

THE PRESENCE OF COPPER IN WHEAT AND MAIZE GRAINS FOLLOWING THE APPLICATION OF FARMYARD MANURE

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RESEARCH ARTICLE

Abstract

This study evaluated the effect of combined NP chemical fertilizers and farmyard manure on copper (Cu) concentration in wheat and maize grains in long-term field trials at the Agricultural Research and Development Station Oradea. Four experimental variants were tested for wheat (V1: N₀P₀ + 0 t/ha manure; V2: N₅₀P₀ + 20 t/ha manure; V3: N₅₀P₅₀ + 40 t/ha manure; V4: N₁₀₀P₁₀₀ + 60 t/ha manure) and corresponding NP doses for maize (N₀P₀, N₄₀P₄₀, N₈₀P₈₀, N₁₆₀P₁₆₀). Plant samples were mineralized and analyzed using atomic absorption spectrophotometry. Results indicated that Cu concentration increased with fertilization intensity. In wheat, Cu ranged from 1.655 mg/kg (control) to 2.250 mg/kg (highest fertilization), while maize ranged from 2.853 mg/kg to 3.745 mg/kg. Statistical analysis confirmed significant differences in higher fertilized variants. Integrated organo-mineral fertilization effectively enhanced microelement content in cereals.

Keywords: copper, wheat, maize, chemical fertilizers, manure

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INTRODUCTION

Copper (Cu) is an essential micronutrient that plays a critical role in plant metabolism, serving as a cofactor for numerous enzymatic reactions, including those involved in photosynthesis, respiration, lignin synthesis, and antioxidant defense mechanisms (Marschner, 2012; Broadley et al., 2012). It is also crucial for plant growth and development, influencing processes such as pollen formation, chlorophyll synthesis, and protein metabolism. Copper deficiency in crops can lead to stunted growth, reduced chlorophyll content, impaired reproductive development, and, ultimately, lower yield and nutritional quality of cereals such as wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) (Kabata-Pendias, 2010; Cakmak, 2008). In addition, inadequate Cu availability in soils has implications for human nutrition, as cereals are a primary source of micronutrients in many diets worldwide (Alloway, 2008).

Soil fertility management plays a pivotal role in ensuring adequate micronutrient availability. The application of chemical nitrogen (N) and phosphorus (P) fertilizers has traditionally been employed to increase crop productivity; however, intensive use of these fertilizers can alter soil chemistry and reduce the bioavailability of micronutrients such as Cu

(Zhao et al., 2020). To address this challenge, integrated nutrient management strategies that combine chemical fertilizers with organic amendments, such as farmyard manure (FYM), compost, or green manures, have been increasingly promoted. Organic amendments can improve soil structure, increase microbial activity, and enhance the chelation and mobility of micronutrients, thereby facilitating their uptake by plants (Liu et al., 2018; Singh et al., 2017). Several studies have reported that the combined application of NP fertilizers and organic amendments significantly increases micronutrient concentrations in wheat and maize grains, improving both yield and grain nutritional quality (Fageria et al., 2011; Kutman et al., 2012).

Long-term field experiments are particularly valuable for evaluating the effects of different fertilization practices on soil fertility and crop micronutrient content, as they capture cumulative impacts that short-term studies may overlook (Zhou et al., 2019). In this context, understanding the interaction between NP fertilizers and organic amendments, and their influence on Cu accumulation in cereal grains, is critical for developing sustainable agronomic practices that support both food security and human nutrition.

The present study aimed to investigate the effects of different doses of NP fertilizers, alone and in combination with farmyard manure, on Cu concentration in wheat and maize grains under long-term cultivation. By elucidating the role of integrated nutrient management on Cu bioavailability and uptake, this research seeks to provide insights that can inform fertilizer recommendations and enhance micronutrient density in staple cereals.

MATERIAL AND METHOD

Experimental Site and Design

Long-term trials were conducted at the Agricultural Research and Development Station Oradea. Wheat and maize were grown under the following variants:

Wheat:

- V1: N₀P₀ + 0 t/ha manure
- V2: N₅₀P₀ + 20 t/ha manure
- V3: N₅₀P₅₀ + 40 t/ha manure
- V4: N₁₀₀P₁₀₀ + 60 t/ha manure

Maize:

- N₀P₀ + 0 t/ha manure
- N₄₀P₄₀ + 20 t/ha manure
- N₈₀P₈₀ + 40 t/ha manure
- N₁₆₀P₁₆₀ + 60 t/ha manure

Sample Preparation and Analysis

Grain samples were collected at maturity and mineralized using a mixture of sulfuric and perchloric acids. Cu concentration was determined by atomic absorption spectrophotometry (SHIMADZU AA-6300).

Statistical Analysis

Data were processed in Microsoft Excel. The best-fit model among linear, exponential, logarithmic, polynomial, and power functions was chosen based on the highest R². Differences were evaluated at 5%, 1%, and 0.1% significance levels.

RESULTS AND DISCUSSIONS

Copper concentration in wheat grains exhibited a clear positive response to both chemical NP fertilization and the addition of farmyard manure. The control variant (N₀P₀ + 0 t/ha manure) registered the lowest Cu content (1.655 mg/kg), establishing a baseline for comparison. The addition of moderate NP fertilizer and 20 t/ha manure (N₅₀P₀ + 20 t/ha) resulted in a 17% increase over control, though this difference was not statistically significant, suggesting that lower levels of fertilization alone may not be sufficient to markedly enhance Cu accumulation in wheat grains.

A more substantial increase was observed in N₅₀P₅₀ + 40 t/ha manure, where Cu concentration reached 2.105 mg/kg, representing a 27.3% increase over control and showing statistical significance (*). This indicates that combining balanced NP fertilization with a higher rate of organic amendment enhances Cu bioavailability, likely due to improved soil cation exchange capacity and chelation of micronutrients by organic matter (Liu et al., 2018; Singh et al., 2017).

The highest Cu concentration (2.250 mg/kg, 36% above control) was recorded in N₁₀₀P₁₀₀ + 60 t/ha manure, also statistically significant. This trend confirms that intensifying organo-mineral fertilization progressively improves Cu accumulation in wheat grains, consistent with findings of Fageria et al. (2011), who reported that integrated nutrient management promotes micronutrient uptake by enhancing soil fertility and microbial activity (Tabel 1).

Overall, these results demonstrate that Cu content in wheat grains is strongly influenced by both fertilizer dose and organic amendment level. Notably, the effect of manure appears synergistic with NP fertilizers, highlighting the importance of integrated approaches rather than sole reliance on chemical fertilization. The increase in Cu concentration also has potential implications for human nutrition, as wheat is a staple cereal and a major dietary source of essential micronutrients (Alloway, 2008).

Mathematical modeling of the results regarding the copper concentration in wheat grains from the variants of the experiment with nitrogen, phosphorus and manure taken into study, of the 5 tested functions (exponential, linear, logarithmic, polynomial, power), the power type function, $y = 1.6563x^{0.2205}$, R² = 0.997, best quantifies the relationship between the doses of nitrogen, phosphorus and manure fertilizers and the copper concentration in wheat grains (Figure 1).

Similar to wheat, maize grains demonstrated a progressive increase in Cu concentration with intensification of NP fertilization. The control variant had a Cu content of 2.853 mg/kg, establishing the reference point. Application of N₄₀P₄₀ increased Cu by 14.1% (3.255 mg/kg), which, although higher than control, did not achieve statistical significance. This suggests that moderate fertilization can partially enhance Cu uptake but may not be sufficient for a consistent effect (Tabel 2).

The N₈₀P₈₀ variant achieved a Cu concentration of 3.451 mg/kg, a 20.8% increase

over control, statistically significant (*), indicating that a higher fertilization rate can effectively promote micronutrient accumulation. The highest Cu content (3.745 mg/kg, 31.2% above control) was recorded in N₁₆₀P₁₆₀, highly significant (**), demonstrating a strong dose-dependent response. The greater response in maize compared to wheat may reflect species-specific differences in root uptake efficiency, Cu translocation, and grain accumulation capacity (Cakmak, 2008).

Mathematical modeling of the results regarding the copper concentration in corn kernels from the variants of the experiment with nitrogen, phosphorus and manure taken into study, shows that the polynomial-type function, $y = -0.027x^2 + 0.4222x + 2.473$, $R^2 = 0.989$, best quantifies the relationship between the doses of NP and manure fertilizers and the copper concentration in maize seeds (Figure 2).

The observed progressive trend underscores the role of combined NP fertilization in

enhancing Cu availability and uptake, supporting the findings of Kutman et al. (2012) and Zhao et al. (2020), who reported that integrated nutrient management improves micronutrient content in cereals. Additionally, the strong response in the highest dose variant highlights the potential of intensive, well-balanced fertilization regimes to increase the nutritional quality of maize grains.

These results confirm that Cu accumulation in cereal grains is highly responsive to both mineral fertilization and organic amendments, emphasizing the need for site-specific nutrient management strategies that optimize crop yield and grain micronutrient content. The findings also suggest that long-term application of integrated fertilization could contribute to biofortification of staple crops, addressing micronutrient deficiencies in human diets.

Table 1

Copper concentration in wheat grains as influenced by different NP fertilizers doses combined with farmyard manure

| Variant | Cu concentration | | Difference | | Statistical significance |
|--|------------------|----------|------------|------|--------------------------|
| | mg/kg | % | mg/kg | % | |
| N ₀ P ₀ + 0 t/ha manure | 1.655 | 100 | - | - | Control |
| N ₅₀ P ₀ + 20 t/ha manure | 1.935 | 117.0 | 0.280 | 17.0 | - |
| N ₅₀ P ₅₀ + 40 t/ha manure | 2.105 | 127.3 | 0.450 | 27.3 | * |
| N ₁₀₀ P ₁₀₀ + 60 t/ha manure | 2.250 | 136.0 | 0.595 | 36.0 | * |
| | | LSD 5% | 0.316 | | |
| | | LSD 1% | 0.618 | | |
| | | LSD 0.1% | 0.970 | | |

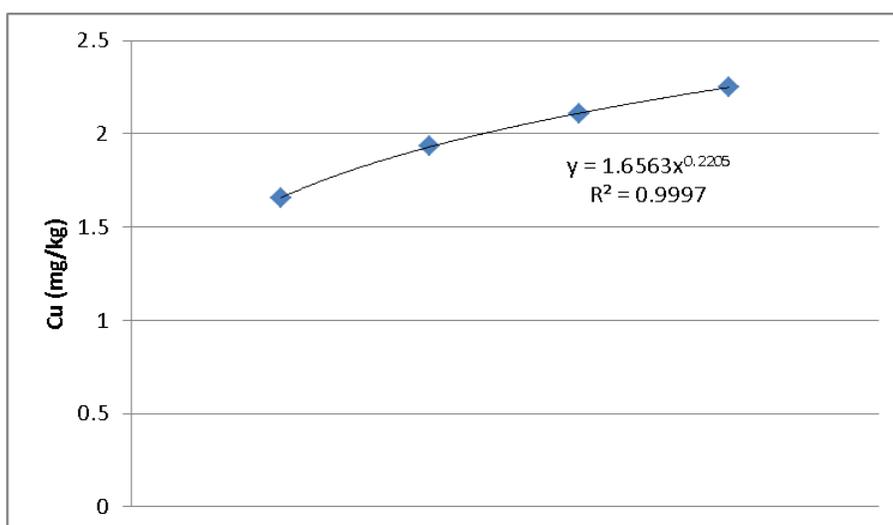


Figure 1 Correlation between doses of NP fertilizers and manure and copper concentration in wheat grains

Table 2

Copper concentration in maize grains as influenced by different NP fertilizers doses combined with farmyard manure

| Variant | Cu concentration | | Difference | | Statistical significance |
|--|------------------|-------|------------|------|--------------------------|
| | mg/kg | % | mg/kg | % | |
| N ₀ P ₀ + 0 t/ha manure | 2.853 | 100 | - | - | Control |
| N ₄₀ P ₄₀ + 20 t/ha manure | 3.255 | 114.1 | 0.402 | 14.1 | - |
| N ₈₀ P ₈₀ + 40 t/ha manure | 3.451 | 120.8 | 0.598 | 20.8 | * |
| N ₁₆₀ P ₁₆₀ + 60 t/ha manure | 3.745 | 131.2 | 0.892 | 31.2 | ** |
| LSD 5% | | | 0,489 | | |
| LSD 1% | | | 0,806 | | |
| LSD 0.1% | | | 1,220 | | |

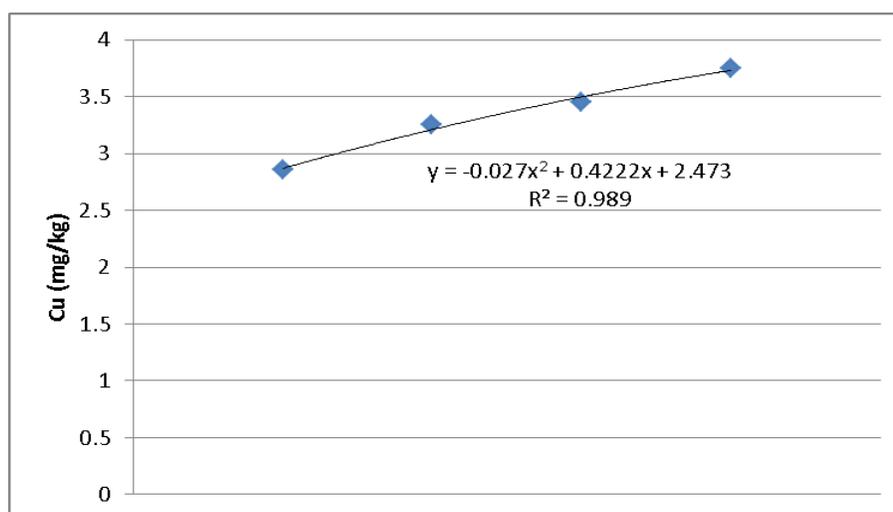


Figure 2 Correlation between doses of NP fertilizers and manure and copper concentration in maize grains

CONCLUSIONS

Copper concentration in wheat and maize increases progressively with NP fertilization and manure application.

Significant differences were observed in high fertilization variants, confirming the effectiveness of integrated organo-mineral fertilization.

The study provides guidance for optimizing fertilization to improve micronutrient content in cereals.

Combined fertilization strategies enhance both crop yield potential and nutritional quality.

REFERENCES

- Alloway, B.J., Ayres, D.C. (1997). *Chemical Principles of Environmental Pollution*. CRC Press.
- Alloway, B.J. (2008). *Micronutrient Deficiencies in Global Crop Production*. Springer.
- Alloway, B.J. (2013). *Heavy Metals in Soils*. Springer.
- Brown, P.H., et al. (1995). Copper in Plants: Deficiency and Toxicity. *Plant Soil*, 174, 7–12.

- Cakmak, I. (2000). Role of micronutrients in crop production. *Plant Soil*, 220, 203–214.
- Fageria, N.K., Baligar, V.C., Jones, C.A. (2011). *Growth and Mineral Nutrition of Field Crops*. CRC Press.
- FAO. (2019). *World Fertilizer Trends and Outlook to 2025*. FAO.
- Frossard, E., et al. (2000). Trace elements in cereals. *Nutrient Cycling in Agroecosystems*, 58, 1–14.
- Gupta, U.C., et al. (2013). *Micronutrients in Soils and Crops*. Springer
- Kabata-Pendias, A. (2011). *Trace Elements in Soils and Plants*. 4th Edition. CRC Press.
- Marschner, H. (2012). *Marschner's Mineral Nutrition of Higher Plants*. 3rd Edition. Academic Press.
- Mengel, K., Kirkby, E.A. (2001). *Principles of Plant Nutrition*. 5th Edition. Kluwer Academic.
- Reuter, D.J., Robinson, J.B. (1997). *Plant Analysis: An Interpretation Manual*. CSIRO Publishing.
- Tisdale, S.L., et al. (2020). *Soil Fertility and Fertilizers*. 9th Edition. Pearson.
- Vuşcan, A. (2014). Influența fertilizatorilor minerali și organici asupra solului, ale unor plante furajere și calității cărnii de pui. Teză de doctorat, Universitatea de Științe Agricole și Medicină Veterinară Cluj-Napoca.
- White, P.J., Broadley, M.R. (2005). Biofortification of crops with mineral elements. *Trends Plant Sci*, 10(12), 586–593.

