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Effect of Different Nutrients on Physical and Chemical Properties of Maize (*Zea mays* L.) Under Long Term Fertilizer Experiment

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Abstract— *Long-term nutrient management plays a crucial role in maintaining soil health and sustaining crop productivity. A field experiment was conducted during kharif 2025 under the Long-Term Fertilizer Experiment (LTFE) at Rajasthan College of Agriculture, Udaipur, to evaluate the effects of integrated nutrient management on selected soil physical and chemical properties in maize (*Zea mays *L.). The experiment was laid out in a randomized block design with 12 nutrient management treatments and four replications. Results revealed that long-term application of farmyard manure (FYM), either alone or in combination with recommended NPK fertilizers, significantly improved soil quality. The lowest bulk density (1.33 Mg m^{-3}) was recorded under FYM @ 20 t ha^{-1} (T_8), representing an 8.90% reduction over the control, while particle density remained unaffected across treatments. Soil pH showed only marginal, non-significant variation, whereas electrical conductivity ranged from 0.82 to 0.93 dS m^{-1}. Organic amendments markedly enhanced soil organic carbon and cation exchange capacity, with the highest values (0.990% OC and 13.54 cmol(p$^+$) kg^{-1} CEC) observed under FYM @ 20 t ha^{-1}. The findings demonstrate that continuous incorporation of FYM, particularly when integrated with balanced fertilization, effectively improves soil physical condition, increases organic carbon, enhances nutrient retention and promotes long-term soil fertility.*

Keywords— ***Integrated nutrient management, long-term fertilizer experiment, farmyard manure, bulk density, soil organic carbon, cation exchange capacity.***

I. INTRODUCTION

Maize (*Zea mays* L.), popularly known as the "Queen of Cereals," is one of the world's most important cereal crops because of its high yield potential, wide adaptability and diverse utilization as food, feed, fodder and industrial raw material. Globally, maize is cultivated on over 203 million hectares, producing more than 1.1 billion tonnes annually, while in India it ranks third after rice and wheat in both area and production, significantly contributing to food security and rural livelihoods (FAOSTAT, 2025; Prasanna *et al*., 2021). Soil physical properties, bulk density (BD) and particle density (PD) are important indicators of soil structural condition. Bulk density reflects the degree of soil compaction and influences root penetration, aeration, water infiltration, and microbial activity. Lower bulk density generally indicates better soil aggregation and greater pore space, particularly under long-term organic manure application. In contrast, particle density represents the density of soil solids and is relatively stable in mineral soils, showing only slight variation with changes in soil organic matter. Consequently, bulk density is considered a more sensitive indicator of management-induced changes than particle density. (Brady and Weil, 2002). Chemical properties such as soil pH, electrical conductivity (EC), cation exchange capacity (CEC), and soil organic carbon (SOC) are essential for evaluating soil fertility. Soil pH regulates nutrient availability and microbial activity, while EC indicates the concentration of soluble salts affecting nutrient uptake and crop growth. Cation exchange capacity determines the soil's ability to retain and supply essential nutrient cations, and is strongly influenced by clay minerals and organic matter. Soil organic carbon is regarded as a major indicator of soil quality because it improves aggregate stability, water-holding capacity, nutrient retention, and biological activity. Long-term incorporation of FYM along with balanced fertilization significantly enhances SOC and CEC while maintaining favourable pH and EC, thereby improving soil fertility and resilience (Hati *et al*., 2021; Dhaliwal *et al*., 2021). Therefore, integrated nutrient management (INM), combining inorganic fertilizers with organic sources such as farmyard manure (FYM), has emerged as an effective strategy to improve nutrient availability, enhance soil organic matter, stimulate microbial activity and sustain long-term soil fertility (Pant *et al*., 2017; Tiwari *et al*., 2024).

II. MATERIALS AND METHODS

A field experiment was conducted during the *kharif* season of 2025 under the All India Coordinated Research Project on Long-Term Fertilizer Experiments (AICRP-LTFE) at the B_2 Instructional Farm, Rajasthan College of Agriculture, Udaipur, Rajasthan, India (24°35′ N, 73°42′ E; 582.2 m above mean sea level). The experiment represents the 29th maize–wheat cropping cycle of the LTFE, which was initiated in 1996. The experimental site falls under Agro-climatic Zone IVa (Sub-Humid Southern Plain and Aravalli Hills) of Rajasthan. Before sowing, composite soil samples (0–15 cm depth) were collected to determine the initial physico-chemical properties of the experimental soil. The soil was sandy clay loam, slightly alkaline (pH 8.26), non-saline (EC 0.88 dS m^{-1}), with 0.529% organic carbon, cation exchange capacity (CEC) of 9.51 cmol(p^+) kg^{-1}, bulk density of 1.47 Mg m^{-3} and particle density of 2.63 Mg m^{-3}. Soil analyses were carried out following standard procedures: bulk density by the core sampler method (Piper, 1950), particle density by Gupta and Dakshina-Moorthy (1980), soil pH and electrical conductivity using a 1:2 soil-water suspension (Richards, 1954) and organic carbon by the Walkley and Black (1934) wet oxidation method. The experiment was laid out in a Randomized Block Design (RBD) with 12 treatments and four replications, comprising 48 plots. The treatments included different combinations of inorganic fertilizers, farmyard manure (FYM), zinc, sulphur and *Azotobacter*: T_1 100% NPK, T_2 100% NPK + Zn, T_3 100% NPK + Zn + S, T_4 100% NPK + S, T_5 100% NPK + *Azotobacter*, T_6 FYM @10 t ha^{-1} + (100% NPK -NPK Content of FYM),T_7 100% NPK + FYM @ 10 t ha^{-1}, T_8 FYM @ 20 t ha^{-1}, T_9 150% NPK, T_{10} 100% NP, T_{11}100% N and T_{12} control. Pratap Hybrid Makka-3 was sown at a seed rate of 25 kg ha^{-1}. The recommended fertilizer dose was 120 kg N, 26 kg P_2O_5, 25 kg K_2O, 5 kg Zn and 20 kg S ha^{-1}, supplied through urea, diammonium phosphate (DAP), muriate of potash (MOP), zinc sulphate ($ZnSO_4 \cdot 7H_2O$) and gypsum. The FYM used in the study contained 0.50% N, 0.25% P_2O_5 and 0.50% K_2O and nutrient contributions from FYM were considered while calculating fertilizer requirements in the integrated nutrient management treatments. At crop harvest, soil samples were collected for the determination of selected physical and chemical properties.

III. RESULTS AND DISCUSSION

1.Effect of Long-Term Nutrient Management on Soil Physical Properties

Long-term nutrient management significantly influenced bulk density (BD**)**, whereas particle density (PD) remained unaffected (Table 1). Bulk density varied from 1.33 to 1.46 Mg m^{-3}**,** with the lowest value under FYM @ 20 t ha^{-1} (T_8), representing an 8.90% reduction over the control (T_{12}). Integrated nutrient management treatments, particularly T_6 (FYM @10 t ha^{-1} + (100% NPK -NPK Content of FYM) and T_7 (100% NPK + FYM @10 t ha^{-1})**,** also recorded lower BD than the sole inorganic fertilizer treatments, indicating improved soil physical condition through long-term organic matter addition. In contrast, the highest BD (1.46 Mg m^{-3}) was observed in the unfertilized control. Particle density ranged from 2.58 to 2.65 Mg m^{-3} and did not differ significantly among treatments, suggesting that long-term nutrient management had negligible influence on the mineral composition of soil particles. Application of FYM alone or in combination with NPK significantly reduced bulk density by improving soil aggregation, pore continuity and biological activity, thereby enhancing soil structure. In contrast, particle density remained unaffected across treatments, indicating its dependence on inherent soil mineral composition rather than nutrient management (Thakur *et al*., 2022; Fageria *et al*., 2023; Ma *et al*., 2025).

Table 1: Effect of organic and inorganic fertilization on bulk density (Mg m^{-3}) and particle density (Mg m^{-3}) of soil after harvest of maize under long term fertilizer experiment

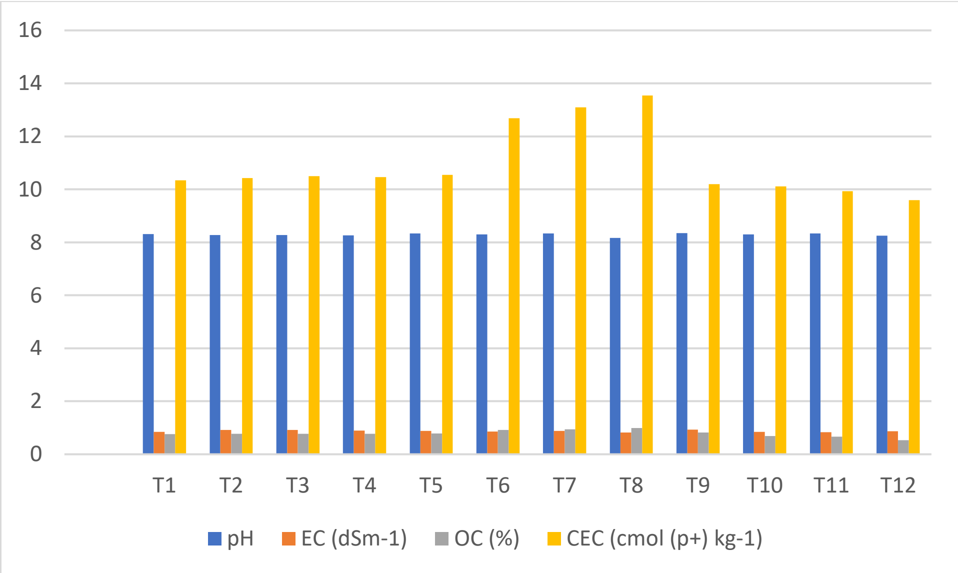
Treatment	**BD (Mg m^{-3})**	**PD (Mg m^{-3})**
T_1:100% NPK	1.41	2.63
T_2:100% NPK + Zn	1.38	2.64
T_3: 100% N P K + Zn + S	1.37	2.65
T_4: 100% N P K + S	1.38	2.63
T_5: 100% N P K + Azotobacter	1.37	2.64
T_6: FYM 10 t ha^{-1} + (100% N P K – NPK Content of FYM)	1.35	2.60
T_7: 100% N P K + FYM 10 t ha^{-1}	1.34	2.61
T_8: FYM @ 20 t ha^{-1}	1.33	2.58
T_9: 150% NPK	1.36	2.64
T_{10}: 100% NP	1.42	2.64
T_{11}: 100% N	1.43	2.64
T_{12}: Control	1.46	2.63
S.Em. +	0.03	0.03
C.D. (P= 0.05)	0.10	NS

Table 2: Effect of organic and inorganic fertilization on available pH, EC (dSm^{-1}), OC & CEC (cmol (p+) kg^{-1}) of soil after harvest of maize under long term fertilizer experiment

Treatments	pH	EC (dSm^{-1})	OC (%)	CEC (cmol (p+) kg^{-1})
T_1:100% NPK	8.31	0.85	0.763	10.34
T_2:100% NPK + Zn	8.28	0.92	0.769	10.43
T_3: 100% N P K + Zn + S	8.28	0.92	0.776	10.50
T_4: 100% N P K + S	8.26	0.89	0.769	10.46
T_5: 100% N P K + Azotobacter	8.33	0.88	0.782	10.55
T_6: FYM 10 t ha^{-1} + (100% N P K – NPK Content of FYM)	8.30	0.86	0.920	12.68
T_7: 100% N P K + FYM 10 t ha^{-1}	8.34	0.88	0.944	13.09
T_8: FYM @ 20 t ha^{-1}	8.17	0.82	0.990	13.54
T_9: 150% NPK	8.35	0.93	0.817	10.20
T_{10}: 100% NP	8.30	0.84	0.693	10.11
T_{11}: 100% N	8.33	0.83	0.659	9.93
T_{12}: Control	8.25	0.87	0.530	9.59
S.Em. +	0.10	0.02	0.01	0.17
C.D. (P= 0.05)	NS	0.05	0.02	0.48

2. Effect of Long-Term Nutrient Management on Soil Chemical Properties

Long-term nutrient management significantly improved soil chemical properties, except soil pH, which remained statistically unchanged despite slight variations (Table 2). Soil pH ranged from 8.17 to 8.35, indicating that the soil remained slightly alkaline across all treatments. Electrical conductivity (EC) varied significantly, with the highest value (0.93 dS m^{-1}) recorded under 150% NPK (T_9), while the lowest EC (0.82 dS m^{-1}) was observed under FYM @ 20 t ha^{-1} (T_8), reflecting the beneficial effect of organic amendments in maintaining lower soluble salt concentrations. Soil organic carbon (OC) increased markedly with organic manure application. The highest OC (0.990%) was recorded in T_8, followed by T_7 (0.944%), whereas the lowest OC (0.530%) occurred in the control. Similarly, cation exchange capacity (CEC) was significantly enhanced by integrated nutrient management. The maximum CEC (13.54 cmol(p^+) kg^{-1}) was observed under T_8, followed by T_7 (13.09 cmol(p^+) kg^{-1}) and T_6 (12.68 cmol(p^+) kg^{-1}), representing increases of 41.18%, 36.49% and 32.22%, respectively, over the control. These findings demonstrate that long-term application of FYM alone or in combination with inorganic fertilizers effectively improved soil organic matter status and nutrient retention capacity while maintaining favorable soil chemical conditions. Long-term FYM application alone or integrated with NPK improved soil chemical properties by maintaining a relatively lower pH, reducing EC and significantly increasing organic carbon and CEC through greater organic matter accumulation and enhanced nutrient retention. In contrast, sole inorganic fertilizer treatments showed comparatively smaller improvements in these properties (Singh *et al*., 2017; Meena *et al*., 2022; Fageria *et al*., 2023; Getaneh *et al*., 2024).



IV. CONCLUSIONS

Long-term nutrient management significantly influenced soil quality, with FYM alone or in combination with NPK producing the most favorable effects. Organic amendments reduced bulk density and markedly increased soil organic carbon and cation exchange capacity while maintaining stable soil pH and electrical conductivity. Among the treatments, FYM @ 20 t ha^{-1} (T_8) followed by 100% NPK + FYM (T_7) proved most effective in improving soil health, highlighting the importance of integrated nutrient management for sustainable maize production.

REFERENCES

[1] Brady, N.C. and Weil, R.R., 2002. *The nature and properties of soils* 13th ed. Prentice Hall. New Jersey, USA, 249.

[2] Dhaliwal, S.S., Sharma, S., Sharma, V., Shukla, A.K., Walia, S.S., Alhomrani, M., Gaber, A., Toor, A.S., Verma, V., Randhawa, M.K. and Pandher, L.K., 2021. Long-term integrated nutrient management in the maize–wheat cropping system in alluvial soils of North-Western India: Influence on soil organic carbon, microbial activity and nutrient status. *Agronomy*, **11**(11):2258.

[3] Fageria, B., Bharose, R., David, A.A., Thomas, T. and Pratihar, A.K.S., 2023. Influence of NPK Levels in Conjugation with FYM on Soil Health Properties at Maize Field in Prayagraj District *(Zea mays L.). International Journal of Plant and Soil Science,* **35**(16):56-66.

[4] FAOSTAT, 2025. FAOSTAT data for maize production. *Food and Agriculture Organization of the United Nations.*

[5] Getaneh, S., Molla, E. and Abera, D., 2024. Effects of integrated fertilizer application on soil properties and yield of Maize (Zea mays L.) on Nitisols in Pawe District,

Northwestern Ethiopia. *Journal of Agriculture and Environmental Sciences*, **9**(1):13-32

[6] Gupta, P.K. and Dakshina-Murthy, K.M., 1980. Procedures for Physical and Chemical Analysis of Soils. *Indian Agricultural Research Institute*, New Delhi.

[7] Hati, K.M., Mandal, K.G., Mishra, A.K., Ghosh, P.K., Bandyopadhyay, K.K. and Acharya, C.L., 2021. Long-term effects of organic amendments on soil physical properties, aggregate stability and crop yields in a Vertisol. *Soil and Tillage Research*, **212**:105044

[8] Ma, X., Zhao, Y., Zheng, Y., Wang, L., Zhang, Y., Sun, Y., Ji, J., Hao, X., Liu, S. and 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.

[9] Meena, R.S., Dwivedi, B.S., Singh, V.K., Gathala, M.K. and Lal, R., 2022. Long-term organic and inorganic nutrient management enhances soil health and productivity in cereal-based systems of the Indo-Gangetic Plains. *Soil Use and Management*, **38**(3):1336–1348.

[10] Pant, P.K., Ram, S. and Singh, V., 2017. Yield and soil organic matter dynamics as affected by the long-term use of organic and inorganic fertilizers under rice–wheat cropping system in subtropical mollisols. *Agricultural research*, **6**:399-409.

[11] Piper, C.S. (1950). *Soil and Plant Analysis*. University of Adelaide, Adelaide, Australia.

[12] Prasanna, B. M., Cairns, J. E., Zaidi, P. H., Beyene, Y., Makumbi, D., Gowda, M. and Zhang, X., 2021. Beat the stress: Breeding for climate resilience in maize for the tropical rainfed environments. *Theoretical and Applied Genetics*, **134**:1729–1752.

[13] Richards, L.A., 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Handbook No. 60, U.S. *Department of Agriculture*, Washington, D.C

[14] Singh, V., Singh, B., and Kumar, R. 2017. Combined use of chemical fertilizers and farmyard manure to enhance soil fertility parameters and maize yield in loamy soils of Haryana. *Indian Journal of Agronomy*, **62**(3):312–318.

[15] Thakur, R., Singh, V.K., Meena, R.S. and Roy, S., 2022. Long-term impact of integrated nutrient management on soil aggregation, wheat productivity and nutrient uptake in a *Typic Haplustert*. *Soil and Tillage Research*, **217**: 105-263.

[16] Tiwari, R., Dwivedi, B.S., Sharma, Y.M., Thakur, R., Sharma, A. and Nagwanshi, A., 2024. Soil properties and soybean yield as influenced by long term fertilizer and organic manure application in a vertisol under soybean-wheat cropping sequence. *Legume Research*, **47**(7): 1158-1164.

[17] Walkley, A. and Black, I.A., 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, **37**:29–38