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STUDY REGARDING THE MAIZE PRODUCTIVITY IN RESPONSE TO SHORT-TERM APPLICATION OF ORGANIC AND MINERAL FERTILIZERS IN A SOUTHEASTERN AREA OF ROMANIA

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Abstract

Maize (Zea mays L.) is the most widely produced food crop globally, providing essential nutrition for both humans and livestock, while also being an important raw material for industrial processes. However, factors such as climatic conditions and fertilization practices significantly affect maize yields. To address these challenges, this study explores the impact of short-term application of organic and mineral fertilizers on maize grain yield and its components. The field trial was conducted at the Moara Domnească Research and Development Station for Agronomy (RDSA) belonging to USAMV Bucharest, Romania, on a preluvosoil. Manure compost was applied in three doses (15 t/ha, 30 t/ha, and 60 t/ha), either alone or in combination with NPK complex fertilizers (20:20:0). Yield components and total production were evaluated prior to harvest, with results showing significant differences between treatments compared to the control (soil).

***Key words**: maize yield, yield components, mineral fertilization, organic fertilization, sustainable production.*

INTRODUCTION

Maize (*Zea mays* L.) is essential for improving global food security and serves as a fundamental component of agricultural production in Romania, particularly in the southeastern regions, where climatic and soil conditions present both opportunities and challenges for crop growth (Prăvălie et al., 2020). Furthermore, maize is a significant source of macro-, micro- and phytonutrients including carbohydrates, fibres, protein, vitamin, minerals, phenolic acids and others, which makes it a suitable staple food (Gogoi et al., 2023).

Maize productivity can be influenced by the environmental conditions, as well as the technological factors. The water supply is an ecological factor that can influence the morphological, physiological, and biochemical processes, ultimately impacting the growth, development, and productivity of maize plants (Bășa et al., 2016). Despite the cultivation of high-performance hybrids, drought conditions during the maize growth stages that require maximum water input significantly impact yield components (Dumbravă et al., 2017).

Another key factor for crop growth is improving technologies to increase the production potential of maize hybrids. Thus, fertilization practices play a vital role in soil-based agricultural systems by improving soil fertility and quality, ultimately leading to increased crop yields (Kim et al., 2022). For instance, nitrogen is a decisive nutrient in agricultural ecosystems and an essential element for plant growth, playing a key role in various physiological and metabolic processes within plants and being the primary yield-limiting factor in crops (Lin et al., 2022; Ramesh Naik et al., 2022). Inefficient nitrogen utilization in maize cultivation is largely attributed to the excessive application of nitrogenous fertilizers by farmers, often without accounting for the nitrogen requirements of crops and growth stages. This mismanagement can result in nitrogen loss from the soil-plant system and low nitrogen use efficiency (Ramesh Naik et al., 2022). Inadequate fertilization practices have also been associated with nitrate leaching into aquatic ecosystems, causing considerable ecological impacts downstream of their source, increased production costs, and a decline in grain quality (Fang et al., 2013; Mahmood et al., 2017; Kong et al., 2022).

Applying organic amendments, such as cattle manure, is a viable alternative to the adverse impacts of inorganic fertilizers due to its widespread availability, its added benefits for soil carbon sequestration, and its ability to store and release nutrients over an extended period (Jjagwe et al., 2020). However, the slow-release rate of nutrients can pose problems in terms of meeting the timely nutritional requirements of plants (Zhai et al., 2023). In this context, the combined application of organic and mineral fertilizers offers a sustainable approach to enhancing nutrient utilization by improving the efficiency of chemical fertilizer, reducing nutrient losses and optimizing crop yields and quality (Schoebitz and Vidal, 2016; Chang et al., 2024), but their effects on maize productivity, especially in the short run, remain a subject of ongoing research.

This study aims at investigating the impact of short-term applications of organic and mineral fertilizers on maize productivity in a southeastern area of Romania, a region characterized by specific climatic and soil conditions. Understanding the interaction between these fertilizers and maize growth is crucial for developing sustainable agricultural practices that maximize yield while minimizing environmental impact.

This research findings aim to provide valuable insights into the efficiency of various fertilization strategies, contributing to the improvement of maize production in this region and potentially in similar agro-ecological areas.

MATERIALS AND METHODS

Study area and climatic conditions. The field experiment was carried out at Moara Domnească Research and Development Station for Agronomy (RDSA) during the 2022 growing season (Figure 1).

Figure 1. Maize experimental field, 2022 growing season, RDSA Moara Domnească

RDSA Moara Domnească is part of the University of Agronomic Sciences and Veterinary Medicine of Bucharest (USAMVB), and it is located in the Romanian Plain, in the southeastern part of Romania.

The climatic conditions in Moara Domnească area influenced the crop growth mainly due to the significant variations. In 2022, the minimum temperatures ranged from -7.9°C (in January and March) to 15.3°C (in August). April 2022, corresponding to the maize sowing period, was characterized by minimum temperatures of 0.1°C and maximum temperatures of 25.9°C.

The precipitation regime in April was very favourable, with a total monthly rainfall of 71.5 mm, which supported soil moisture levels necessary for proper seedling establishment and early growth of maize. This rainfall, along with generally mild temperatures in the spring, created optimal conditions for the initial stages of maize growth.

The summer months were characterized by high temperatures, with maximum values reaching 36.2°C in August. This hot period provided a favourable environment for maize growth, as crops thrive in warm temperatures. However, the relatively high maximum temperatures also posed a potential stress factor, particularly during the grain filling phase of maize.

The hot and dry conditions in late summer presented challenges for the maize crop, especially because irrigation was not available to supplement the water shortage. The precipitation regime and monthly temperatures can be seen in Figure 2.

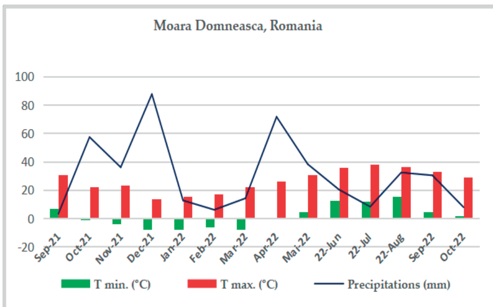


Figure 2. Precipitations (mm) and monthly temperatures (°C) in the Moara Domnească area between September 2021 and October 2022

Soil conditions. The soil at Moara Domnească is classified as red preluvosoil. To evaluate its chemical properties prior to land preparation and maize sowing, soil samples were collected from six locations at a depth of 0-20 cm. The samples were air-dried, sifted, and subsequently analyzed to determine the agro-chemical characteristics (Table 1).

Table 1. Agrochemical characteristics of red preluvosoil from Moara Domnească, before maize sowing

Soil characteristics	Mean values ± SD*
pH	5.90 ± 0.244
C org. (%)	2.11 ± 0.178
N_{total} (%)	0.17 ± 0.007
N-NO_3 (mg/kg d.m.)	49.0 ± 8.041
N-NH_4 (mg/kg d.m.)	5.33 ± 4.027
P_{AL} (mg/kg d.m.)	113.6 ± 5.230
K_{AL} (mg/kg d.m.)	373.3 ± 8.556

*SD – standard deviation

Due to autumn drought conditions that hindered ploughing, the soil was scarified twice to a depth of 40 cm. To prepare the seedbed, two passes with a cultivator were carried out, and the preceding crop was alfalfa.

The compost utilized in the experiment was obtained from cattle manure and straw collected at the RDSA Moara Domnească farm. Maize hybrid, SY Carioca, was sown on April 15, 2022, at a seeding rate of 15 kg/ha and a row spacing of 70 cm.

Experimental design. The experiment was conducted using a randomized complete block design, comprising 8 treatments and 4 replications. Each plot measured 15 m² (5 m long and 3 m wide).

The fertilization treatment involved three different doses of manure compost: 15 t/ha, 30 t/ha, and 60 t/ha (Figure 3 and Table 2).

Figure 3. Different doses of manure compost applied on the experimental plots, Moara Domnească, autumn of 2021

These doses were applied at the end of September 2021, either individually or in combination with NPK complex fertilizers (20:20:0).

The NPK fertilizer was applied in multiple fractions, based on the nutrient requirements of the maize crop.

Table 2. Treatment variants and doses of mineral fertilizers applied for maize during the 2022 vegetation period

Treatment	Maize		
	Doses of mineral fertilizers		
	Fraction (kg/ha)		
	1	2	3
	15.04.2022	15.05.2022	15.06.2022
V1 - soil (Control)	-	-	-
V2 - NPK	28 N; 28 P_2O_5 0 K_2O	46 N; 46 P_2O_5; 0 K_2O	29 N; 29 P_2O_5; 0 K_2O
V3 - 15 t/ha MC*	-	-	-
V4 - 15 t/ha MC + NPK	29 N; 29 P_2O_5 0 K_2O	34 N; 34 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	19 N; 19P_2O_5; 0 K_2O	22 N; 22 P_2O_5; 0 K_2O	14 N;14 P_2O_5; 0 K_2O
V7 - 60 t/ha MC	-	-	-
V8 - 60 t/ha MC + NPK	According to the dose calculation, in V_8, the quantity of MC should have covered the nutrient requirements (NPK) and it was decided not to supplement it with chemical fertilizers		

*MC - manure compost

Yield components and grain yield determination methods. At harvest time, 5 cobs from each treatment and replication were manually harvested at their physiological maturity to determine the yield components, i.e. cob length (cm), number of grain rows/cobs, number of grains/cobs, grain weight/cob (g), and thousand grain weight (TGW) (g).

The grain weight/cob was measured using an electronic weighing balance. Thousand grain weight was determined by weighing 1,000 grains. Grain yield was registered from each experimental plots. The data was adjusted at 14% moisture level and reported as grain yield kg ha^{-1}.

Statistical analysis. A statistical analysis was conducted using *Analyse-it software* for Microsoft Excel. A one-way analysis of variance (ANOVA) was applied to evaluate all parameters and determine statistically significant differences between treatments (p<0.05). Furthermore, the least significant differences (LSD) were calculated using Microsoft Excel.

RESULTS AND DISCUSSIONS

Maize yield components. The data analysis revealed variations in cob length across the different variants. The control variant (V1) had the shortest cob length (13.4 cm), while the longest was observed in V6, measuring 16.5 cm. This was followed by V7 (16.3 cm) and V5 (16.1 cm) (Table 3 and Figure 4). Mohsin et al. (2012) and Bhatt et al. (2020) also observed that the application of chemical fertilizers in combination with organic fertilizers led to an increase in cob length, compared to the use of chemical fertilizers alone.

Table 3. Maize yield components during the 2022 growing season, RDSA Moara Domnească experimental field

Yield components/ Vt	Cob length (cm)	No. grain rows/ cob	No. grains/ cob	Grain weight/ cob (g)	TGW (g)
V1	13.4^{c}	13.5^{c}	256.0^{d}	44.2^{d}	172.9^{d}
V2	14.7^{bc}	14.0^{b}	298.0^{cd}	55.3^{cd}	185.7^{cd}
V3	15.5^{b}	14.1^{b}	315.6^{c}	59.6^{c}	188.9^{c}
V4	15.7^{b}	14.3^{ab}	358.3^{bc}	76.7^{bc}	214.1^{a}
V5	16.1^{ab}	14.0^{b}	376.2^{b}	74.5^{b}	198.0^{bc}
V6	16.5^{a}	14.5^{a}	405.2^{a}	83.3^{a}	205.5^{b}
V7	16.3^{a}	14.5^{a}	393.6^{ab}	83.2^{a}	211.3^{ab}
V8	16.0^{ab}	14.3^{ab}	388.5^{ab}	80.6^{ab}	207.5^{b}
LSD 0.5	*0.29*	*0.19*	*20.53*	*3.02*	*4.62*
Similar letters show that there is no significant difference according to Duncan's test at the 5% probability level					

The number of rows per cob varied from 13.5 rows in the Control variant (V1), to 14.5 rows in V6 and V7. The differences between treated variants were statistically insignificant.

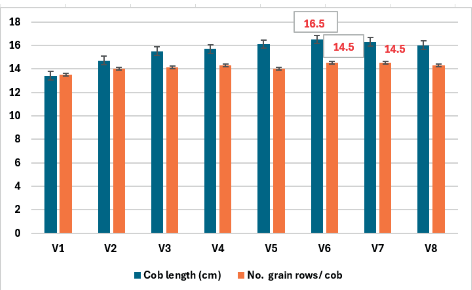


Figure 4. The cob length and number of grain rows/cob at maize under various doses of manure compost and chemical fertilizers, 2022 growing season. The bars stand for the standard errors

The number of grains per cob was influenced by the size of the grains, and it varied across treatments. During the 2022 cropping season, the results showed a decrease in the number of grains per cob when manure compost was applied alone. However, a significantly higher number of grains was noted when a combination of 30 t/ha of manure compost and NPK fertilizers was used, i.e. 405.2 grains, followed by 60 t/ha manure compost and NPK (V7), respectively 393.6 grains (Table 3 and Figure 5). The increased number of grains per cob might be attributed to the availability of more nitrogen and other nutrients from manure compost and chemical fertilizers to the maize plants through their life cycle. This finding is consistent with Bhatt et al. (2020), who suggested that the timely availability of nitrogen, along with improvements in moisture retention and soil structure through the application of organic manures, can enhance the number of grains per cob. The control treatment gave a statistically lower number of grains per cob (256), which can be attributed to the insufficient availability of nutrients in the soil.

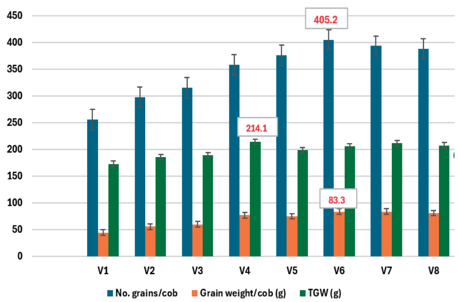
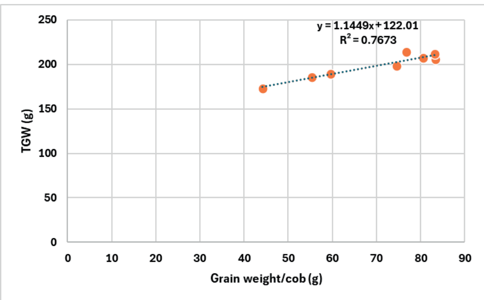


Figure 5. Number of grains/cob, grains weight/cob and TGW at maize under various doses of manure compost and chemical fertilizers, 2022 growing season. The bars stand for the standard errors

The grain weight per cob is an important factor in determining the overall productivity of maize crop. The highest value was recorded in the variant where 30 t/ha of manure compost and NPK fertilizer were applied (V6), i.e. 83.3 g, which is 47% higher than the control (only soil). This result can reflect the efficient utilization of nutrients by the plants and their subsequent translocation to the generative structures.
Thousand grain weight (TGW) is an important agronomic feature used to assess the size and weight of maize grains and is a significant

indicator of grain quality. TGW can vary depending on various factors such as variety, growing conditions, management practices, or climate.
The data showed that TGW were not significantly affected by different levels of organic and inorganic fertilizers. However, a higher TGW, i.e. 214.1 g, was found in V4 (15 t/ha manure compost and NPK), followed by V7 (211.3 g) and V8 (207.5 g) (Table 3 and Figure 5).
The correlation between grain weight per cob and thousand grain weight is positive ($R^2 = 0.76$) and can be attributed to the fact that as thousand grain weight (TGW) increases, resulting in larger individual grains, the total grain weight per cob also tends to rise. Additionally, there is a strong correlation between the number of grains per cob and the total grain weight ($R^2 = 0.99$), indicating that an increase in the number of grains per cob leads to a corresponding increase in the total grain weight. Specifically, the grain weight per cob is directly influenced by both the number of grains per cob and the average weight of each grain (Figure 6a and 6b).

a.



b.

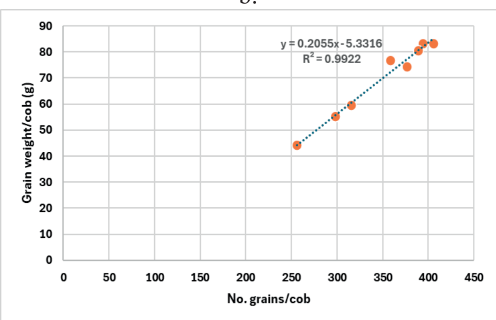


Figure 6. Correlation between the grain weight/cob and TGW (a) and the number of grains/cob and grains weight/cob (b)

Maize grain yield at 14% moisture. The drought conditions in 2022 resulted in a noticeable decrease in maize yield, and this effect was observed across the variants evaluated in our study.The data presented in Table 4 clearly showed that the highest grain yield of 3,264 kg/ha was registered in the variant where 30 t/ha of manure compost and NPK (V6) were applied, followed by V7 (3,186 kg/ha), V8 (3,160 kg/ha) and V4 (3,008 kg/ha). The values obtained for these treatments were statistically confirmed as distinct significant positive, suggesting that they are providing the optimal conditions for maximizing maize yields (Table 4).

Table 4. Maize yield under different doses of manure compost and chemical fertilizers, Moara Domnească, 2022 growing season

Variant	Yield (kg/ha) at 14% moisture	Differences from the Control		Significance
		kg/ha	%	
V1	1,735	-	100	-
V2	2,169	434	125	ns
V3	2,337	602	135	*
V4	3,008	1,273	173	***
V5	2,920	1,185	168	**
V6	3,264	1,529	188	***
V7	3,186	1,451	184	***
V8	3,160	1,425	182	***

DL5% - 504 kg/ha *ns-insignificant*
DL 1% -763 kg/ha
DL0.1% - 1,225 kg/ha

The lowest grain yield was obtained in the variant where there was no use of organic and chemical fertilizers (V1-1,735 kg/ha) (Table 4). Similar results were reported by Rajesh et al. (2014) and Mhoro et al. (2025).
In the context of global warming, where crop plants are heavily affected, maize being among the most vulnerable, it is becoming essential to find technical solutions to adapt to the effects of these climate changes. Irrigation and fertilizer management strategies that concurrently optimize yield, water use efficiency, and fertilizer efficiency are essential for ensuring sustainable agricultural production (Chen et al., 2024).

CONCLUSIONS

The combined application of organic and mineral fertilizers can offer a sustainable approach to enhancing nutrient utilization, improving the efficiency of chemical fertilizers and optimizing crop yields.

The yield components were influenced by the different fertilizer treatments as follows: the application of manure compost in combination with NPK fertilizers resulted in longer cob lengths compared to the control treatment (only soil).

As far as the number of rows per cob is concerned, the differences between treatments were statistically insignificant, indicating that the number of rows might be less responsive to the treatments compared to other factors like cob length or grain number/cob.

The increase in the number of grain/cobs can be attributed to the enhanced availability of nutrients (especially nitrogen) from the manure compost and NPK fertilizers and the variation between treatments is likely due to the varying levels of nutrient availability, soil organic matter, and the interaction between slow-release nutrients from compost and immediate nutrients from chemical fertilizers.

While the TGW did not show significant statistical differences across treatments, the trend suggests that a combination of organic and inorganic fertilizers may slightly enhance the size and weight of individual grains.

A strong positive correlation was observed between the grain weight per cob and the TGW, indicating that as TGW increases, the individual grains grow larger, leading to a higher total grain weight per cob. There was also a very strong correlation between the number of grains per cob and the total grain weight, which suggests that an increase in the number of grains per cob directly contributes to higher grain weight, further emphasizing the importance of both grain count and individual grain size in determining overall productivity.

The combination of manure compost and NPK fertilizers, particularly at the 30 t/ha manure compost and NPK rate (V6), had a significant positive impact on maize productivity, improving cob length, the number of grains per cob, grain weight per cob, and overall grain yield.

The 2022 climatic conditions at Moara Domnească had a mixed effect on maize productivity, with favourable temperatures and precipitation early in the season, followed by heat stress in the summer. This prolonged drought and climate variability diminished the crop yield.

Such climatic conditions emphasize the importance of water management strategies, as moisture stress during the later stages of maize development can reduce yield potential. Also, these factors underline the complex relationship between climatic conditions and maize productivity, highlighting the need for adaptive farming practices to mitigate adverse weather conditions.

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