International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664
Received: 18-04-2026, Accepted: 19-05-2026, Published: 03-06-2026
Volume 8, Issue 2, 2026, Page No. 214-217

Effect of INM on Physico-chemical properties of soil during two seasons of maize (*Zea mays* l.) Crop in the Inceptisol of western Uttar Pradesh

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DOI: https://doi.org/10.66856/ijaps.2026.8.2.8110

Abstract
A field experiment was conducted during 2023 and 2024 in Rampur Maniharan, Saharanpur, Uttar Pradesh, to assess the effect of integrated nutrient management (INM) on the physico-chemical properties of soil under maize. The trial was laid out in a Randomized Block Design with thirteen treatments and three replications. Treatments consisted of varying combinations of recommended dose of fertilizers (RDF), FYM, compost, phosphate-solubilizing bacteria (PSB), and vermicompost. The initial soil was sandy loam, medium in organic carbon and available nutrients, with near-neutral to slightly alkaline reaction. Post-harvest soil analysis revealed significant differences in available nitrogen, phosphorus, potassium, and organic carbon due to INM treatments, whereas soil pH, electrical conductivity, bulk density, and $CaCO_3$ equivalent remained within narrow and non-problematic limits. The highest pooled available nitrogen (312.80 kg/ha) and potassium (286.45 kg/ha) were recorded under 75% RDF + Compost @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha (T4). The highest available phosphorus (29.85 kg/ha) and organic carbon (0.70%) were observed under 50% RDF + FYM @ 3 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha (T13). The treatment 75% RDF + FYM @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha (T7) remained at par with the best treatments for most fertility parameters and offered a balanced combination of residual fertility improvement and crop productivity. Sole application of 100% RDF resulted in lower organic carbon (0.58%) than integrated treatments. The findings demonstrate that INM improves residual soil fertility and soil organic matter status without causing adverse changes in pH, EC, bulk density, or $CaCO_3$ under maize cultivation in the Inceptisols of Western Uttar Pradesh.

Keywords: Maize, integrated nutrient management, soil fertility, organic carbon, available nitrogen, available phosphorus, available potassium, Inceptisols

Introduction

Sustaining maize production requires not only high crop yield but also the preservation of soil quality. Continuous dependence on mineral fertilizers alone may meet short-term crop demand, but it can gradually reduce soil organic matter, disturb nutrient balance, and weaken soil biological functioning. Diacono and Montemurro (2010) [5] emphasized that long-term soil fertility depends on the balanced use of organic and inorganic inputs, while Geisseler and Scow (2014) [7] noted that mineral fertilization alone may reduce microbial diversity and biological activity in soil. Integrated nutrient management offers a more sustainable alternative. Chivenge *et. al.* (2011) [4] defined integrated soil fertility management as the combined use of organic, inorganic, and biological resources to optimize nutrient efficiency and sustain soil function. The operational logic of this approach aligns with the "4R" principle described by IFA (2025), which emphasizes the right source, rate, time, and place of nutrient application. In maize systems, this strategy is especially relevant because maize has high nutrient demand and responds strongly to balanced nutrition.

Organic amendments such as FYM, compost, and vermicompost improve soil structure, organic carbon, cation exchange capacity, and moisture retention. Manna *et al.* (2005) [15] demonstrated that combined fertilizer and manure use improves soil organic carbon and yield sustainability, while Bhattacharyya *et al.* (2010) [3] reported that integrated nutrient use supports soil quality in intensively cultivated systems. Liu *et al.* (2010) [13] likewise observed that manure application improves soil properties and crop response in cereal-based rotations.

Biofertilizers also contribute to soil nutrient dynamics. Khan *et al.* (2007) [11] showed that phosphate-solubilizing bacteria release organic acids and phosphatases that mobilize unavailable phosphorus in soil. Richardson and Simpson (2011) [18] further explained that soil microorganisms mediate phosphorus availability and play a central role in nutrient cycling. These biological processes are particularly important in maize cultivation, where phosphorus availability often constrains early growth and productivity. Research by Albiach *et al.* (2000) [2] demonstrated that organic amendments stimulate microbial biomass and enzymatic activity, while Manna *et al.* (2007) [16] noted that repeated organic inputs build soil organic matter and improve long-term fertility. In the context of maize, Kannan *et al.* (2013) and Patra and Biswas (2009) [10, 17] reported that integrated nutrient management improves both crop performance and soil fertility. Conservation agriculture studies by Gathala *et. al.* (2015) and Sapkota *et al.* (2017) [6, 19] also confirmed that residue retention and organic inputs improve soil buffering and reduce yield variability.

Given the importance of soil quality for long-term maize sustainability, the present study was undertaken to evaluate the effect of integrated nutrient management on the physico-chemical properties of soil under maize in the Inceptisols of Western Uttar Pradesh across two seasons.

Materials and Methods

Experimental site, climate, and soil

The experiment was conducted in 2023 and 2024 at Rampur Maniharan, Saharanpur, Uttar Pradesh. The climate is semi-arid subtropical with hot summers, cool winters, and monsoon-dominated rainfall.

The initial experimental soil was sandy loam with moderate fertility and non-saline condition.

Table 1: Initial physico-chemical properties of the experimental soil

Property	2023	2024
Fine sand (%)	55.1	55.7
Silt (%)	21.8	21.4
Clay (%)	20.2	21.1
Texture	Sandy loam	Sandy loam
Organic carbon (%)	0.64	0.69
Available N (kg/ha)	294	310
Available P (kg/ha)	25	28
Available K (kg/ha)	280	289
pH	7.2	7.6
EC (dS/m)	0.28	0.24
$CaCO_3$ (%)	1.64	1.65
Bulk density (g cm^{-3})	1.36	1.35

Treatments and design

The experiment consisted of 13 treatments arranged in Randomized Block Design with 3 replications.

Table 2: Treatment details

Treatment	Combination
T1	100% RDF
T2	75% RDF + Compost @ 2 t/ha
T3	75% RDF + Compost @ 2 t/ha + PSB @ 1 kg/ha
T4	75% RDF + Compost @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha
T5	75% RDF + FYM @ 2 t/ha
T6	75% RDF + FYM @ 2 t/ha + PSB @ 1 kg/ha
T7	75% RDF + FYM @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha
T8	50% RDF + Compost @ 3 t/ha
T9	50% RDF + Compost @ 3 t/ha + PSB @ 1 kg/ha
T10	50% RDF + Compost @ 3 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha
T11	50% RDF + FYM @ 3 t/ha
T12	50% RDF + FYM @ 3 t/ha + PSB @ 1 kg/ha
T13	50% RDF + FYM @ 3 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha

Soil sampling and analysis

Soil samples were collected before sowing and after harvest and analyzed for available nitrogen, available phosphorus, available potassium, organic carbon, pH, electrical conductivity, bulk density, and $CaCO_3$ equivalent following standard procedures. Statistical analysis was performed using ANOVA under RBD.

Table 3: Effect of INM on Physico-Chemical properties of Soil (Pooled data)

S.No.	Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	EC (ds/m)	pH	BD (g cm-3)	% CaCO3
T1	100% RDF	303.40	27.75	285.30	0.58	0.25	7.1	1.35	1.65
T2	75% RDF + Compost	296.50	26.95	282.70	0.60	0.26	7.2	1.38	1.66
T3	75% RDF + Compost + PSB	302.75	27.00	280.65	0.67	0.27	7.3	1.36	1.64
T4	75% RDF + compost + PSB + Vermicompost	312.80	28.65	286.45	0.69	0.30	7.2	1.37	1.66
T5	75% RDF + FYM	298.60	27.35	282.60	0.61	0.27	6.9	1.39	1.66
T6	75% RDF + FYM + PSB	304.25	29.00	285.55	0.62	0.27	6.9	1.35	1.67
T7	75% RDF + FYM + PSB + Vermicompost	312.25	29.25	284.35	0.66	0.30	7.0	1.37	1.68
T8	50% RDF + Compost	296.90	26.40	280.70	0.59	0.25	7.2	1.39	1.68
T9	50% RDF + Compost + PSB	297.70	27.70	282.00	0.61	0.27	7.1	1.38	1.64
T10	50% RDF + Compost+ PSB +vermicompost	303.45	28.30	281.75	0.67	0.32	7.1	1.37	1.66
T11	50% RDF + FYM	295.90	26.15	279.30	0.64	0.27	6.8	1.37	1.67
T12	50% RDF + FYM + PSB	303.90	27.80	280.20	0.63	0.28	7.3	1.37	1.66
T13	50% RDF + FYM + PSB +vermicompost	303.05	29.85	282.10	0.70	0.31	7.2	1.36	1.67
CD		5.20	2.45	3.40	0.06	0.06	0.5	0.45	0.45
SE		1.95	1.23	1.79	0.01	0.03	0.2	0.20	0.20

Results and Discussion

Available nitrogen

Available nitrogen after harvest was significantly influenced by INM. The highest pooled available N was recorded under T4 (312.80 kg/ha), which was at par with T7 (312.25 kg/ha). The value under T1 (100% RDF) was 303.40 kg/ha, while the lowest value was recorded under T11 (295.90 kg/ha). The higher residual nitrogen in T4 and T7 indicates that integrated application of mineral fertilizer with organics and biofertilizers improved nutrient retention and release patterns. Organic inputs likely reduced nitrogen loss pathways while contributing to more sustained mineralization.

Available phosphorus

Available phosphorus also improved under integrated nutrient management. The highest pooled available P was recorded under T13 (29.85 kg/ha), followed by T7 (29.25 kg/ha) and T6 (29.00 kg/ha). T4 also remained statistically comparable with 28.65 kg/ha. The lowest available P was recorded under T11 (26.15 kg/ha) and T8 (26.40 kg/ha). The beneficial effect of PSB-containing treatments on phosphorus status strongly suggests enhanced P solubilization and improved availability in the rhizosphere. Organic matter may also have moderated phosphorus fixation, especially in slightly alkaline soil conditions.

Available potassium

Post-harvest potassium status was highest under T4 (286.45 kg/ha). This value was at par with T6 (285.55 kg/ha) and T1 (285.30 kg/ha). The lowest pooled potassium content was recorded under T11 (279.30 kg/ha). The maintenance of potassium under integrated treatments may be attributed to improved soil buffering and reduced nutrient depletion due to better nutrient balance and rhizosphere function.

Organic carbon

One of the clearest effects of INM was observed in soil organic carbon. The highest pooled organic carbon was recorded under T13 (0.70%), followed by T4 (0.69%). In contrast, T1 (100% RDF) recorded the lowest value of 0.58%. This clearly indicates the role of FYM, compost, and vermicompost in improving soil organic matter. Even over two seasons, integrated treatments increased carbon status meaningfully relative to sole fertilizer use.

Soil EC, pH, bulk density, and $CaCO_3$

The effects of INM on the broader physico-chemical environment of the soil were comparatively small, but important from a sustainability perspective.

Table 4: Range of post-harvest soil physico-chemical properties under INM

Property	Range / key values	Interpretation
EC (dS/m)	0.245–0.315	All treatments remained non-saline
Highest EC	T10 = 0.315; T13 = 0.31; T7 = 0.30	Slight increase with organics + vermicompost, but safe
Lowest EC	T1 = 0.245; T8 = 0.245	No salinity concern
pH	6.8–7.3	Soil remained near neutral
Highest pH	T3 = 7.3; T12 = 7.3	Slightly alkaline but acceptable
Lowest pH	T11 = 6.8; T6 = 6.9	No harmful acidification
Bulk density (g cm^{-3})	1.35–1.39	Very narrow variation
Lowest bulk density	T1 = 1.35; T6 = 1.35	No compaction issue
Highest bulk density	T5 = 1.39; T8 = 1.39; T11 = 1.39	Still within acceptable range
$CaCO_3$ (%)	1.64–1.68	Non-significant variation
Highest $CaCO_3$	T7 = 1.68; T8 = 1.68	Stable carbonate status
Lowest $CaCO_3$	T3 = 1.64; T9 = 1.64	No meaningful change

These findings confirm that INM improved nutrient availability and organic carbon without disturbing soil chemical balance. The absence of harmful changes in pH, EC, bulk density, and $CaCO_3$ indicates that such nutrient strategies are compatible with long-term soil sustainability.

Integrated interpretation

The post-harvest soil fertility pattern suggests that different INM combinations influenced different fertility components: Although T13 recorded the highest phosphorus and organic carbon, the agronomic performance of T7 and T4 was stronger overall. Thus, from a combined soil fertility and crop productivity perspective, T7 and T4 represent more balanced INM packages. The lower organic carbon under 100% RDF indicates that sole chemical fertilization may sustain short-term productivity but is less effective for soil quality improvement. In contrast, organics and biofertilizers contributed to both immediate nutrient availability and long-term soil restoration. Similar results were also obtained when few trials were carried out comparing RDF alone to INM (FYM/vermicompost + PSB + balanced NPK) which showed higher yields, Agronomic Efficiency (AE), and Partial Factor Productivity (PFP) under INM—especially with Zn/S corrections in alkaline soils and also few integrated strategies confirm that combining FYM/compost and biofertilizers with balanced RDF improves nutrient synchrony and reduces losses, translating into higher maize NUE and yield stability across diverse soils. Combining PSB with modest mineral P (RDF) and organics consistently improves maize P uptake and growth in high pH and P fixing soils (Kumar *et al.,* 2018; Diacono and Montemurro, 2010; Agegnehu *et al.,* 2016; Illmer and Schinner, 1995; Malboobi *et al.*, 2009) [1, 5, 9, 14].

Conclusion

The present study demonstrated that integrated nutrient management markedly improved the physico-chemical properties of soil under maize in the Inceptisols of Western Uttar Pradesh. Significant improvements were observed in available nitrogen, phosphorus, potassium, and organic carbon, while soil pH, EC, bulk density, and $CaCO_3$ remained within safe and stable ranges. The treatment 75% RDF + Compost @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha was most effective for improving residual nitrogen and potassium, whereas 50% RDF + FYM @ 3 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha recorded the highest residual phosphorus and organic carbon. However, considering both soil fertility improvement and practical agronomic performance, 75% RDF + FYM @ 2 t/ha + PSB @ 1 kg/ha + Vermicompost @ 10 kg/ha emerges as the most balanced recommendation. The study confirms that INM is a viable pathway for sustaining maize-based production systems while improving soil health in Western Uttar Pradesh.

References

1. Agegnehu G, Bass AM, Nelson PN, Bird MI. Benefits of biochar, compost and biochar-compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil. Science of the Total Environment,2016:543(A):295-306.
2. Albiach R, Canet R, Pomares F, Ingelmo F. Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. Bioresource Technology,2000:75:43-48.
3. Bhattacharyya R, Prakash V, Kundu S, Srivastva AK, Gupta HS, Mitra S. Long term effects of fertilization on carbon and nitrogen sequestration and aggregate associated carbon and nitrogen in the Indian sub-Himalayas. Nutrient Cycling in Agroecosystems,2010:86:1-16.
4. Chivenge P, Vanlauwe B, Six J. Does the combined application of organic and mineral nutrient sources influence maize productivity. Plant and Soil,2011:342:1-30.
5. Diacono M, Montemurro F. Long-term effects of organic amendments on soil fertility: A review. Agronomy for Sustainable Development,2010:30(2):401-422.
6. Gathala MK, Timsina J, Islam MS, Rahman MM, Hossain MI, Rashid MH, *et al*. Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems: Evidence from Bangladesh. Field Crops Research,2015:172:85-98.
7. Geisseler D, Scow KM. Long-term effects of mineral fertilizers on soil microorganisms—A review. Soil Biology & Biochemistry,2014:75:54-63.
8. International Fertilizer Association (IFA). 4R Nutrient Stewardship resources. International Fertilizer Association, 2025.

9. Illmer P, Schinner F. Solubilization of inorganic calcium phosphate—Solubilization mechanisms. Soil Biology & Biochemistry,1995:27(3):257-263.
10. Kannan RL, Dhivya M, Abinaya D, Krishna RL, Krishnakumar S. Effect of Integrated Nutrient Management on Soil Fertility and Productivity in Maize. Bulletin of Environment, Pharmacology and Life Sciences,2013:2(8):61-67.
11. Khan MS, Zaidi A, Wani PA. Role of phosphate-solubilizing microorganisms in sustainable agriculture A review. Agronomy for Sustainable Development,2007:27:29-43.
12. Kumar M, Singh B, Dhaka AK. Integrated nutrient management strategies for increasing annual forage crops productivity– a review. Forage Research,2017:43(1):9-16.
13. Liu E, Yan C, Mei X, He W, Bing SH, Ding L, *et al*. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. Geoderma,2010:158:173-180.
14. Malboobi MA, Behbahani M, Madani H, Owlia P, Deljou A, Yakhchali B, *et al*. Performance evaluation of potent phosphate solubilizing bacteria in potato rhizosphere. World Journal of Microbiology and Biotechnology,2009:25:1479-1484.
15. Manna MC, Swarup A, Wanjari RH, Ravankar HN, Mishra B, Saha MN, *et al*. Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. Field Crops Research,2005:93(2-3):264-280.
16. Manna MC, Swarup A, Wanjari RH, Mishra B, Shahi DK. Long-term fertilization, manure and liming effects on soil organic matter and crop yields. Soil and Tillage Research,2007:94(2):397-409.
17. Patra PS, Biswas S. Integrated nutrient management on growth, yield and economics of maize (*Zea mays* L.) under tarai region. Journal of Crop and Weed,2009:5(1):136-139.
18. Richardson AE, Simpson RJ. Soil Microorganisms Mediating Phosphorus Availability Update on Microbial Phosphorus. Plant Physiology,2011:156(3):989-996.
19. Sapkota TB, Jat RK, Singh RG, Jat ML, Stirling CM, Jat MK, *et al*. Soil organic carbon changes after seven years of conservation agriculture in a rice–wheat system of the eastern Indo-Gangetic Plains. Soil Use and Management,2017:33(1):81-89.