Nitrogen Mineralization Dynamics of Organic Manures and Their Effects on Nitrogen Uptake and Productivity of Maize (Zea mays L.) under Acidic Soils of North-East India

RAJESH KUMAR JATOLIYA*, DIVYANGI SAMUCHIA[1], G. P. MEENA[2], SANTOSH LAL JAT[3] AND NIKITA CHOUDHARY[4]

*Presently working as Assistant Professor, School of Agriculture, University of Technology, Jaipur, Rajasthan

[1]Assistant Professor, School of Agriculture, University of Technology, Jaipur, Rajasthan

[2]Professor & Dean, School of Agriculture, University of Technology, Jaipur, Rajasthan

[3]HOD, School of Agriculture, University of Technology, Jaipur, Rajasthan

[4]Assistant Professor, School of Agriculture, University of Technology, Jaipur, Rajasthan

ABSTRACT

A field experiment was conducted during the kharif season of 2016 at the Experimental Farm of the School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, to investigate the nitrogen (N) mineralization pattern of different organic manures under maize cultivation in acidic soil. Farmyard manure (FYM), Vermi-compost (VC), and poultry manure (PM) were applied at two rates (2.5 and 5.0 t ha^{-1}), along with an Unmanured control, in a randomized block design with three replications. The study also evaluated maize growth, biomass production, grain yield, and nitrogen uptake at different crop growth stages. The chemical characteristics of the organic manures, particularly nutrient concentration, C:N ratio, lignin content, and lignin:N ratio, significantly influenced nitrogen mineralization. Nitrogen mineralization increased progressively throughout the crop growth period; however, net nitrogen immobilization was observed at 15 days after sowing (DAS) in FYM- and VC-treated plots, with greater immobilization occurring at the higher application rate. At 90 DAS, poultry manure applied at 5.0 t ha^{-1} recorded the highest amount of mineralized nitrogen (44.80 kg ha^{-1}), followed by poultry manure at 2.5 t ha^{-1} (35.20 kg ha^{-1}), Vermi-compost at 5.0 t ha^{-1} (18.15 kg ha^{-1}), Vermi-compost at 2.5 t ha^{-1} (16.82 kg ha^{-1}), FYM at 5.0 t ha^{-1} (12.75 kg ha^{-1}), and FYM at 2.5 t ha^{-1} (12.05 kg ha^{-1}), whereas the control treatment recorded the lowest nitrogen mineralization. Among the organic amendments, poultry manure consistently produced significantly higher biomass yield, grain yield, and nitrogen uptake throughout the crop growth period than FYM and Vermi-compost. Strong positive correlations were observed between nitrogen mineralization, grain yield, and grain nitrogen uptake across treatments. The findings demonstrate that the quality and application rate of organic manures govern nitrogen release patterns and crop nutrient availability. Appropriate selection and timely application of organic manures, particularly poultry manure, can improve nitrogen use efficiency, sustain soil fertility, and enhance maize productivity under acidic soil conditions. Organic manure → Nitrogen mineralization → Nitrogen uptake → Biomass → Grain yield → Residual soil fertility

Keywords: Maize, nitrogen mineralization, poultry manure, farmyard manure, Vermi-compost, nitrogen uptake, acidic soil, organic nutrient management

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most important cereal crops and ranks third after rice and wheat in terms of global cultivation and production. It serves as a staple food, livestock feed, and industrial raw material, making it indispensable for ensuring food and nutritional security. In India, maize occupies approximately 8.69 million hectares with a production of 21.81 million tonnes and an average productivity of 2.51 t ha^{-1}. In the North-Eastern region, particularly in Nagaland, maize is an important rain-fed crop cultivated under diverse agro-ecological conditions. However, crop productivity remains relatively low because of acidic soils, poor nutrient availability, and inadequate nutrient management practices.

Continuous dependence on inorganic fertilizers has raised concerns regarding soil degradation, declining soil organic matter, nutrient imbalance, and environmental pollution. Consequently, the integration of organic nutrient sources into crop production systems has become an essential strategy for improving soil health and sustaining agricultural productivity. Organic manures such as farmyard manure (FYM), vermicompost, and poultry manure not only supply essential plant nutrients but also improve soil physical, chemical, and biological properties. Nitrogen is the nutrient required in the greatest quantity by maize and often limits crop productivity. However, unlike inorganic fertilizers, nitrogen present in organic manures must first be converted into plant-available forms through microbial mineralization. The rate and extent of nitrogen mineralization depend on several factors, including manure composition, carbon-to-nitrogen (C:N) ratio, lignin content, lignin-to-nitrogen ratio, soil properties, moisture, temperature, and microbial activity. Therefore, understanding nitrogen release patterns from different organic manures is essential for synchronizing nutrient availability with crop demand and improving nitrogen use efficiency.

Previous studies have demonstrated that organic amendments differ considerably in their decomposition behaviour and nutrient release characteristics. Organic materials with lower C:N ratio and lignin content generally mineralize nitrogen more rapidly than those containing higher concentrations of resistant organic compounds. Conversely, materials with wider C:N ratios may initially immobilize soil nitrogen, temporarily reducing nutrient availability to crops. Such variations greatly influence crop growth, nutrient uptake, and yield performance.

In the acidic soils of North-East India, information on nitrogen mineralization dynamics of locally available organic manures under field conditions is limited. Scientific evidence regarding the timing and quantity of nitrogen released from these organic amendments is required to formulate efficient nutrient management strategies that maximize crop productivity while maintaining soil fertility. A better understanding of nitrogen release patterns would also facilitate synchronization between nutrient availability and crop demand, thereby minimizing nutrient losses and improving fertilizer use efficiency.

Therefore, the present investigation was undertaken to:

(i) Evaluate the nitrogen mineralization pattern of farmyard manure, vermicompost, and poultry manure applied at different rates under maize cultivation;
(ii) Assess their effects on biomass production, grain yield, and nitrogen uptake of maize;
(iii)Examine the relationship between nitrogen mineralization and crop productivity under acidic soil conditions of Nagaland.

MATERIALS AND METHODS

Experimental Site: - A field experiment was conducted during the kharif season of 2018 at the Experimental Farm of the School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland, India. The experimental site is located at 25°45′43″ N latitude and 95°53′04″ E longitude and experiences a humid subtropical climate characterized by high rainfall and moderate temperatures. During the experimental period, a total rainfall of 1233.9 mm was received. The maximum and minimum temperatures recorded were 34.7°C and 20.0°C, respectively, while the relative humidity ranged from 52% to 94%. The experimental soil was sandy clay loam in texture, strongly acidic in reaction (pH 4.12), and contained 19.2 g kg^{-1} organic carbon. The initial available nitrogen, phosphorus (P_2O_5), and potassium (K_2O) contents were 200.1, 20.2, and 255.8 kg ha^{-1}, respectively.

Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) comprising seven treatments with three replications. The treatments consisted of different organic manures applied at two application rates Viz., T_1; **(**Control No manure), T_2; Farmyard manure (FYM) @ 2.5 t ha^{-1}, T_3; Farmyard manure (FYM) @ 5.0 t ha^{-1} , T_4; Vermicompost (VC) @ 2.5 t ha^{-1} , T_5;Vermicompost (VC) @ 5.0 t ha^{-1} , T_6; Poultry manure (PM) @ 2.5

t ha^{-1} , T_7; Poultry manure (PM) @ 5.0 t ha^{-1} The maize variety **IMH-224** was used as the test crop. Well-decomposed organic manures were incorporated into the soil before sowing according to the treatment schedule. A uniform dose of 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} was applied through single superphosphate and muriate of potash, respectively, to all plots. Representative plant samples were collected at 15, 30, 45, 60, 75, and 90 days after sowing (DAS) and at harvest (135 DAS). The samples were oven-dried to constant weight, and the dry matter was recorded. Biomass yield was expressed as quintals per hectare (q ha^{-1}). The dried plant samples were finely ground and analyzed for total nitrogen content following the standard procedure described by Jackson (1973)**.** N-uptake by plants at different DAS and at harvest was calculated for each stages of growth. Soil samples (both initial and final) were analyzed for physicochemical parameters following standard procedures. Mineralized N-content was determined at periodic intervals in the samples collected at different DAS by 2M KCl extraction procedure described by Gianello and Bremmer, (1986).

The cumulative amount of N-mineralized from soil organic matter at time‘t’ was calculated from the equation

N(min)control=Ni(control)t—Ni(control)t=0 ....(1)

The cumulative amount of N released from applied N source at time ‘t’ was calculated from equation

N (rel) N source= Ni (N treated soil)t–Ni(control)t–Ni(N source) ....(2)

Grain nitrogen uptake at harvest was calculated using the same approach based on grain yield and grain nitrogen concentration. Initial and post-harvest soil samples were analyzed for, Soil pH, Electrical conductivity (EC), Organic carbon, Available nitrogen, Available phosphorus, Available potassium using standard analytical procedures routinely followed for soil analysis. The experimental data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design as described by Gomez and Gomez (1984)**.** Treatment means were compared using the Least Significant Difference (LSD) test at the 5% probability level ($P \leq 0.05$)**.** Correlation analysis was also performed to evaluate the relationships among nitrogen mineralization, grain yield, and nitrogen uptake.

RESULT AND DISCUSSION

Characterization of Organic Manures

The chemical characteristics of the organic manures differed considerably and had a significant influence on nitrogen mineralization and crop performance (Table 1). The pH of all three organic manures ranged from 6.84 to 7.30, indicating a nearly neutral reaction suitable for agricultural application. Farmyard manure (FYM) contained the highest total carbon content (38.0%), whereas poultry manure (PM) exhibited the highest nitrogen concentration (2.00%), followed by vermicompost (1.44%). Vermicompost possessed the narrowest C:N ratio (12.6:1), while FYM recorded the widest ratio (44.2:1). Poultry manure was characterized by the lowest lignin content (15%) and lignin:N ratio (13.6:1), suggesting greater susceptibility to microbial decomposition and faster nitrogen release. In contrast, vermicompost contained the highest lignin content (48%) and lignin:N ratio (33.3:1), indicating comparatively slower decomposition despite its relatively narrow C:N ratio. These differences in chemical composition largely governed the mineralization behaviour of the manures. Organic materials with higher nitrogen concentration and lower lignin content generally decompose more rapidly, thereby releasing plant-available nitrogen at a faster rate. Similar observations have been reported by Bordoloi (2014), who highlighted the importance of manure quality in regulating nitrogen mineralization.

Table 1: Chemical composition of organic manures used in the study

Manures	pH	Total C (%)	Total N (%)	C:N ratio	Total P (%)	Total K (%)	Lignin content (%)	Lignin: Nitrogen
FYM	7.30	38.0	0.86	44.2 :1	0.39	0.65	19.7	22.9 :1
Vermicompost	7.00	18.2	1.44	12.6 :1	1.00	1.55	48.0	33.3 :1
Poultry manure	6.84	30.7	2.00	15.3 :1	1.10	0.92	15.0	13.6 :1

Effect of Organic Manures on Nitrogen Mineralization

Nitrogen mineralization followed a distinct temporal pattern depending on the type and application rate of organic manure (Table 2). During the initial 15 days after sowing (DAS), negative nitrogen mineralization (immobilization) was observed in plots receiving FYM and vermicompost at both application rates. The magnitude of immobilization increased with higher manure application (5 t ha^{-1}), indicating greater microbial immobilization due to the decomposition of carbon-rich organic substrates. Poultry manure, however, did not exhibit immobilization at this stage, reflecting its rapid decomposition and early nitrogen release. Thereafter, nitrogen mineralization increased progressively throughout the crop growth period in all manure-treated plots. At 90 DAS, poultry manure applied at 5 t ha^{-1} (T_7) recorded the highest nitrogen mineralization **(**44.80 kg ha^{-1}**),** followed by poultry manure at 2.5 t ha^{-1} (35.20 kg ha^{-1})**.** Vermicompost treatments showed intermediate nitrogen release, whereas FYM exhibited comparatively slower mineralization. The Un-manured control consistently recorded the lowest amount of mineralized nitrogen throughout the study. The superior performance of poultry manure can be attributed to its higher nitrogen concentration, lower C:N ratio, and lower lignin content, which favour rapid microbial decomposition and nutrient release. Conversely, the relatively high lignin content of FYM and vermicompost slowed organic matter decomposition, resulting in delayed nitrogen availability. The results clearly demonstrate that both manure quality and application rate regulate nitrogen mineralization under acidic soil conditions. Similar findings have been reported by Kumar and Goh (2003), Griffin et al. (2005), and Azeez and Van Averbeke (2010), who concluded that manure composition is one of the principal determinants of nitrogen release dynamics.

Table 2: N-mineralization (pattern) at different growth stages (Day after sowing) of maize as affected by manures

Treatment	Mineralized N (kg ha^{-1})						
	15 Days	30 Days	45Days	60 Days	75 Days	90 Days	135 Days
T_1 Control	0.46	0.40	4.70	8.06	9.40	9.44	4.48
T_2 FYM @ 2.5 t ha^{-1}	-6.71	1.18	5.15	8.75	11.42	12.07	9.54
T_3 FYM @ 5 t ha^{-1}	-13.40	0.88	6.50	10.71	12.76	12.76	9.69
T_4 VC @ 2.5 t ha^{-1}	-9.85	0.47	8.29	15.46	16.12	16.88	11.53
T_5 VC @ 5 t ha^{-1}	-15.23	1.30	6.72	15.90	17.80	18.10	14.55
T_6 PM @ 2.5 t ha^{-1}	4.48	12.36	20.83	26.54	30.10	35.25	23.07
T_7 PM @ 5 t ha^{-1}	4.36	17.29	33.60	38.77	40.55	44.87	37.18
SEm ±	0.31	0.08	0.26	0.26	0.26	0.26	0.14
CD (P=0.05)	1.11	0.29	0.93	0.94	0.94	0.94	0.51

Biomass Production and Nitrogen Uptake

Application of organic manures significantly enhanced biomass accumulation throughout the crop growth period (Table 3). Among the treatments, poultry manure consistently produced the highest biomass yield at all growth stages. At harvest, the highest biomass yield was recorded under PM @ 5 t ha^{-1} (T_7), followed by PM @ 2.5 t ha^{-1} (T_6)**.** The enhanced biomass production under poultry manure can be attributed to continuous nitrogen availability during the active vegetative phase, which promoted leaf development, photosynthetic efficiency, and dry matter accumulation. Nitrogen uptake increased progressively with crop growth and closely followed the pattern of biomass accumulation. The highest nitrogen uptake was recorded in T_7, followed by T_6**,** reflecting the greater availability of mineral nitrogen in these treatments. The superior performance of poultry manure may also be associated with its high proportion of readily mineralizable nitrogen forms, particularly ammoniacal and uric acid nitrogen, which become rapidly available to plants after application. Consequently, maize plants absorbed nitrogen more efficiently, resulting in greater biomass production and nutrient accumulation. These observations are consistent with the findings of Moore et al. (2010) and Nhahm (2003), who reported improved nitrogen uptake and biomass production following poultry manure application.

Table 3: Dry matter accumulation/Biomass yield (q ha^{-1}) and Biomass N-uptake (kg ha^{-1}) of maize at different growth stages as affected by manures

Treatments	15 Days		30 Days		45Days		60 Days		75 Days		90 Days		135 Days	
	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake	Yield	Uptake
T_1	3.90	2.5	5.00	3.2	12.90	3.9	20.40	6.0	30.90	10.2	43.10	13.9	50.10	15.5
T_2	3.12	3.0	6.60	3.3	13.30	3.9	21.10	5.9	33.10	10.9	53.10	15.9	70.40	20.8
T_3	4.67	2.9	7.00	3.5	15.10	4.9	25.40	7.7	38.90	12.6	60.20	19.8	74.50	23.9
T_4	5.20	2.9	6.60	3.4	13.10	4.3	21.00	6.7	33.10	11.0	54.50	17.3	68.00	19.3
T_5	5.00	2.9	9.00	3.4	17.00	4.1	26.90	6.6	39.00	10.9	53.10	18.0	70.50	20.6
T_6	7.30	7.7	8.00	8.6	16.00	12.6	25.90	17.6	38.10	26.4	66.10	36.9	85.00	39.4
T_7	7.20	8.4	7.90	10.0	16.90	15.9	25.00	22.4	38.00	33.9	73.20	45.4	92.98	47.4
SEm ±	0.11	0.02	0.13	0.02	0.026	0.02	0.20	0.13	0.02	0.02	0.02	0.02	0.03	0.03
CD(P=0.05)	0.41	0.07	0.50	0.07	0.095	0.10	0.75	0.47	0.07	0.10	0.09	0.07	0.14	0.10

Grain Yield and Grain Nitrogen Uptake

Significant differences in grain yield were observed among the treatments (Table 4). Poultry manure at 5 t ha^{-1} (T_7) produced the highest grain yield (27.94 q ha^{-1}**)**, followed by PM @ 2.5 t ha^{-1} (23.96 q ha^{-1})**.** Compared with the control, grain yield increased by approximately 156% under T_7. The increased grain yield under poultry manure can be attributed to improved nitrogen mineralization throughout the crop growth period, resulting in better vegetative growth, higher biomass accumulation, and efficient translocation of assimilates towards grain development. Grain nitrogen concentration and grain nitrogen uptake followed a similar trend. Maximum grain nitrogen uptake (45.9 kg ha^{-1}**)** was recorded under poultry manure applied at 5 t ha^{-1}**,** indicating enhanced nitrogen acquisition and utilization efficiency. The comparatively lower grain yield and nitrogen uptake observed under FYM and vermicompost treatments may be due to slower nitrogen release and temporary immobilization during the early stages of crop growth, which reduced nutrient availability during critical periods of maize development.

Table 4: Grain yield (q ha^{-1}), grain N-content (%) and grain N-uptake (kg ha^{-1}) of maize as affected by application of manures

Treatment	Grain yield (q ha^{-1})	Grain N content (%)	Grain N uptake (kg ha^{-1})
T_1 Control	10.90	0.89	9.7
T_2 FYM @ 2.5 t ha^{-1}	12.40	0.99	12.4
T_3 FYM @ 5 t ha^{-1}	16.42	1.02	16.9
T_4 VC @ 2.5 t ha^{-1}	13.40	0.97	13.1
T_5 VC @ 5 t ha^{-1}	15.78	0.94	14.9
T_6 PM @ 2.5 t ha^{-1}	23.96	1.16	28.0
T_7 PM @ 5.0 t ha^{-1}	27.94	1.64	45.9
SEm ±	0.29	0.03	0.52
CD (P=0.05)	1.07	0.10	1.88

Correlation among Nitrogen Mineralization, Grain Yield and Nitrogen Uptake

Correlation analysis revealed strong positive relationships among nitrogen mineralization, grain yield, and grain nitrogen uptake (Table 5). Nitrogen mineralization exhibited a highly significant positive correlation with grain yield (r = 0.95**)** and grain nitrogen uptake (r = 0.98). Similarly, grain yield was strongly correlated with grain nitrogen uptake (r = 0.96). These relationships indicate that increased nitrogen mineralization improved nitrogen availability throughout crop growth, thereby enhancing nitrogen uptake and ultimately increasing grain yield. The results emphasize the importance of synchronizing nitrogen release from organic manures with crop nutrient demand to maximize nitrogen use efficiency and productivity.

Table 5: Correlation between amount of N-released (at harvest), grain yield of maize and grain- N-uptake

	Amount of N released (at harvest)	Grain yield	Grain N uptake
Amount of N released (at harvest)	1		
Grain yield	0.95**	1	
Grain N uptake	0.98**	0.96**	1

*** Significant at 1 % level   * Significant at 5 % level*

Residual Soil Fertility

Application of organic manures significantly improved post-harvest soil fertility compared with the control (Table 6).The highest residual soil nitrogen (300.1 kg ha^{-1}**)**, available phosphorus (35.5 kg ha^{-1}), and available potassium (299.8 kg ha^{-1}**)** were recorded under poultry manure applied at 5 t ha^{-1}**.** Organic carbon content and soil pH also improved following manure application, indicating a beneficial effect on soil quality. The improvement in soil fertility may be attributed to gradual decomposition of organic residues, enhanced microbial activity, and continuous nutrient release during crop growth. These findings suggest that poultry manure not only enhances immediate crop productivity but also contributes to long-term maintenance of soil fertility under acidic conditions.

Table 6: Residual soil nutrient availability as affected by application of manures

Treatments	pH (1:2.5)	OC (g kg^{-1})	Av. N (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})
T_1 Control	4.30	18.5	196.5	17.6	215.9
T_2 FYM @ 2.5 t ha^{-1}	4.93	20.0	215.3	25.5	272.3
T_3 FYM @ 5 t ha^{-1}	4.90	22.3	235.3	27.6	276.2
T_4 VC @ 2.5 t ha^{-1}	4.60	23.6	225.0	27.7	279.5
T_5 VC @ 5 t ha^{-1}	4.70	26.0	250.0	32.4	282.5
T_6 PM @ 2.5 t ha^{-1}	4.70	20.0	277.4	32.3	286.6
T_7 PM @ 5.0 t ha^{-1}	4.86	23.0	300.1	35.5	299.8
SEm ±	0.15	0.80	0.35	0.08	2.78
CD (P=0.05)	0.56	3.00	1.29	0.32	10.09
Initial value	4.12	19.2	200.1	20.2	255.8

Conclusion:

The present investigation demonstrated that the quality and application rate of organic manures significantly influence nitrogen mineralization dynamics, nitrogen uptake, and maize productivity under the acidic soils of Nagaland. Farmyard manure and vermicompost exhibited an initial phase of nitrogen immobilization during the first 15 days after sowing, particularly at the higher application rate, owing to their comparatively higher lignin content and lignin-to-nitrogen ratio. In contrast, poultry manure showed rapid nitrogen mineralization without any initial immobilization, resulting in greater nitrogen availability throughout the crop growth period. Among the organic nutrient sources evaluated, poultry manure applied at 5.0 t ha^{-1} proved to be the most effective treatment by recording the highest nitrogen mineralization, biomass production, grain yield, grain nitrogen uptake, and residual soil fertility. The strong positive correlations observed between nitrogen mineralization, grain yield, and grain nitrogen uptake indicate that synchronization of nitrogen release with crop demand plays a crucial role in improving nitrogen use efficiency and crop productivity. The findings suggest that poultry manure can serve as an efficient organic nitrogen source for maize cultivation in acidic soils due to its favourable chemical composition and rapid mineralization characteristics. Conversely, the relatively slower nitrogen release from farmyard manure and vermicompost indicates that these materials should be applied sufficiently before sowing to ensure adequate nitrogen availability during the early stages of crop growth. Overall, the study highlights the importance of selecting appropriate organic nutrient sources and optimizing their application rate and timing to improve nutrient availability, sustain soil fertility, and enhance maize productivity under rainfed acidic soil conditions. Future research should focus on validating these findings across different soil types, climatic conditions, cropping systems, and integrated nutrient management strategies to develop location-specific recommendations for sustainable maize production.

REFERNCES

Anonymous. (2015–16). *Director's Review*. ICAR–Indian Institute of Maize Research, New Delhi.

Anonymous. (2016). *Agricultural Statistics at a Glance 2016*. Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics, Government of India.

Agegnehu, G., Bass, A. M., Nelson, P. N. and Bird, M. I. (2021). Biochar and organic amendments improve soil fertility, nitrogen availability and maize productivity: A review. *Agronomy*, **11**, 1265.

Azeez, J. O. and Van Averbeke, W. (2010). Fate of manure phosphorus in a weathered sandy clay loam soil amended with three animal manures. *Bioresource Technology*, **101**, 6584–6588.

Boateng, S., Zickermann, A. J. and Kornaharens, M. (2006). Effect of poultry manure on growth and yield of maize. *West African Journal of Applied Ecology*, **9**, 1–11.

Bordoloi, L. J. (2014). *Evaluation of Soil Nitrogen Availability Indices and Kinetics of N Release from Organic Inputs in Maize (Zea mays L.)*. Ph.D. Thesis, Nagaland University, School of Agricultural Sciences and Rural Development, Medziphema Campus, India.

Choudhary, M., Jat, M. L., Datta, A., Sapkota, T. B. and Sharma, P. C. (2021). Integrated nutrient management for sustainable maize production under changing climatic conditions. *Field Crops Research*, **270**, 108198.

FAO. (2023). *The Status of the World's Soil Resources: Progress Report 2023*. Food and Agriculture Organization of the United Nations, Rome.

Gianello, C. and Bremner, J. M. (1986). A simple chemical method for assessing potentially mineralizable organic nitrogen in soil. *Communications in Soil Science and Plant Analysis*, **17**, 195–214.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research* (2nd ed.). John Wiley & Sons, New York.

Griffin, T. S., He, Z. and Honeycutt, C. W. (2005). Manure composition affects net transformation of nitrogen from dairy manure. *Plant and Soil*, **273**, 29–38.

Hertz, T. K., Mitchell, J. P. and Giannini, C. (2000). Nitrogen and carbon mineralization dynamics of manures and composts. *HortScience*, **31**, 961–964.

ICAR–Indian Institute of Maize Research. (2024). *Annual Report 2023–24*. ICAR-IIMR, Ludhiana, India.

Jackson, M. L. (1973). *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Khalil, M. I., Hossain, M. B. and Schmidhalter, U. (2005). Carbon and nitrogen mineralization in different upland soils of the subtropics treated with organic materials. *Soil Biology and Biochemistry*, **37**, 1507–1518.

Kumar, K. and Goh, K. M. (2003). Nitrogen release from crop residues and organic amendments as affected by biochemical composition. *Communications in Soil Science and Plant Analysis*, **34**, 2441–2460.

Kumar, R., Singh, A. K., Meena, R. S. and Sharma, R. (2022). Effect of integrated nutrient management on nitrogen uptake, productivity and soil health in maize (*Zea mays* L.). *Journal of Plant Nutrition*, **45**, 2681–2696.

Kumar, P., Sharma, R., Meena, R. S. and Singh, A. (2025). Organic nutrient sources and nitrogen synchronization for sustainable maize production: Recent advances and future perspectives. *Frontiers in Agronomy*, **7**, Article ID pending.

Li, Y., Zhang, X., Wang, J., Liu, H. and Chen, Q. (2021). Nitrogen mineralization dynamics following application of organic amendments under contrasting soil conditions. *Applied Soil Ecology*, **167**, 104081.

Liu, H., Chen, D., Li, Y., Wang, Z. and Xu, M. (2023). Organic amendments regulate nitrogen mineralization and microbial community dynamics in agricultural soils: A meta-analysis. *Geoderma*, **430**, 116279.

Meena, R. S., Kumar, S., Kumar, V. and Yadav, G. S. (2023). Organic nutrient management for improving nitrogen use efficiency and productivity of maize under sustainable production systems. *Frontiers in Sustainable Food Systems*, **7**, 1187654.

Meena, R. S., Lal, R., Kumar, S. and Sharma, N. (2024). Organic manure-mediated improvement in soil health and nutrient cycling under maize production systems. *Agronomy*, **14**, 623.

Mohanty, M., Probert, M. E., Sammi Reddy, K., Dalal, R. C., Subba Rao, A. and Menzies, N. W. (2010). Modelling N mineralization from green manure and farmyard manure from a laboratory incubation study. *Proceedings of the 19th World Congress of Soil Science*, Brisbane, Australia.

Mohanty, S., Panda, M. K., Sahoo, S. and Nayak, S. (2011). Rapid and stable propagation of an economically important endemic species of *Zingiber rubens* Roxb. *Biologia Plantarum*, **55**(1), 16–20.

Moore, A. D., Alva, A. K., Collins, H. P. and Boydston, R. A. (2010). Mineralization of nitrogen from biofuel by-products and animal manures amended to a sandy soil. *Communications in Soil Science and Plant Analysis*, **41**(11), 1315–1326.

Nhahm, K. H. (2003). Evaluation of nitrogen content in poultry manure. *World's Poultry Science Journal*, **59**, 77–88.

Sheoran, H. S., Duhan, S. B., Grewal, S. K. and Sheoran, S. (2015). Grain yield and NPK uptake of wheat (*Triticum aestivum* L.) as influenced by nitrogen, vermicompost and herbicide (Clodinafop-propargyl). *African Journal of Agricultural Research*, **10**(42), 3952–3961.

Singh, S., Ghoshal, N. and Singh, K. P. (2007). Synchronizing nitrogen availability through application of organic inputs of varying resource quality in a tropical dryland agroecosystem. *Applied Soil Ecology*, **36**, 164–175.

Singh, R., Meena, B. L., Sharma, S. K. and Kumar, P. (2024). Nitrogen mineralization from organic nutrient sources and its effect on crop productivity: A review. *Journal of Soil Science and Plant Nutrition*, **24**, 1456–1478.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, **418**, 671–677.

Velmurugan, A. and Swarnam, T. P. (2013). Nitrogen release pattern from organic manures applied to an acid soil. *Journal of Agricultural Science*, **5**(6), 174–184.

Wang, X., Li, S., Fan, B., Zhang, H. and Zhao, Y. (2022). Organic manure application enhances soil microbial activity, nitrogen transformation and maize productivity in agricultural soils. *Soil and Tillage Research*, **216**, 105257.

Zhang, J., Liu, Z., Wang, Y., Li, X. and Sun, H. (2022). Long-term application of organic manure improves soil fertility and nitrogen use efficiency in maize-based cropping systems. *Agriculture, Ecosystems & Environment*, **330**, 107904.

Zhang, H., Li, J., Chen, X., Wang, L. and Liu, Y. (2025). Long-term organic nutrient management improves nitrogen mineralization, soil quality and maize productivity in acidic soils. *Soil Use and Management*. (In press).

Zhao, P., Wang, Y., Li, X., Chen, S. and Liu, J. (2023). Nitrogen release characteristics of organic manures and their influence on maize growth and nutrient uptake. *Archives of Agronomy and Soil Science*, **69**, 2156–2172.