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YIELD AND GRAIN QUALITY OF WINTER WHEAT UNDER SHORT-TERM ORGANIC AND MINERAL FERTILIZATION IN A SYLVOSTEPPE AREA FROM ROMANIA

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Abstract

Common wheat (Triticum aestivum L.) is one of the most widespread cereal crops in Romania. Various factors, including the fertilization regime, climatic conditions, etc. can influence wheat yield and quality. It is commonly known that fertilization has a fundamental position in obtaining high yields and high-quality grains. Given the current trend towards the use of organic matter for fertilization and the reduction of synthetic fertilizers to mitigate the climate effects, our study aimed to assess the effects of short-term organic and mineral fertilization on wheat grain yield and quality. The field trial was set up at the Research and Development Station for Agronomy (RDSA) of Moara Domnească belonging to USAMV of Bucharest, Romania, on a preluvosoil-type soil. Three doses of manure compost (15 t/ha; 30 t/ha and 60 t/ha) were applied in the autumn of 2021 either alone or in combination with NPK complex fertilizers 20:20:0. The yield components, yield, and grain quality of winter wheat were positively affected by the application of organic and mineral fertilizers, with significant differences being observed between variants and compared to the control (soil).

Key words: *winter wheat, organic amendments, mineral fertilization, wheat yield, grain quality.*

INTRODUCTION

Common wheat (*Triticum aestivum* L.) is among the most widely grown cereal crops in Romania, with a cultivation area of 2,311,095 ha in 2023 and an average yield of 4,154 kg/ha (INS, 2024). The chemical composition of wheat grains, which includes carbohydrates, protein, dietary fibers, lipids, minerals, and vitamins (Mitura et al., 2023), makes it a valuable food source and plays an important role in the production of high-quality grain products (Hospodarenko & Liubych, 2022). For example, protein content significantly influences the quality, technological properties, and nutritional value of flour, making it an important factor for farmers when selecting wheat cultivars and establishing agronomic management strategies (Lachuta et al., 2024).

Globally, wheat production has more than doubled since 1960. However, the frequency of dry seasons has risen over the past century, becoming a significant stress factor that negatively impacts wheat productivity and quality (Hernandez-Ochoa et al., 2023). High and constant yields are essential in wheat production systems and are gaining importance for agronomists (Macholdt et al., 2019). Wheat yield and quality are influenced by several factors, including cultivation practices, soil and climate conditions, crop rotation or cultivar selection (Tudor et al., 2023). Additionally, nutrient supply is a critical factor for enhancing and stabilizing wheat yields (Macholdt et al., 2019).

It is well established that adequate nutrient provision plays an important role in producing high-quality grains. Among these nutrients, nitrogen is particularly crucial for plant nutrition, as it often determines both the yield level and the baking quality of wheat due to its impact on grain protein content (Chiriță et al., 2023). Hlisnikovský and Kunzová (2014) point out that nitrogen promotes optimal conditions for wheat growth and increases seed protein content, but it has a negative effect on starch content. As it is one of the most mobile nutrients in the soil, nitrogen requires careful

management. High rates of nitrogen fertilizer rates must be evaluated, as improper applications can result in increased nitrate leaching, which in turn contributes to surface water eutrophication (Litke et al., 2018).
The concentration of nitrogen and other macronutrients in the upper soil layer can be influenced by the application of both organic and mineral fertilizers (Holik et al., 2018). Organic manures, for instance, have both direct and indirect impacts on the soil. Directly, they contribute to nutrient availability through the gradual release of nutrients via mineralization. Indirectly, they improve soil structure, which can further increase nutrient availability (Holik et al., 2018).
Using organic manures in combination with mineral fertilizers can reduce the need for chemical fertilizers while enhancing soil and crop quality, offering a sustainable technological solution (Chang et al., 2024). This combined approach also plays an important role in optimizing the soil nutrient pool, increasing crop yields, and improving water use efficiency (Zhang et al., 2016).
Given the growing emphasis on using organic matter for fertilization and reducing chemical fertilizers to address climate effects, our study aimed to evaluate the effects of short-term organic and mineral fertilization on wheat grain yield and quality.
The specific objective was to determine how different combinations of mineral and organic fertilizers influence the grain yield of winter wheat and to assess the grain quality.

MATERIALS AND METHODS

Experimental design

The field experiment was carried out during the 2021-2022 period at the Research and Development Station for Agronomy (RDSA) in Moara Domnească, part of the University of Agronomic Sciences and Veterinary Medicine of Bucharest (USAMV). RDSA Moara Domnească is located in the Romanian Plain, within a sylvosteppe area (Figure 1).
The experiment was organized using a randomized block design with four blocks, featuring eight different fertilization treatments and four replicates (Table 1). Each plot was 15 m² in size (5 m in length × 3 m in width).

Figure 1. Winter wheat experimental field, 2021-2022 growing season, RDSA Moara Domnească

Table 1. Treatment variants and doses of mineral fertilizers applied for winter wheat during the 2021-2022 vegetation period

Treatment	Winter wheat	
	Doses of mineral fertilizers	
	Fraction (kg/ha)	
	1	**2**
	24.03.2022	15.04.2022
V1 - soil (Control)	-	-
V2 - NPK	57 N; 57 P_2O_5; 0 K_2O	28 N; 28 P_2O_5; 0 K_2O
V3 - 15 t/ha MC*	-	-
V4 - 15 t/ha MC + NPK	42 N; 42 P_2O_5; 0 K_2O	21 N; 21 P_2O_5; 0 K_2O
V5 - 30 t/ha MC	-	-
V6 - 30 t/ha MC + NPK	27 N; 27 P_2O_5; 0 K_2O	13 N; 13 P_2O_5; 0 K_2O
V7 - 60 t/ha MC	-	-
V8 - 60 t/ha MC + NPK	According to dose calculation, in V_8, the amount of MC should have ensured the nutrient requirements (NPK) and it was decided not to supplement it with chemical fertilizers	

*MC - manure compost

The fertilization treatment included three doses of manure compost - 15 t/ha, 30 t/ha, and 60 t/ha. These were applied at the end of September 2021, either alone or in combination with NPK complex fertilizers (20:20:0).
The NPK fertilizer was applied in fractions based on the nutrient requirements of the wheat crop (Figure 2).

Figure 2. Different doses of manure compost applied on the Moara Domnească experimental field in 2021

Climatic conditions

From September 2021 to October 2022, the climatic conditions in the Moara Domnească area influenced the crop growth.

During the growing season, the average rainfall was 30.29 mm. The monthly maximum and minimum temperatures are detailed in Figure 3.

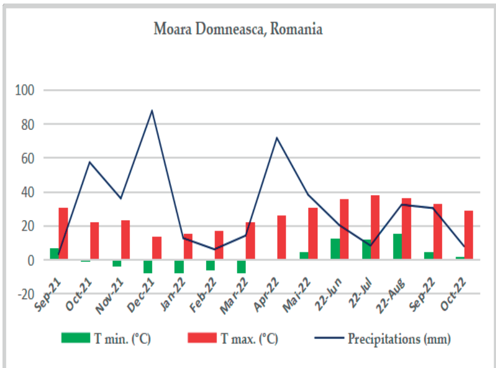

Figure 3. Rainfall (mm) and monthly temperatures (°C) in the Moara Domnească area between September 2021 and October 2022

Soil conditions

The soil in Moara Domnească is classified as red preluvosoil. Samples were collected from six points at a depth of 0-20 cm in order to assess its chemical characteristics prior to land preparation and winter wheat sowing. The samples were air-dried, sifted, and various chemical properties were analysed (Table 2).

Table 2. Agrochemical characteristics of red preluvosoil from Moara Domnească, before winter wheat sowing

Soil characteristics	Mean values ± SD*
pH	6.01 ± 0.154
C_org. (%)	1.94 ± 0.088
N_{total} (%)	0.31 ± 0.011
$N\text{-}NO_3$ (mg/kg d.m.)	9.63 ± 2.498
$N\text{-}NH_4$ (mg/kg d.m.)	10.11 ± 1.055
P_{AL} (mg/kg d.m.)	73.6 ± 10.561
K_{AL} (mg/kg d.m.)	243.3± 30.411

*SD – standard deviation

The soil was scarified twice to a depth of 40 cm due to autumn drought conditions, which prevented ploughing. Two passes with a cultivator were performed to prepare the seedbed. Alfalfa was the preceding crop. The compost used in the experiment was derived from cattle manure and straw collected at the RDSA Moara Domnească farm.

Winter wheat (Jaguar variety from ITC Seeds) was sown on October 22, 2021, and harvested on June 24, 2022.

Yield components, grain yield and quality determinations methods

Grain yield (kg/ha) and the yield components of winter wheat were assessed, including spike length (cm), number of spikelets per spike, number of grains per spike, grain weight per spike (g), and thousand grain weight (TGW) (g).

To evaluate the quality of winter wheat yield, the following characteristics were analysed: moisture content (%), hectolitre mass (HLM) (kg/hl), protein content (%), and starch content (%).

For the TGW determination, 100 g of grains were weighed and counted once per replicate. The spike length, number of spikelets per spike, number of grains per spike, and grain weight per spike (g) were determined from samples of 10 randomly selected spikes.

During wheat harvesting, a representative 1 m x 1 m plot was selected from each experimental plot. The spikes were threshed to separate the grains, which were then weighed to determine the yield.

To asses winter wheat grain quality, a Hectolitre Measuring System - Chondrometer with a 0.5-liter capacity was used to determine hectolitre mass (HLM). Moisture, protein, and starch content were measured using a NIR Inframatic

9200 Product Instalab-Analizer (Ionescu et al., 2021).

Statistical analysis

A statistical analysis was performed using *Analyse-it* software for Microsoft Excel. A one-way analysis of variance (ANOVA) was employed to test all parameters and identify statistically significant differences between treatments ($p<0.05$). Additionally, the least significant differences (LSD) were calculated using Microsoft Excel.

RESULTS AND DISCUSSIONS

Winter wheat yield components

Data analysis revealed low differences in spike length between variants. The highest spike length was observed in V3, measuring 6.87 cm, followed by V6, V7 and V8 (Table 3).

Table 3. Winter wheat yield components in the 2021-2022 growing season, RDSA Moara Domnească experimental field

Variant/ Yield components	Spike length (cm)	No. of spikelets/ spike	No. of grains/ spike	Grain weight/ spike (g)	TGW (g)
V1	6.20^{c}	17.30^{c}	25.35^{c}	1.01^{b}	33.04^{c}
V2	6.23^{c}	17.42^{bc}	26.80^{bc}	1.02^{b}	33.31^{c}
V3	6.87^{a}	18.50^{a}	34.30^{a}	1.20^{a}	37.12^{a}
V4	6.29^{bc}	17.55^{bc}	23.90^{d}	0.98^{c}	32.94^{d}
V5	6.41^{b}	17.82^{b}	28.43^{b}	1.05^{b}	35.56 ^{b}
V6	6.75^{ab}	18.10^{ab}	29.73^{b}	1.13^{ab}	36.40 ^{ab}
V7	6.70^{ab}	18.02^{ab}	28.50^{b}	1.11^{ab}	36.24^{ab}
V8	6.67^{ab}	17.90^{b}	27.96^{bc}	1.03^{b}	34.26 ^{bc}
The similar letters show that there is no significant difference according to Duncan's test at the level of 5% probability					

For the number of spikelets per spike, no significant differences were observed among the variants, with values ranging from 17.3 (Control) to 18.5 (V3).

The number of grains per spike, which depends on the number of spikelets, varied across treatments. The highest number of grains per spike was found in V3 (15 t/ha MC), with 34.30 grains. This was followed by V6 (30 t/ha MC + NPK) with 29.73 grains per spike, and V7 (30 t/ha MC) with 28.50 grains per spike. The lowest number of grains per spike was noted in V4 (30 t/ha MC+ NPK), with 23.90 grains.

The grain weight per spike, which reflects the efficient use of nutrients by plants and their translocation to generative parts, plays an important role in winter wheat yield formation (Protić et al., 2013). The grain weight per spike ranged from 0.98 g (V4) to 1.20 g in V3 (15 t/ha MC), though these differences were not significant.

The dry climate of 2022 strongly impacted the thousand-grain weight, a key yield component examined in this study. TGW was highest in V3 (37.12 g), with 15 t/ha manure compost, and lowest in V4 (32.94 g) (Table 3).

The yield components were less influenced by the different fertilizer treatments, possibly due to the slow-release effect of organic fertilizers throughout the growing season.

Winter wheat yield

Grain yield in winter wheat varied between treatments. While most mineral and organic fertilized variants produced in most cases slightly higher yields, statistically significant differences compared to the control were observed only in V6 and V7 (Figure 4).

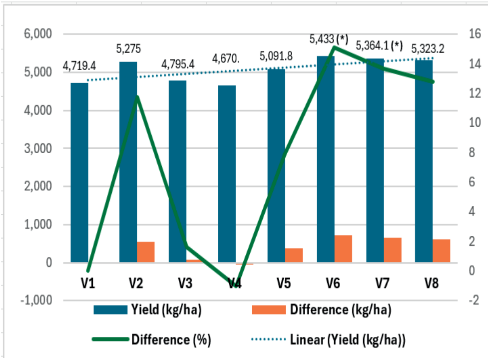

Figure 4. Winter wheat yield in the 2021-2022 growing season, RDSA Moara Domnească experimental field

The lowest yield was registered in V4 (4,670.6 kg/ha), which was 48.8 kg/ha less than the Control. Conversely, the highest yield was determined in V6 (5,433 kg/ha), where 30 t/ha of compost + NPK were applied. In V6, this represented a 15.12% increase compared to the Control (Figure 4 and Table 4).

Table 4. Winter wheat grain yield, 2021-2022 growing season, Moara Domneasca experimental field

Variant	Yield (kg/ha) - 14% moisture	Differences from the Control		Significance
		kg/ha	%	
V1	4,719.4	-	-	-
V2	5,275.0	555.6	11.77	ns
V3	4,795.4	76.0	1.61	ns
V4	4,670.6	-48.8	-1.03	ns
V5	5,091.8	372.4	7.89	ns
V6	5,433.0	713.6	15.12	*
V7	5,364.1	644.7	13.66	*
V8	5,323.2	603.8	12.79	ns

LSD 5% - 610.41 kg/ha *ns – not significant*
LSD 1% - 830.51 kg/ha
LSD 0.1% - 1121.17 kg/ha

Winter wheat grain quality

After harvesting, several winter wheat grain quality parameters were assessed to evaluate the impact of mineral or organic fertilization, or their combination.

The grain moisture content ranged from 11.75% in V4 to 11.95% in V8 and Control (V1), with no significant differences between treatments (Table 5).

Table 5. Winter wheat grain quality after harvesting, 2021-2022 growing season, RDSA Moara Domnească experimental field

Variant	Grain quality parameters			
	Moisture (%)	HLM (kg/hl)	Protein (%)	Starch (%)
	Mean values and SD*			
V1	11.95±0.07	74.35±0.21	11.30±0.28	66.35±0.64
V2	11.90±0.14	73.65±3.6	14.15±0.35	64.00±0.57
V3	11.90±0.01	73.00±0.14	11.50±0.14	65.45±0.35
V4	11.75±0.07	70.50±0.70	13.15±0.07	64.75±0.07
V5	11.85±0.07	73.80±0.56	11.60±0.99	66.50±0.42
V6	11.90± 0.01	74.20±0.91	13.50±0.57	64.70±0.14
V7	11.90±0.01	74.45±0.84	11.35±0.35	66.45±0.07
V8	11.95±0.07	74.20±0.01	11.95±0.07	65.95±0.07
SD	± 0.6	± 1.30	± 1.12	± 0.95

Hectolitre mass (HLM) can be influenced by factors such as soil and climatic conditions, crop management practices, pest attack, and impurity level (Dumbravă et al., 2019).

In this study, the lowest HLM value was registered in variant V4 (70.5 kg/hl), where 15 t/ha MC were applied combined with NPK. The highest HLM value was observed in V7 (74.45 kg/hl), with the application of 60 t/ha of manure compost (Figure 5).

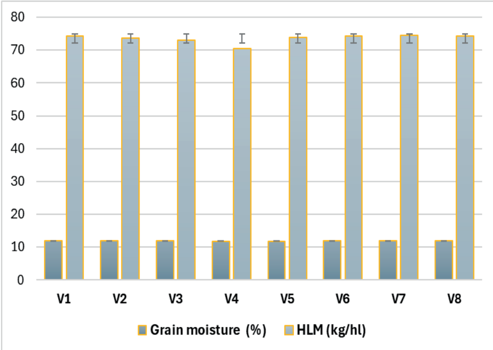

Figure 5. Moisture and hectolitre mass (HLM) for winter wheat grains, 2021-2022 growing season, RDSA Moara Domnească experimental field. The bars represent the standard deviation

The grain protein and starch contents varied with different fertilizer rates (Figure 6). Compared to the Control (V1), the grain protein contents were slightly higher in V7 (11.35%), V3 (11.50%), V5 (11.60%), and V8 (11.95%) with even higher values in V4 (13.15%) and V6 (13.50%). The highest protein content was registered in V2 (only NPK), at 14.15%.

Starch content in the wheat grains ranged from 64% in V2 (only NPK) to 66.50% in V5 (30 t/ha MC) (Figure 6).

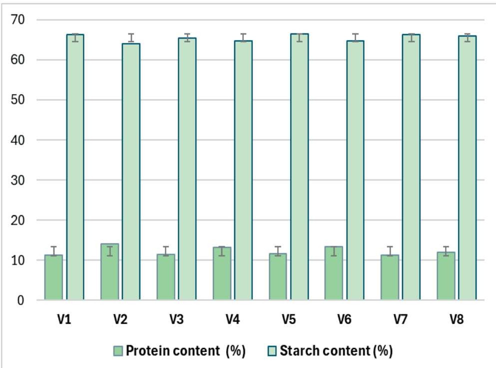

Figure 6. Protein and starch contents (%) for winter wheat grains, 2021-2022 growing season, RDSA Moara Domnească experimental field. The bars represent the standard deviation

The data from this study indicates a trend where increased grain protein content corresponds to decreased starch content, an aspect also reported by Balla et al. (2011). This could be attributed to the fact that higher protein levels could reduce starch accumulation by decreasing starch synthase activity, leading to lower starch levels. However, it is important to note that starch content does not consistently correlate with protein content (Yu et al., 2017).

CONCLUSIONS

The impact of different nutrient regimes on wheat yield components and production requires ongoing research. A significant challenge in this area is the scarcity of long-term field experiments that can reflect the complexity of factors affecting these characteristics.

The analysed data indicated that small doses of organic fertilizers positively affected yield components. For yield and yield quality, medium to high doses of organic fertilizers - either alone or in combination with mineral fertilizers - demonstrated beneficial effects. The environmental conditions during the growing season play a crucial role (Dumbravă et al., 2019). In our study, both TGW and protein content were also influenced by water stress and other environmental factors.

Wheat yield varied among experimental variants, with higher values observed in the treated variants. The highest yield was registered in V6, with the application of 30 t/ha of manure compost and NPK. Additionally, the thousand grain weight, protein content and starch content also varied between treatments. Notably, an increase in protein content was associated with a decrease in starch content in the grains.

Optimizing fertilization strategy is crucial for sustaining crop productivity, reducing nitrate residues (Liu et al, 2024) and maintaining grain quality. Implementing sustainable agricultural practices can enhance resource use efficiency and the overall sustainability of agroecosystems. The results from this study lay the foundations for further research into the impact of different fertilization practices on yield and grain quality in the short and long term in a preluvosoil within a sylvosteppe area of Romania.

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