RESEARCH ON THE CHANGES IN SOIL ANALYSIS DEPENDING ON DIFFERENTIAL ORGANO-MINERAL FERTILIZATION APPLIED TO MAIZE CULTIVATED IN THE BURNAS PLAIN

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Abstract

A two-factor field experiment was carried out in 2024 on the chernozem soil of the Burnas Plain, Teleorman County, under irrigated conditions, to evaluate the impact of differentiated organo-mineral fertilization on soil properties and maize performance. The experiment was conducted at the S.C. MILAGRO ANG S.R.L. farm in Sfințești, using six maize hybrids (MAS DM 5332, GIRO, P 0450, P 0710, DKC 5810, and DKC 5709) and five fertilization treatments: unfertilized control (M), organic fertilization with 40 t ha^{-1} poultry manure (O), organic + mineral fertilization with 20 t ha^{-1} poultry manure + 111 kg ha^{-1} NPK 20:20:0 (O + NPK), mineral fertilization with 222 kg ha^{-1} NPK 20:20:0 (NPK), and urea fertilization at 310 kg ha^{-1} (U).

Soil samples were collected before fertilization and after harvest to determine pH, humus, total nitrogen, available phosphorus and potassium, zinc, copper, and magnesium. The results indicated that poultry manure significantly increased soil humus content and nutrient availability, especially when combined with mineral fertilizers. The organic + NPK treatment recorded the highest improvement in humus content (2.48% in the 0 - 20 cm layer) and enhanced levels of available phosphorus and potassium compared to the control.

The findings highlight that balanced organo-mineral fertilization can improve soil fertility, sustain maize productivity, and contribute to sustainable nutrient management on chernozem soils in southern Romania.

Keywords: maize, organo-mineral fertilization, soil analysis, chernozem, humus, macronutrients

INTRODUCTION

The cultivation of maize (Zea mays L.) on the Romanian Plain constitutes a cornerstone of cereal production in Eastern Europe, contributing significantly to national grain output and food security (Dragomir et al., 2022). In years favorable for maize cultivation, hybrids from the FAO groups 260–340, 350–390, and 400–460 grown on chernozem soils achieve similar yield levels (Ștefan et al., 2024).Nutrient management remains a key determinant of maize productivity, influencing physiological processes, grain yield and quality (Petre, 2022). Foliar fertilization of maize crop provides an effective solution for a rapid and targeted supply of nutrients and to fully exploit the yield potential of maize (Cioboată et al., 2025) However, aside from chemical nutrition, the physical status of the soil, particularly bulk density, total porosity and compaction plays an increasingly recognised role in mediating crop response to fertilisation regimes (Jiang et al., 2025). Indeed, elevated bulk density and reduced porosity inhibit root penetration, restrict water and nutrient movement, and impair maize growth (Frene & Pandey, 2024). In this context, differentiated fertilisation strategies that integrate organic amendments (e.g., poultry manure) with mineral fertilisers may offer dual benefits: nutrient supply and enhancement of soil physical quality.

Soil bulk density (BD), defined as the mass of oven-dry soil per unit volume including pore space, is a widely used indicator of soil compaction and root-growth constraint. Higher BD values indicate more dense, less porous soils, which can lead to restricted root growth, reduced aeration and slower nutrient uptake (Wang et al., 2025). Total porosity (TP), the fraction of the soil volume comprised of pores, is inversely related to bulk density and indicates the capacity of the soil to hold both air and water (Odugbenro et al., 2023). In many studies, fertilisation with organic amendments has been shown to reduce bulk density and increase porosity, thereby improving soil structural conditions (Wang et al., 2020). The degree of densification or compaction, often measured indirectly via BD and TP, emerges as a critical parameter in assessing the resilience of soils under intensive fertilisation (Frene & Pandey, 2024).

Fertilisation practices influence soil physical properties both directly and indirectly. For example, the addition of organic matter increases aggregate stability, promotes the formation of stable biopores and enhances soil porosity, thereby reducing the potential for densification (Abbas et al., 2024). On the other hand, heavy reliance on mineral fertilisers, particularly when not accompanied by organic amendments, may accelerate structural degradation, increase compaction risk and elevate bulk density (Jiang et al., 2025). Several meta-analyses have documented a negative correlation between maize grain yield and bulk density across a range of fertilisation regimes, reinforcing the need to integrate physical soil quality into fertiliser strategy design.

In the specific context of organo-mineral fertilisation, treatments combining organic and mineral sources often outperform mineral-only regimes in terms of both soil physical improvement and yield response (Ma et al., 2025). For instance, one study found that an optimised fertilisation regime (organic + mineral) slightly reduced bulk density and improved soil porosity compared to conventional mineral fertilisation on an albic soil in Northeast China (Ma et al., 2025). Similarly, organic amendments alone (e.g., poultry manure, biochar) significantly lowered bulk density and increased total porosity in maize cropping systems, especially in the upper soil layer (Odugbenro et al., 2023). These findings suggest that spatial and temporal dynamics of BD and TP should be considered within fertilisation experiments.

The interplay between fertilisation level and depth of soil sampling is also critical. Many fertilisation-physical-soil studies report stronger effects in the topsoil (0–20 cm) than deeper layers, likely due to root activity, amendments placement and tillage history (Odugbenro et al., 2023). Bulk density reductions and porosity increases were mainly observed in the 0–20 cm layer under organic amendment treatments, whereas deeper layers often showed minimal change (Ma et al., 2025). This vertical heterogeneity underscores the importance of measuring soil physical parameters at multiple depths when evaluating fertilisation impacts.

Beyond bulk density and porosity, the concept of soil compaction or densification is increasingly used to interpret the cumulative effect of management, loading and fertilisation on soil physical quality (Frene & Pandey, 2024). Compacted soils restrict not only root growth but also microbial activity and nutrient cycling, thereby compromising crop responses to fertilisers. Integrated fertiliser strategies that prevent compaction (for instance through organic matter addition) are therefore indispensable for sustainable maize production (Abrol et al., 2024). Indeed, long-term experiments demonstrate that combined organic and mineral fertiliser regimes reduce compaction risks and maintain favourable BD/TP ratios over time (Abrol et al., 2024).

When organic fertilisation (such as poultry manure) is applied in judicious doses, improvements in soil chemical fertility (humus content, available P and K) are often accompanied by physical enhancements (reduced bulk density, increased porosity) (Wang et al., 2020). Consequently, exploring organo-mineral fertilisation effects on BD, TP and soil densification, alongside nutrient and yield responses, is essential to develop locally-adapted fertilisation recommendation.

MATERIALS AND METHODS

The Sfințești commune, where the S.C. MILAGRO ANG S.R.L. farm is located and where the field experiment was established, lies in the central-southern part of the Romanian Plain, Teleorman County, a geographical area particularly favorable for field crops.

A two-factor experiment was established in 2024 at the S.C. MILAGRO ANG S.R.L. farm in Sfințești, Teleorman County.

Factor A (the type of fertilization) included five levels: b_1 = unfertilized (control – M); b_2 = organic fertilization with 40 t/ha poultry manure; b_3 = combined fertilization with 20 t/ha poultry manure + 111 kg/ha NPK 20:20:0; b_4 = NPK 20:20:0 at 222 kg/ha; b_5 = urea at 310 kg/ha.

Factor B (the hybrid) included six levels: a_1 = MAS DM 5332, a_2 = GIRO, a_3 = P 0450, a_4 = P 0710, a_5 = DKC 5810, and a_6 = DKC 5709.

Soil samples were collected both before fertilization and after harvest.

The following parameters were analyzed: soil pH, humus content, bulk density, porosity, degree of compaction, total nitrogen, available phosphorus and potassium, zinc, copper and magnesium contents.

The analytical methods used were as follows:

• Determination of soil pH in aqueous suspension (1:2.5): SDR 7184-13:2001; PTL 04 ed.3 rev 0.

• Determination of humus content by wet oxidation: STAS 7184-13:2001; PTL 12 ed.3 rev 0.

• Determination of total nitrogen (Nt) by the Kjeldahl method: STAS 7184-13:2001; PTL 09 ed.3 rev 0.
• Determination of available phosphorus (PAL) by ammonium acetate-lactate extraction: SDR 7184-13:2001; PTL 19 ed.3 rev 0.
• Determination of available potassium (KAL) by ammonium acetate-lactate extraction: SDR 7184-13:2001; PTL 22 ed.3 rev 0.
• Determination of mobile forms of Cu, Fe, Mn and Zn extractable in EDTA solution: PTL 32 ed.3 rev 0.
• Determination of available magnesium (Mg) content: according to Methods for Assessing the Soil Fertility Status (Borlan & Hera, 1973; PT 152).

Poultry manure used in the experiment represents a valuable organic fertilizer, distinguished by its high content of nitrogen, phosphorus, and potassium, nutrients essential for the optimal development of maize crops. Its relatively high concentration of readily available nutrients promotes an early release of nitrogen into the soil and supports vigorous vegetative growth, as demonstrated by Rasool et al. (2023) and Fiyyaz et al. (2021), who reported significant improvements in maize physiological traits and early biomass when poultry manure was applied.

Poultry manure contains substantial amounts of organic matter that enhance soil structure, increase water-holding capacity, and stimulate beneficial microbial activity. Long-term applications contribute to higher humus content, improved aggregation, reduced compaction, and better soil aeration, key conditions for healthy maize root development. Similar findings were reported by Ewulo et al. (2008) and Agbede (2025), who showed that poultry manure significantly improves both soil physical properties and crop performance.

Poultry manure also influences the availability of phosphorus and micronutrients by maintaining a soil pH favorable to nutrient uptake and by reducing the fixation of phosphorus into insoluble forms. According to Hanč et al. (2008), poultry-based organic fertilizers increase the bioavailability of P and K and improve nutrient-use efficiency. When applied alone or combined with mineral fertilizers, poultry manure has been shown to generate considerable yield increases in maize, as highlighted in studies by Fiyyaz et al. (2021) and Batyrbek et al. (2022).

However, improper application, particularly in excessive doses or without prior composting, may lead to nitrate leaching and contamination of groundwater. da Rosa et al. (2020) documented significant nitrogen losses following the application of poultry litter on maize systems, while Foley et al. (2012) emphasized the risks of groundwater pollution associated with nitrate mobility. For these reasons, application rates must be adjusted according to crop needs and soil characteristics, and composting practices should be integrated to optimize nutrient efficiency and minimize environmental risks.

The composition of poultry manure is presented in Table 1.

Table 1. Chemical composition of the poultry manure used in the experiment

Parameter	Value	Notes
pH	6.13	-
Moisture (Umd)	52,86	%
Crude Protein (PC)	42,33	%
Organic Matter (MO)	48,40	%
Organic Carbon (Corg)	11,80	% dry matter
Total Nitrogen (N)	2,30	% dry matter
Phosphorus (P)	0,91	% dry matter
Potassium (K)	1,79	% dry matter
Calcium (Ca)	0,64	% dry matter
Magnesium (Mg)	0,72	% dry matter

For the second data set, used to determine bulk density, total porosity, and degree of compaction, soil samples were collected from the differentiated irrigation treatments.

The interpretation of the results was carried out using the method described by Săulescu and Săulescu (1965) for the analysis of bifactorial experiments.

RESULTS AND DISCUSSION

A comparative analysis of the soil indicators determined for the treatments established under factor A, in relation both to the initial analyses conducted before the experiment was set up and to the unfertilized control soil, revealed a series of changes, as presented in Table 2:

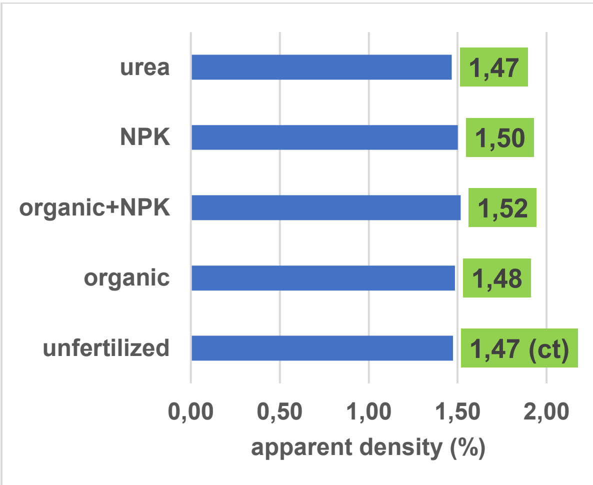
- while pH and copper content remained at values similar to the initial ones, all other parameters showed noticeable differences compared with the baseline analyses;
- phosphorus content, humus content, and copper content showed no differentiation or only very slight variation between soil depths;
- humus content was differentiated according to fertilization, recording a value of 2.48% in the 0 - 20 cm layer under the organic + NPK fertilization treatment;

A certain uniformity was observed in the Cu and Mg contents, regardless of fertilization or depth. For both elements, there was also an increase in values compared with the soil analyzed prior to fertilization and sowing.

Table 2. Comparative results of soil analysis according to differentiated organo-mineral fertilization

Identification according to the graduations of factor B	Depth (cm)	pH (units)	Humus (%)	Nt (%)	PAL (mg/kg)	KAL (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mg în CaCl2 (mg/100g)
	Before fertilization and sowing								
Sol nefertilizat	0-20	5,63	2,66	0,135	61	186	0,60	3,17	13,13
	20-40	5,75	2,69	0,113	61	193	0,75	3,20	14,7
After fertilization and harvest									
Control soil	0-20	5,50	2,17	0,117	33	164	1,1	3,6	19,7
	20-40	5,61	2,11	0,103	18	106	0,7	3,5	19,4
Unfertilized control soil	0-20	5,41	2,36	0,121	42	158	1,7	3,5	19,8
	20-40	5,25	2,24	0,108	32	118	1,2	3,5	24,0
Soil with organic +NPKfertilization	0-20	5,62	2,48	0,137	42	160	3,0	4,3	20,7
	20-40	5,26	2,36	0,135	31	164	1,4	3,4	19,5
Soil with NPK fertilization	0-20	5,45	2,40	0,120	43	174	1,9	3,5	19,5
	20-40	5,54	2,42	0,128	32	139	1,1	3,3	19,9
Soil with urea fertilization	0-20	5,66	2,36	0,128	32	139	1,1	3,0	18,7
	20-40	5,54	2,42	0,135	32	139	0,8	3,4	20,2

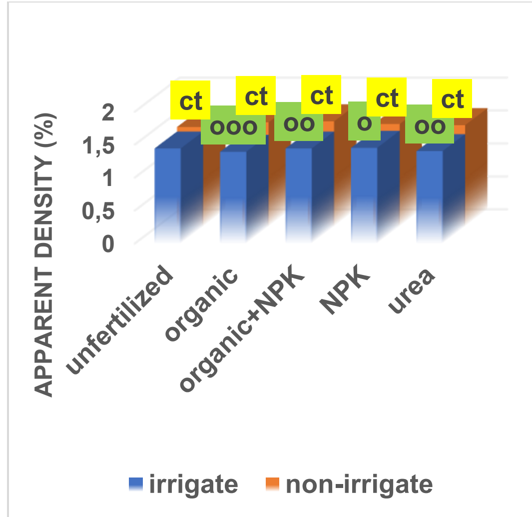
Bulk density. The type of fertilization used in the experiment did not influence soil bulk density. The recorded values showed only slight variation, ranging between 1.47 and 1.52 g/cm³ (Figure 1).



DL 5%	**0,08 %**
DL 1%	**0,11%**
DL 0.1%	**0,15%**

Figure 1. Influence of fertilization type on soil bulk density in the 0 - 20 cm layer

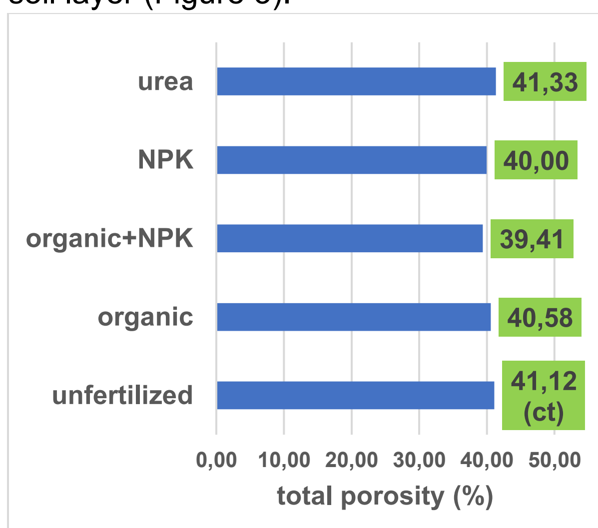
In general, bulk density values were higher under non-irrigated conditions. The interaction between the two factors had a strong influence on bulk density, such that in the fertilized treatments it decreased significantly, with statistical assurance, under irrigation conditions (Figure 2).



DL 5%	**0,10 %**
DL 1%	**0,14%**
DL 0.1%	**0,19%**

Figure 2. Influence of the fertilization type × irrigation level interaction on soil bulk density in the 0 - 20 cm layer

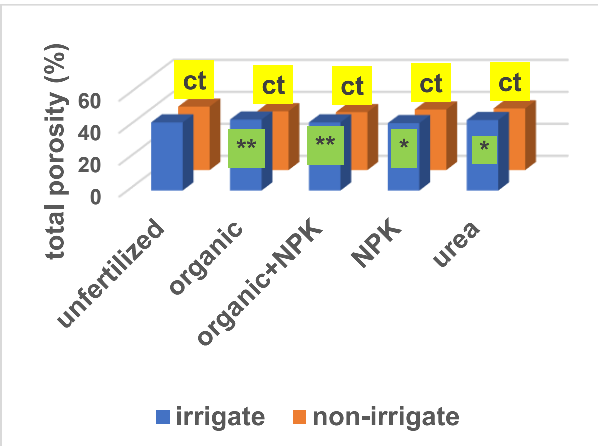
Total porosity. As in the case of bulk density, the type of fertilization did not influence total porosity in the 0–20 cm soil layer (Figure 3).



DL 5%	**3,43 %**
DL 1%	**4,65%**
DL 0.1%	**6,21%**

Figure 3. Influence of fertilization type on total soil porosity in the 0 - 20 cm layer

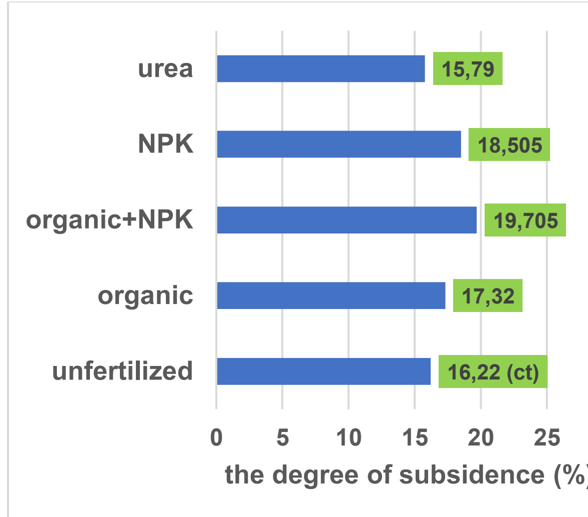
Under irrigation conditions, total porosity recorded higher values, all statistically significant in the fertilized treatments (Figure 4). The highest total porosity value was observed under organic fertilization with irrigation, reaching 51.57%. Under these conditions, the results suggest that the interaction between the studied factors significantly influences total soil porosity.



DL 5%	**4,21 %**
DL 1%	**5,71%**
DL 0.1%	**7,63%**

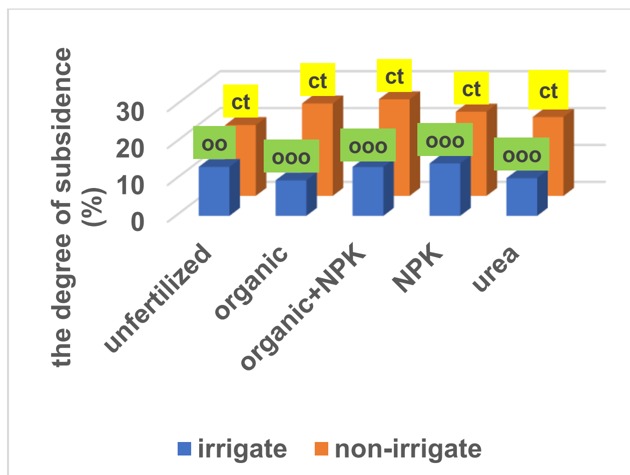
Figure 4. Influence of the fertilization type × irrigation level interaction on soil bulk density in the 0 - 20 cm layer

Soil compaction degree. This soil analysis indicator was not influenced by the type of fertilization (Figure 5). However, the interaction between fertilization type and irrigation level strongly affected the degree of soil compaction, including in the unfertilized treatment (Figure 6).



DL 5%	**4,25 %**
DL 1%	**6,05%**
DL 0.1%	**8,75%**

Figure 5. Influence of fertilization type on soil compaction degree in the 0 - 20 cm layer



DL 5%	**3,67 %**
DL 1%	**5,24%**
DL 0.1%	**7,59%**

Figure 6. Influence of the fertilization type × irrigation level interaction on soil compaction degree in the 0 - 20 cm layer

CONCLUSIONS

A comparative assessment of the soil indicators determined in the analyzed profile, interpreted according to the graduations of factor A and reported both to the initial analyses conducted prior to the establishment of the experiment and to the unfertilized control, highlights a clear differentiation of humus content as influenced by the fertilization regime. The highest value, 2.48% in the 0 - 20 cm layer, was recorded in the variant combining organic fertilization with NPK mineral inputs.

In the second dataset, the type of fertilization, organic, mineral, or the combination of the two, did not exert a significant influence on bulk density, total porosity, or soil compaction degree within the 0 - 20 cm depth.

Furthermore, the interaction between fertilization type and irrigation level strongly affected all three physical soil properties. Irrigation led to a statistically significant increase in total porosity, while bulk density and compaction degree recorded statistically assured decreases compared with the non-irrigated variant.

REFERENCES

Abbas, A., et al. (2024). The efficacy of organic amendments on maize productivity and soil health. Spanish *Journal of Soil Science*, 1, Article 12814. https://doi.org/10.3389/sjss.2024.12814.

Abrol, V., Sharma, P., Chary, G. R., et al. (2024). Integrated organic and mineral fertilizer strategies for achieving sustainable maize yield and soil quality in dry sub-humid Inceptisols. *Scientific Reports*, 14, 74727. https://doi.org/10.1038/s41598-024-74727-4

Agbede, T. M. (2025). Poultry manure improves soil properties and grain mineral composition, maize productivity and economic profitability. *Scientific Reports*, 15, 3948. https://doi.org/10.1038/s41598-025-00394-8

Batyrbek, M., Abbas, F., Fan, R., & Han, Q. (2022). Influence of mineral fertilizer and manure application on the yield and quality of maize in relation to intercropping in the Southeast Republic of Kazakhstan. *Plants*, 11(19), 2644. https://doi.org/10.3390/plants11192644

Borlan Z., Hera C., Dornescu D., Kurtinecz P., Rusu M., Buzdugan I., Tănase G. (1994). *Fertilitatea şi fertilizarea solurilor. Compendiu de agrochimie*. Bucureşti: Editura Ceres

Cioboată, M. N., Păunescu, R. A., Florea, D. F., Roșculete, C. A., & Roșculete, E. (2025). Influence of foliar fertilization with boron and zinc for maize grain crop in the hilly area of south-western Romania. *Romanian Agricultural Research*, 42, 577–586. https://doi.org/10.59665/rar4249

da Rosa, G. M., Gabriel, M., da Silva, J. C., Mendonça, A. M., Costa Junior, J. A., & Wastowski, A. D. (2020). Leaching of the different forms of nitrogen by the application of poultry litter, swine waste, and mineral nitrogen on corn cultures (Zea mays L.). *Environmental Quality Management*, 28(4), 131–138. https://doi.org/10.1002/tqem.21586

Dragomir, N., Voicu, R., Mărginean, R., & Popescu, L. (2022). An overview of the global maize market compared to Romanian production. *Romanian Agricultural Research*, 39, 51–58. https://www.incda-fundulea.ro/rar/nr39/rar39.51.pdf

Ewulo, B. S., Ojeniyi, S. O., & Akanni, D. A. (2008). Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. *African Journal of Agricultural Research*, 3(9), 612–616.

Riaz, A. (2021). Integration of mineral fertilizer and poultry manure for improving soil health and maize growth under calcareous soil environment. *Pakistan Journal of Agricultural Research*, 34(3), 495–500. https://doi.org/10.17582/journal.pjar/2021/34.3.495.500

Fiyyaz, M., Sarwar, G., Noor-Us-Sabah, Tahir, M. A., Aftab, M., Manzoor, M. Z., Hussain, S., Zafar, A., Shehzad, I., &

Fiyyaz, M., Sarwar, G., Noor-Us-Sabah, Tahir, M. A., Aftab, M., Manzoor, M. Z., Muhammad, S., Latif, M., Zafar, A., Shehzad, I., Hussain, S., Riaz, A., & Niaz, A. (2021). Efficiency of poultry manure for improving nutrient composition of maize plants under calcareous soil environment. *Pakistan Journal of Agricultural Research*, 34(3), 473–478. https://doi.org/10.17582/journal.pjar/2021/34.3.473.478

Foley, K. M., Doniger, A. R., Shock, C. C., Horneck, D. A., & Welch, T. K. (2012). *Nitrate pollution in groundwater: A grower's guide* (Ext/CrS 137). Oregon State University Extension Service.

Frene, J. P., & Pandey, B. K. (2024). Elucidating soil compaction and its effect on soil functions. *Plant and Soil*. https://doi.org/10.1007/s11104-024-06573-2

Hanč, A., Tlustoš, P., Száková, J., & Balík, J. (2008). The influence of organic fertilizers application on phosphorus and potassium bioavailability. *Plant, Soil and Environment*, 54(6), 247–254.

Jiang, Y., et al. (2025). A meta-analysis of the effects of nitrogen fertilizer on maize yield and soil bulk density. *Frontiers in Plant Science*, 15, 1485237. https://doi.org/10.3389/fpls.2024.1485237

Ma, X., Zhao, Y., Zheng, Y., Wang, L., Zhang, Y., Sun, Y., Ji, J., Hao, X., Liu, S., & Sun, N. (2025). Effect of different fertilization on soil fertility, biological activity, and maize yield in the albic soil area of China. *Plants*, 14(5), 810. https://doi.org/10.3390/plants14050810

Odugbenro, G. O., et al. (2023). Soil quality alteration and maize (Zea mays L.) yield after different organic amendments. *Soil Science Annual*, Article 177042.

Pacheco, C. A., et al. (2023). Effects of mineral and organic fertilization on forage maize and soil physical/chemical properties. *Springer Nature Agronomy Journal*, Article 10.1007/s42106-023-00250-7.

Petre, A. (2022). Competitiveness of foreign trade in cereals at county level

(Romania). In Proceedings of the International Management Conference (pp. 245–252). Bucharest University of *Economic Studies*. https://conference.management.ase.ro/archives/2022/pdf_IMC_2022/3_7.pdf

Rasool, A., Ghani, A., Nawaz, R., Ahmad, S., Shahzad, K., Rebi, A., … Ercisli, S. (2023). Effects of poultry manure on the growth, physiology, yield, and yield-related traits of maize varieties. *ACS Omega*, 8(29), 25766–25779. https://doi.org/10.1021/acsomega.3c00880

Săulescu, N. N. (1967). *Câmpul de experiență*. București: Editura Agro-Silvică.

Ștefan, I. O., Păunescu, G., Păunescu, R. A., Olaru, A.-L., & Ștefan, M. (2024). Study of the early–production relationship in maize hybrids grown at Caracal, Romania. Scientific Papers. Series A. Agronomy, 67(2), 411–416.

Tabler, T., Hawkins, S., Walker, F., Rius, A., Thornton, T., Liang, Y., Moon, J., & Urrutia, J. (2025). *Challenges and benefits of managing and utilizing poultry litter inside and outside the broiler house* (W1329). University of Tennessee Extension.

Wang, X., et al. (2020). Organic manure input improves soil water and nutrients use under maize in Loess Plateau of China. *PLoS ONE*, 15(8), e0238042. https://doi.org/10.1371/journal.pone.0238042