It has an important economic and environmental aspect. In agricultural practice, foliar spraying is often preceded by an assessment of the nutritional status of plants and the architecture of the field. Various methods, both destructive and nondestructive, serve this purpose [3]. Jankowski et al. [4] emphasize that foliar fertilizers allow increasing the yield of wheat without damaging the natural environment. Dick et al. [5] showed that the use of nitrogen in the later development stages increases the protein content of wheat grains. It was dependent on the location of the experience and years of research. Sobolewska et al. [6] confirmed that foliar fertilization has a positive effect on the size and quality of winter wheat yield. However, it is decided by the dose and the date of the applied fertilizers. Additionally, the effectiveness of foliar fertilizers depends on other factors, such as weather or forecrop. Tsvey et al. [7] believe that the most important for winter wheat is spring fertilization. The highest grain yield (6.90 t·ha^{-1}) was obtained after the combined use of solid and foliar fertilizers. In turn, Froese et al. [8], after foliar application of phosphorus, achieved a marginal increase in yield and wheat grain quality. Fageria et al. [2] showed that if foliar fertilization is applied with postemergence herbicides, insecticides, or fungicides, the yield increase can be increased and the cost of agrochemical application reduced. Therefore, the issues in the studied area are multifaceted and topical.

2. Materials and Methods

A field experiment was carried out at the Podkarpackie Agricultural Advisory Center in Boguchwała (21° 57′E, 49° 59'N). The tests were performed in the 2017/2018 - 2019/2020 seasons. The investigated factor were various variants of winter wheat fertilization, as presented in Table 1. The experiment was performed in a randomized block design with four replications. The RGT Kilimanjaro (RAGT Semences) variety was selected for the study. It is one of the most fertile varieties of winter wheat with good grain quality. Since 2017, it has been recommended for cultivation in the Podkarpackie Province.

Table 1. Scheme of diversified fertilization of winter wheat (L·ha^{-1})

Variant of foliar fertilization	**Development phase (skale BBCH)**			
	BBCH 14	BBCH 28	BBCH 49	BBCH 73
(A) - Control	-	-	-	-
(B) - YaraVita Gramitrel	1	1	1	
(C) - YaraVita Kombiphos	-	4	3	-
(D) - YaraVita Thiotrac	-	-	-	5
(E) - YaraVita Gramitrel+YaraVita Kombiphos	1 + 0	0.5 + 2	0.5 + 2	-
(F) - YaraVita Gramitrel + YaraVita Thiotrac	1	1	1	5
(G) - YaraVita Kombiphos + YaraVita Thiotrac	-	4	3	5
(H) - YaraVita Gramitrel + YaraVita Kombiphos + YaraVita Thiotrac	1 + 0	0.5 + 2	0.5+ 2	5

Solid fertilizers were used for the whole experiment: YaraMila 14–14–21 Viking (300 kg·ha^{-1}) before the start of vegetation in the spring, YaraBela EXTRAN (200 kg·ha^{-1}) in the stem shooting phase and YaraBela Sulfan (200 kg·ha^{-1}) at the beginning of the heading stage. In autumn, solid fertilizers were not applied. The following were selected for foliar fertilization:

- YaraVita Gramitrel contains per g·L^{-1}: 64 nitrogen, 250 magnesium, 50 copper, 150 manganese, 80 zinc,
- YaraVita Kombiphos contains per g·L^{-1}: 440 phosphorus, 75 potassium, 67 magnesium, 10 manganese, 5 zinc,

•YaraVita Thiotrac contains in g·L^{-1}: 200 nitrogen, 750 sulfur.

The experiment was established on a medium soil, very good wheat complex, valuation class II. It was proper brown soil, slightly acidic (6.1-6.4 pH in KCl), and medium humus content (1.6-1.8%). The content of assimilable phosphorus (17.6-19.3 mg·100 g^{-1} of soil) and potassium (21.9-22.6 mg·100 g^{-1} of soil) was high, magnesium was average (6.3-7.2 mg·100 g^{-1} of soil), and low sulfur (64.3-71.6 mg·100 g^{-1} of soil). The content of micronutrients was average except for low boron (0.9-1.2 mg·1000 g^{-1} of soil). The analysis of soil samples was performed at the Regional Chemical and Agricultural Station in Rzeszów, according to Polish standards. The weather conditions are given according to the quotations of the weather station of the Podkarpackie Agricultural Advisory Center in Boguchwała.

The area of a single plot was 15.0 m^2 and the insulation strips 1 m. The seeds were sown to a depth of 3-4 cm and the width of the inter rows was 12.5 cm. The forecrop was winter oilseed rape. The seed was treated with Gizmo 060 FS (50 mL·100 kg^{-1} of grain). Sowing was performed on 29.09.2017, 28.09.2018, and 01.10.2019. The sowing rate was 350 seeds·m^{-2}. Chemical plant protection was carried out during the growing season. Pesticides were used according to the manufacturer's label. Chemical treatments were performed with a tractor sprayer and foliar fertilization with a knapsack sprayer. The development phases are given according to the BBCH scale (Bundesanstalt, Bundessortenamt und CHemische Industrie). Measurement of the stomatal conductivity of the leaves (Gs) was performed with a Porometer SC-1 apparatus (Meter, USA). Leaf greenness index (SPAD) was measured with a SPAD 502P chlorophyllometer (Konica Minolta, Japan). A LAI-2000 apparatus (LI-COR, USA) was used to determine the leaf area (LAI) and leaf angle (MTA). The Gs, SPAD, and LAI measurements were measured in the BBCH 75 phase. The ear counts were reported from an area of 1 m^2. The mean number of grains per ear and MTZ was counted on 20 random plants. Harvesting was carried out on: 3.08. 2018, 30.07. 2019, and 11.08.2020. The yield obtained was converted into 1 ha at 14% grain moisture. The chemical composition of the grain was determined by the near infrared method with a FT-LSD MPA spectrometer (Bruker company, Germany). To determine the individual elements, the grain samples were mineralized in HNO_3: $HClO_4$: HS2O$_4$ in the ratio 20: 5: 1 in an open system in a Tecator heating block (FOSS, Denmark). The content of K, Mg, Zn, Mn, and Cu in the obtained samples was determined by atomic absorption spectroscopy (FAAS) using the Hitachi Z-2000 apparatus (Tokyo, Japan). The Shimadzu UV-VIS spectrophotometer (Kyoto, Japan), vanadium-molybdenum method, was used to determine phosphorus.

3. Results and Discussion

Weather conditions were variable in the years of the study, which influenced the effectiveness of foliar feeding. Rainfall below the long-term average was recorded in April. In May 2020, rainfall was intense, while July and August were dry. The temperatures in the analyzed period were generally above the long-term average. Only March in 2018 and May in 2020 were colder (Figure 1). Ceglar and Toreti [9] report that weather forecasting is important in the cultivation of plants. This allows you to minimize environmental stress and makes rational agrotechnical decisions.

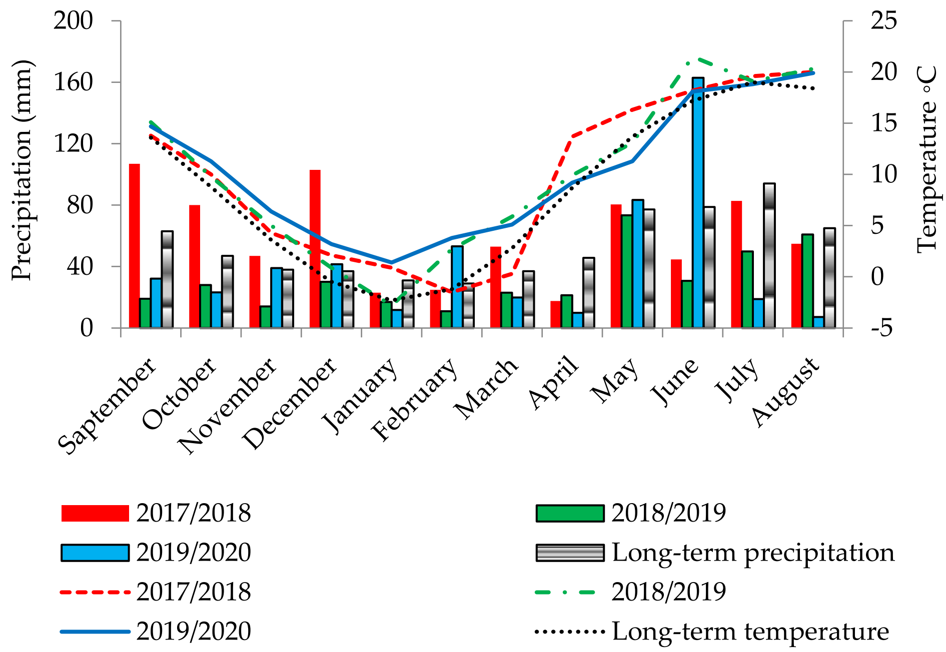

Figure 1. Weather conditions

Foliar fertilization had no significant effect on the spike density per m^2 and the number of grains per spike. It was shown that the applied variants of fertilization (C, D, E, F, G, H) significantly increased the MTZ in comparison to the control (A). As a result, wheat yield increased after foliar fertilization, except for spraying with YaraVita Gramitrel (B). The obtained grain yield difference after applying variants G and H was 0.58 t·ha^{-1} and 0.62 t·ha^{-1}, respectively, compared to the control. Foliar fertilizers had a positive effect on the nutritional status of plants (SPAD index) and on the LAI index compared to the control. In turn, the MTA index decreased after foliar fertilization. Measurement of the stomatal conductivity of the leaves (Gs) showed that variant H fertilization resulted in a reduction in readings relative to the control. After foliar fertilization, the protein content of the grain increased and the fibers decreased. Under the influence of foliar fertilization, except for variant D, an increase in the content of microelements in the grain was noted (Table 2). The concentration of macronutrients was stable. Chwil et al. [10] reported that foliar fertilizer had a greater impact on yield and gluten content than on the mineral composition of winter wheat grain and straw.

Table 2. Features and parameters of winter wheat (mean for year)

Parameter	**Variant of foliar fertilization**							
	A	B	C	D	E	F	G	H
Number of ears (pcs·m^2)	586	588	587	586	590	589	588	589
Number of grains per spike	31.2	31.4	31.5	31.7	32.0	32.2	32.3	32.4
1000 grain weight (g)	41.3^{c}	41.6^{bc}	41.8^{b}	42.3^{ab}	42.0^{b}	42.5^{a}	42.8^{a}	42.8^{a}
Yield (t·ha^{-1})	7.55^{c}	7.68^{bc}	7.73^{b}	7.82^{ab}	7.97^{ab}	8.06^{ab}	8.13^{a}	8.17^{a}
SPAD	50.3^{c}	51.2^{b}	51.0^{b}	53.8^{a}	51.4^{b}	54.2^{a}	54.0^{a}	54.4^{a}
LAI	3.95^{c}	4.09^{a}	4.12^{a}	3.98^{b}	4.13^{a}	4.09^{a}	4.12^{a}	4.15^{a}
MTA	57.3^{a}	55.2^{b}	55.0^{b}	53.5^{c}	55.0^{b}	53.4^{c}	53.3^{c}	53.2^{c}

Gs	692.2^{a}	690.2^{ab}	688.4^{ab}	675.2^{ab}	687.2^{ab}	678.6^{ab}	372.2^{ab}	371.3^{b}
Protein (% DM)	13.8^{c}	14.2^{b}	14.2^{b}	14.6^{a}	14.2^{b}	14.7^{a}	14.7^{a}	14.8^{a}
Starch (% DM)	62.4	62.3	62.1	62.3	62.5	61.9	61.5	61.3
Ash (% DM)	1.46	1.48	1.48	1.46	1.49	14.48	1.51	1.50
Fiber (% DM)	2.88^{a}	2.82^{b}	2.81^{b}	2.77^{c}	2.80^{b}	2.76^{c}	2.76^{c}	2.75^{c}
P ($g \cdot kg^{-1}$)	3.31	3.28	3.35	3.25	3.36	3.23	3.36	3.34
K ($g \cdot kg^{-1}$)	3.83	3.80	3.86	3.79	3.85	3.78	3.87	3.86
Mg ($g \cdot kg^{-1}$)	1.21	1.28	1.23	1.19	1.32	1.27	1.22	1.30
Cu ($mg \cdot kg^{-1}$)	2.24^{b}	2.29^{a}	2.22^{a}	2.18^{b}	2.34^{a}	2.33^{a}	2.18^{a}	2.26^{a}
Mn ($mg \cdot kg^{-1}$)	25.3^{b}	25.6^{a}	25.3^{a}	24.9^{b}	25.8^{a}	25.7^{a}	25.4^{a}	26.1^{a}
Zn ($mg \cdot kg^{-1}$)	37.2^{b}	37.8^{a}	37.4^{a}	36.4^{b}	37.8^{a}	37.6^{a}	37.2^{a}	37.9^{a}

4. Conclusions

Foliar fertilization is a commonly used procedure in plant cultivation. As a result of the experiment, it was shown that both the composition of the fertilizer, the dose and the time of application modify the size and quality of winter wheat grain yield. Therefore, it is important to determine the best variant of foliar fertilization for agricultural practice. The experiment showed that the best results were obtained when combined with three fertilizers in the fall and spring. Smaller effects were obtained after the combined application of two fertilizers and the lowest after the application of a single fertilizer.

Author Contributions: Conceptualization, W.J. and M.C.; methodology, W.J. and M.C.; formal analysis, W.J.; data curation, M.C.; writing—original draft preparation, W.J. and M.C.; visualization, W.J. and M.C.; supervision, W.J. All authors have read and agreed to the published version of the manuscript.

Funding: Please add: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Černý, J.; Balík, J.; Kulhánek, M.; Čásová, K.; Nedvěd, V. Mineral and organic fertilization efficiency in long-term stationary experiments. *Plant Soil Environ*. **2010**, *56*, 28-36. https://doi.org/10.17221/200/2009-PSE
2. Fageria, N.K.; Barbosa, Filho M.P.; Moreira, A.; Guimarães, C.M. Foliar Fertilization of Crop Plants. *J. Plant Nutr.* **2009**, *32*, 1044-1064, DOI: 10.1080/01904160902872826
3. Rachoń, L.; Szumiło, G.; Michałek, W.; Bobryk-Mamczarz, A. Zmienność wskaźnika powierzchni liści (LAI) i promieniowania fotosyntetycznie aktywnego (PAR) w zależności od genotypu pszenicy i intensyfikacji technologii uprawy. *Agronomy Sci.* **2018**, *73*, 63-71. https://doi.org/10.24326/asx.2018.1.6
4. Jankowski, K.J.; Hulanicki, P.S.; Sokólski, M.; Hulanicki, P.; Dubis, B. Yield and quality of winter wheat (*Triticum aestivum* L.) in response to different systems of foliar fertilization. *J. Elem*. **2016**, *21*, 715-728. DOI: 10.5601/ jelem.2015.20.4.1036
5. Dick, C.D.; Thompson, N.M.; Epplin, F.M.; Arnall, D.B. Managing late-season foliar nitrogen fertilization to increase grain protein for winter wheat. *Agron. J.* **2016**, *108*, 2329-2338. https://doi.org/10.2134/agronj2016.02.0106
6. Sobolewska, M.; Wenda-Piesik, A.; Jaroszewska, A.; Stankowski, S. Effect of habitat and foliar fertilization with K, Zn and Mn on winter wheat grain and baking qualities. *Agronomy* **2020**, *10*, 276. DOI: 10.3390/agronomy10020276

7. Tsvey, Y.; Ivanina, R.; Ivanina, V.; Senchuk, S. Yield and quality of winter wheat (*Triticum aestivum* L.) grain in relation to nitrogen fertilization. *Rev. Fac. Nac. Agron. Medellín* **2021**, *74*, 9413-9422. DOI: 10.15446/rfnam.v74n1.88835
8. Froese, S.; Wiens, J.T.; Warkentin, T.; Schoenau, J.J. Response of canola, wheat and pea to foliar phosphorus fertilization at a phosphorus deficient site in eastern Saskatchewan. *Can. J. Plant Sci.* **2020**, *100*, 642-652. https://doi.org/10.1139/cjps-2019-0276
9. Ceglar, A.; Toreti, A. Seasonal climate forecast can inform the European agricultural sector well in advance of harvesting. *npj Clim. Atmos. Sci.* **2021**, 4, 42. https://doi.org/10.1038/s41612-021-00198-3
10. Chwil, S. Effects of foliar feeding under different soil fertilization conditions on the yield structure and quality of winter wheat (*Triticum aestivum* L.). *Acta Agrobot*. **2014**, *67*, 135-144. DOI: 10.5586/aa.2014.059