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Original Research Article

Residual effect of organic amendments (FYM and biochar) and urea types on soil nitrogen dynamics and wheat (*Triticum aestivum* L.) performance

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ABSTRACT

Integrated Nutrient Management (INM), which combines organic soil amendments with synthetic fertilizers, is an important strategy for maintaining soil fertility and crop productivity. The aim of this study was to evaluate the performance of wheat (*var. Zinc Gahun-1*) and the post-harvest soil nitrogen dynamics under residual effects of organic amendments with varied urea types and rates in Rupandehi, Nepal. A split plot experiment was conducted using Farmyard Manure (FYM) and biochar as main-plot factors and five urea treatments with 100% Neem Coated Urea (NCU), 50% NCU, 100% Prilled Urea (PU), 50% PU and a zero-urea (control) as sub-plot factors. Post-harvest soil total nitrogen (TN%) in topsoil (0-15cm) and subsoil (15-30cm) was evaluated using the Kjeldhal apparatus alongside key agronomic traits. The 100% NCU treatment yielded peak performance with 87.37cm plant height, 202.8 tillers/m^2, 43.2 grains/spike and 3.65 t ha^{-1} while, the control attributed 76.83cm plant height, 184.98 tiller numbers/m^2, 35.63 grains/spike and grain yield of 2.36 t ha^{-1}. 50% NCU and 100% PU showed statistically similar performance in almost all variables. Soil total nitrogen correlated strongly to topsoil (0- 15cm) at 0.099% compared to subsoil (15- 30cm) at 0.043%, indicating lower nitrate leaching. However, organic amendments showed negligible statistical differences with slight numerical edge of biochar compared to FYM. Thus, this indicated that farmers in terai of Nepal can effectively reduce the input costs for fertilizers by substituting conventional prilled urea with neem coated urea for similar crop productivity while maintaining organic amendments for long term soil health.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the third most vital cereal crop in Nepal, covering 681,851 hectares in area and annual production of 2,035,559 metric tons with majority of production in terai region (MoALD, 2025). Nitrogen(N) is an indispensable nutrient for wheat productivity and physiology, however Nitrogen Use Efficiency (NUE) especially in rice-wheat cropping system in Nepal remains low at 30-40%, which suggests more than half of the applied Nitrogen is lost through volatilization and leaching (Begho *et al*., 2025; Hafiza *et al*., 2025). As chemical fertilizers are easy to handle and show quick plant response on application along with increasing demand and lack of organic alternatives, reliance on chemical fertilizers especially urea has increased, reaching 259,542 mt in 2025 from 226,148 mt in 2024 (MoALD, 2025). Farmers use urea in higher doses without following the recommendations, usually only during the basal application which leads to higher yield gaps and lower fertilizer use efficiency (Devkota *et al*., 2018; Pandit *et al*., 2022). Continuous and irrational application of synthetic fertilizers along with inadequate organic inputs has resulted in soil health degradation like soil acidification, environmental pollution with reduced crop productivity causing financial constraints for farmers (Duan *et al*., 2019; Anas *et al*., 2020; Yadav, 2024). Similarly, acute fertilizer shortage especially urea during the peak cropping season calls for search of better alternatives (Khadka *et al*., 2025).

Integrated Nutrient Management (INM) which combines organic amendments like Farm Yard Manure and biochar with enhanced efficiency fertilizers presents a viable and long term solution for degraded soil by reducing dependency on chemical fertilizers and incorporation of organic sources (Tiwari *et al.*, 2009; Panta & Parajulee, 2021; Yimer & Tarwana, 2025). FYM, the complex of macronutrients and micronutrients improves microbial activity, soil aeration, water retention and nutrient mobilization which ultimately improves the soil structure and nutrient composition (Lamichhane *et al.*, 2022; Sheoran *et al.*, 2024). Biochar, on the other hand, also called "black gold" has porous structure and high charge density which helps in carbon stability, balancing pH, increasing microbial activity and water retention, thus restoring soil health (Abel *et al.*, 2013; Herath *et al.*, 2013; Zhang *et al.*, 2021). Combined application of FYM and Biochar help in amelioration of poor and degraded soil by transforming soil biological, chemical and physical properties in a sustainable way which ultimately increases crop productivity (Singh *et al.*, 2019; Pandey *et al.*, 2023; Dotaniya *et al.*, 2024). Additionally, slow release coated urea formulations such as Neem Coated Urea (NUE) contain nitrification inhibitors which helps to maintain supply of N throughout the crop cycle and reduce losses due to volatilization and runoff (Ghafoor *et al.*, 2021; Rehman *et al.*, 2021; Pandit *et al.*, 2022).

While prior studies have examined the effect of FYM, Biochar or slow release urea independently, combined research including residual effects of organic amendments along with varied urea formulations is lacking particularly within the subtropical terai region of Nepal. Hence, this study aims to evaluate the carryover effects of FYM and Biochar with different urea types and rates on post harvest soil total nitrogen and wheat productivity to address the local productivity constraints and soil degradation.

MATERIALS AND METHODS

Study area

The study was conducted at the Agronomy Farm of the Institute of Agriculture and Animal Science (IAAS), Paklihawa campus, Rupandehi district, Nepal. The site is geographically located at 27°29′ 02′ ′ N latitude and 83°27′17′ ′ E longitude at an altitude of 110 masl. The soil of the site is classified as sandy loam with pH 6.32, Nitrogen % 0.0877% and 2.144% organic matter showing medium fertility status. Wheat variety Zinc Gahun-1, a biofortified variety was used which is adapted to Terai agro-ecology.

Experimental design and treatment details

The experiment followed split plot design where the main factor was organic amendments while the sub- plots were urea types and rates (Figure 1). The study included 10 treatment combinations, replicated 3 times with 30 treatment plots. The total experiment field measured 30m × 17m with area of a single plot 12m^2 and spacing of 1.5m space between replications, 1m between main plots and 0.5m between sub-plots. Organic amendments (FYM and biochar) at the rate of 20 t/ha were applied two years earlier to the study and no fresh additions were made during the experiment. Preparation of biochar was done with majority of coconut waste and other tropical agricultural byproducts while FYM was prepared by composting available crop residues, cattle dung and livestock bedding materials. There were five varying nitrogen levels used in following doses at the recommended dose of 120: 40:40 NPK kg/ha. Urea was divided into three splits 50% at basal application, 25% at tillering and 25% at booting stage.

T_1: Farmyard Manure (FYM)

T_2: Biochar

t_1: Control, no urea (N0)

t_2: 100% Recommended Dose of Nitrogen (RDN) as Prilled Urea (PU100)

t_3: 50% RDN as Prilled Urea (PU50)

t_4: 100% RDN as Neem-Coated Urea (NCU100)

t_5: 50% RDN as Neem-Coated Urea (NCU 50)

The total experiment field measured 30m × 17m with area of a single plot 12m^2 and spacing of 1.5m space between replications, 1m between main plots and 0.5m between sub-plots.

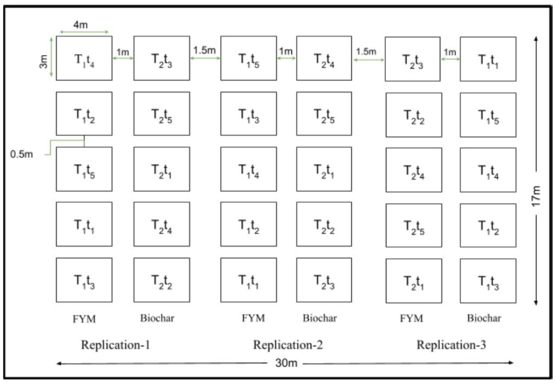

Figure 1. *Split plot experimental layout used in the study.*

Cultivation practices

The land was ploughed, levelled, irrigated and prepared according to the previous layout. The recommended dose of urea, DAP and Potassium were applied during the sowing. Line sowing was followed by manually sowing at a seed rate of 140 kg/ha where seeds were placed in rows spaced at 20cm. Weeding and irrigation was provided at regular intervals.

Data collection

Data were collected on wheat performance parameters: plant height (cm) at maturity, number of tillers per square meter, number of grains per spike and grain yield (t/ha). After harvesting, three random soil samples were collected using a soil sampling hand auger from each plot at two different depths: surface layer (0-15cm) and sub-surface layer (15-30cm). The soil samples were composited for each plot, air-dried and sieved through a 2mm mesh sieve. Total nitrogen in soil was determined using the Kjeldahl method (Bremner & Mulvaney, 1982).

Total Nitrogen % = [1.4007 *n* (S-B) *100] ÷ W

Where, n = normality of acid, S = Sample after titration, B = Blank after titration and W = weight of soil sample

Statistical analysis

Data collection, arrangement and organization was carried out using Microsoft Office-Excel 2013. Data analysis was done using Rstudio version 4.5.1 for Analysis of Variance (ANOVA) to test main plot, sub-plot, and interaction effects. Mean separation was done using the Least Significant Difference (LSD) test at 5% and 1% levels of significance. The significance of differences among treatment effects was tested by the 'F' test with p-value <0.05. Regression was employed to study relationships between soil nitrogen content in varied depth and wheat yield using MS excel.

RESULTS AND DISCUSSION

Soil total nitrogen

During the study, soil total nitrogen (TN %) was comparatively higher in topsoil (0-15cm) than subsoil (15-30 cm) for all factors. TN in NCU100% plots ranged from 0.0990% at 0-15cm to 0.0427% at 15-30cm, while PU100% varied from 0.0801% in topsoil to 0.0427% in subsoil. However, N level for control was 0.0643% and declined to 0.0364% in subsoil. This effectively shows vertical stratification of N in soil attributed to surface application of fertilizers, microbial activity and also due to adsorption capacity of biochar ultimately mitigating nitrate leaching (Li *et al*., 2023; Neupane & Kafle, 2025). The higher TN content under NCU100% implies the effectiveness of neem coating by slowing inorganic N release and reducing ammonia and nitrate loss via volatilization and leaching (Ghafoor *et al*., 2021). Likewise, Surekha *et al.* (2024) observed that neem coated urea demonstrated nitrification inhibition with ammonia retention in soil and reduced N loss. On the other hand, the lower TN values in reduced urea treatments show that replenishment of nutrients in soil was poor. Although the effect of organic amendments along with the interactive effects on TN was not statistically significant, biochar resulted in higher levels in both topsoil (0.083%) and subsoil (0.042%) compared to FYM, which yielded 0.0764% in topsoil and 0.0411% in the subsoil. Khan *et al.* (2024) also observed similar results where integrating biochar showed higher TN compared to FYM as N source. This may also be due to the masking effect of synthetic fertilizers over organic amendments in short-period.

Table 1. Wheat growth and yield response to organic amendments and nitrogen sources.

Treatment	Plant height(cm)	Tiller no/m^2	Grain/ spike	Grain yield(t/ha)
Factor A				
Biochar	83.40^a	183.05^a	40.12^a	3.24^a
FYM	79.99^a	178.53^a	40.11^a	3.02^a
CV	2.8	6.3	5.8	9.5
Grand mean	81.69	180.79	40.11	3.13
F-test	NS	NS	NS	NS
LSD	3.59	17.92	3.63	0.46
SE(±)	0.59	2.94	0.59	0.07
Factor B				
N0	76.83^c	184.98^b	35.63^e	2.36^d
NCU100%	87.37^a	202.83^a	43.15^a	3.65^a
NCU50%	83.78^b	177.46^{bc}	41.33^c	3.25^{bc}
PU100%	83.71^b	171.66^{bc}	41.91^b	3.36^b
PU50%	76.78^c	167.03^c	38.56^e	3.03^c
CV	3.1	7	7.1	5.8
Grand mean	81.69	180.79	40.11	3.13
F-test	***	**	**	***
LSD	3.11	15.04	3.47	0.22
SE(±)	1.03	5.13	1.15	0.07

Note: NS-Non significance (p>0.05), -significant (p<0.05), *-highly significant (p<0.01), ***- extremely highly significant (p<0.001), LSD- Least Significant Difference, SE-Standard Error and CV-Coefficient of variance, (T/ha-tonnes per hectare).

Agronomical parameters of wheat

The results on agronomical parameters of wheat are given in Tables 1, 2, 3. Application of urea significantly influenced all evaluated wheat parameters, especially NCU showed superior performance, by minimizing soil N losses and synchronizing N availability with crop demand (Ghafoor *et al*., 2021; Abdel-hamied *et al*., 2024). Notably, NCU applied at 50% performed similar to PU100%, as a result of rapid N release and volatilization and leaching loss, similar to findings of Ghafoor *et al.* (2021). However, Biochar and FYM did not show significant effects on wheat growth and yield, likely attributed to their structural stability and slow nutrient mineralization leading to low immediate effect on crop performance. As supported by Keller *et al.* (2023), improvements in soil structure, water retention and microbial activity driven by biochar generally is seen after sustained, multi-season application.

Table 2. Effect of organic amendments with varied urea treatments.

Treatment	TN %(0-15cm)	TN %(15-30cm)
Factor A		
Biochar	0.083^a	0.043^a
FYM	0.0764^a	0.0411^a
CV	18.12	19.077
Grand mean	0.0797	0.042
F-test	NS	NS
LSD	0.0227	0.0126
SE(±)	0.0037	0.0079
Factor B		
N0	0.0643^c	0.0364^b
NCU100%	0.0990^a	0.0427^a
NCU50%	0.08057^b	0.0422^{ab}
PU100%	0.08016^b	0.0427^{ab}
PU50%	0.0747^{bc}	0.0411^{ab}
CV	11.81	13.40
Grand mean	0.0808	0.041
F-test	***	*
LSD	0.0115	0.0069
SE(±)	0.0038	0.0023

Note: NS-Non significance (p>0.05), -significant (p<0.05), *-highly significant (p<0.01), ***- extremely highly significant (p<0.001), LSD- Least Significant Difference, SE- Standard Error and CV-Coefficient of variance.

Table 3. Interaction between FYM, biochar and urea forms in relation to soil total nitrogen in varied depths.

Interaction	TN % (0-15 cm)	TN% (15-30 cm)
Biochar: N0	0.0686^{cd}	0.0372^{bc}
Biochar: NCU100	0.1074^{a}	0.0494^{ab}
Biochar: NCU50	0.0821^{bc}	0.0440^{abc}
Biochar:PU100	0.0810^{bc}	0.0439^{abc}
Biochar:PU50	0.0761^{bcd}	0.0405^{abc}
FYM: N0	0.0600^{d}	0.0356^{c}
FYM: NCU100	0.0905^{b}	0.0466^{ab}
FYM: NCU50	0.0790^{bc}	0.0403^{abc}
FYM:PU100	0.0793^{bc}	0.0414^{abc}
FYM:PU50	0.0732^{cd}	0.0418^{abc}
CV%	11.81	18.4
Grand mean	0.07972	0.04207
F-test	NS	NS
LSD	0.0163	0.0097
SE(±)	0.0054	0.0032

Note: NS-Non significance (p>0.05), -significant (p<0.05), *-highly significant (p<0.01), ***- extremely highly significant (p<0.001), LSD- Least Significant Difference, SE- Standard Error and CV-Coefficient of variance.

Plant height

Nitrogen treatments significantly increased plant height such that tallest plants were recorded under NCU 100% (87.37cm). NCU 50% showed similar plant height as PU 100% (83.78cm and 83.71 cm) (Table 1). Previous findings support that neem coated urea supported plant height and overall vegetative growth compared to conventional urea (Aziz *et al*., 2025). In contrast, plant height was not significantly affected by organic amendments alone but biochar treated plots produced average height of 83.40 cm while FYM treated plots averaged 79.99cm showing 4.26% difference. It may be attributed to water and nutrient retention of biochar, particularly nitrogen (Rehman *et al*., 2021).

Tiller number

NCU100% produced the highest tiller number per unit area (202.83), followed by NCU50% (177.46), PU100% (171.66), PU50% (167.03), and control (184.98) (Table 1). The higher tiller number for NCU100% may be due to continuous and steady supply of nitrogen which helps tiller initiationand survival of the tillers productively. Neem oil coating serves as a nitrification inhibitor which slows the conversion of ammonium into nitrate, synchronizing N release with crop demand (Aziz *et al*., 2025). Tiller number was slightly higher under biochar (183.05) than FYM (178.53), but showed non-significance

Grain per spike

Grains per spike was almost identical under biochar (40.12) and FYM (40.11), the highest number of grains per spikes were observed under NCU100% (43.15), followed by PU100% (41.91), NCU50% (41.33), PU50% (38.56), and control (35.63) (Table 1). The positive effect of NCU100% on grains per spike highlights the importance of consistent nitrogen availability during reproductive stages for floret survival and grain set (Rehman *et al*., 2021). Reduced nitrogen levels in PU50% or control likely limited floret development, leading to fewer grains per spike. Previous findings reveal the effectiveness of coated urea compared to normal urea by Aziz *et al*. (2025) and Ghafoor *et al*. (2021).

Grain yield

Grain yield was slightly higher under biochar (3.24 t ha^{-1}) than FYM (3.02 t ha^{-1}) while Nitrogen treatments significantly influenced yield with NCU100% producing the highest yield (3.65 t ha^{-1}), followed by PU100% (3.36 t ha^{-1}), NCU50% (3.25 t ha^{-1}), PU50% (3.03 t ha^{-1}), and control (2.36 t ha^{-1}) (Table 1). Urea caused significant effects on all wheat parameters especially, NCU slow-release urea showed superior performance, synchronizing N availability with crop demand also reported by Abdelhamied *et al*. (2024) and Rehman *et al*. (2021). NCU50% showed almost similar performance as PU100% due to fast release of N and loss during volatilization and leaching as observed by Ghafoor *et al*. (2021) when NCU performed better than uncoated urea. Regression analysis revealed a strong positive relationship between grain yield and post-harvest residual soil total nitrogen (TN%) within the 0-15cm depth profile (R^2=0.44) and moderately at the depth of 15-30cm (R^2=0.40) (Figure 2). These findings of higher concentrations of soil nitrogen after crop harvest indicate nutrient pool preservation for subsequent seasons. Slow mineralization of organic amendments along with sustained inorganic nitrogen sources of coated urea likely helped in crop yield and improved soil nitrogen pool which is similar to findings of Aziz *et al*. (2025).

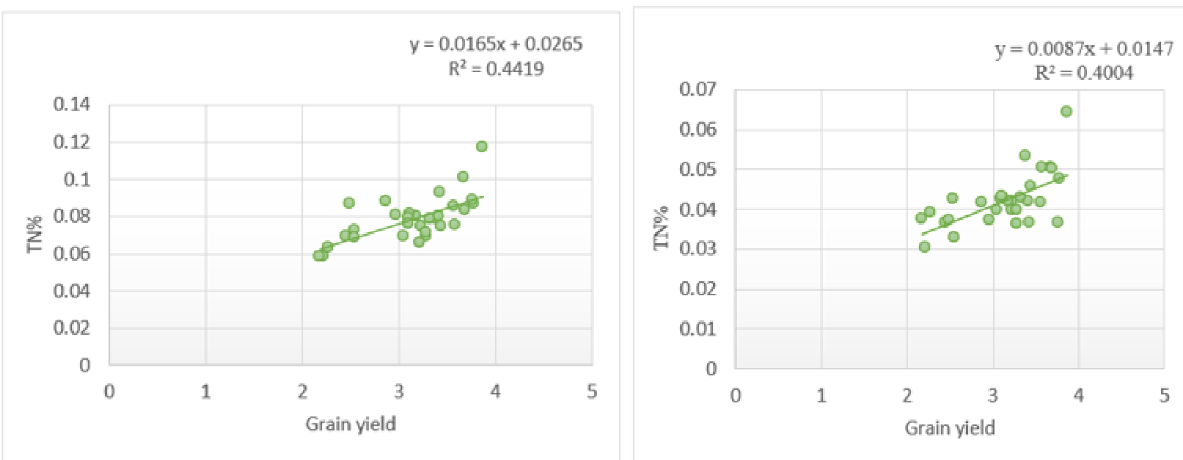

Figure 2. *Regression analysis of grain yield and residual total nitrogen (TN%).*

Conclusion

This study conducted in Rupandehi, Nepal, demonstrated that coated urea, particularly, full-dose neem coated urea (100% NCU) was significantly superior compared to standard prilled urea. NCU enhances major agronomic parameters of wheat including plant height, tiller numbers, grain per spike and grain yield while also maintaining soil total nitrogen. Full dose PU achieved similar vegetative and grain performance as half dose NCU, which proves that neem coating enhances NUE and limits N losses. However, short-term and single season application of FYM and Biochar produced no immediate effects or interaction effect with urea on wheat productivity and soil N. This suggests that organic amendments require multi-season and sustained implementation for nutrient mobilization. Biochar, though not statistically significant, showed slight advantage over FYM in nutrient retention due to its porous structure and adsorption capacity. Furthermore, soil profile testing shows residual N stratification within topsoil and subsoil, suggesting nutrient capturing in topsoil as a result of reduced leaching through slow release urea and biochar. This research confirms that nutrient management strategy involving high efficiency fertilizers like NCU presents an actionable and cost-effective path for Nepalese farmers to increase crop productivity while also conserving soil and reducing expensive fertilizers use. Moving forward, multi-season field trials and tracking of real time crop N uptake and losses are suggested to account for the effectiveness of fertilizers for enhanced productivity and sustainable soil health.

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DECLARATIONS

Authors' contribution statement: Conceptualization, Methodology: J.J.G; Software, Validation, Data curation, Formal analysis, Visualization, Review & editing, M.S; Writing, Original draft preparation, J.J.G., M.S. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

Abdelhamied, A. S., Selim, E. M. M., & Mosaad, I. S. M. (2024). Modified slow-release urea fertilizers on yield and nitrogen use efficiency of wheat crop (*Triticum aestivum* L.) for a safe and sustainable agricultural system. *Communications in Soil Science and Plant Analysis*, *55*(22), 3497–3509. https://doi.org/10.1080/00103624.2024.2402794

Abel, S., Peters, A., Trinks, S., Schonsky, H., Facklam, M., & Wessolek, G. (2013). Impact of biochar and hydrochar addition on water retention and water repellency of sandy soil. *Geoderma*, *202–203*, 183–191. https://doi.org/10.1016/j.geoderma.2013.03.003

Anas, M., Liao, F., Verma, K. K., Sarwar, M. A., Mahmood, A., Chen, Z.L., Li, Q., Zeng, X.P., Liu, Y., & Li, Y.R. (2020). Fate of nitrogen in agriculture and environment: Agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency. *Biological Research*, *53*, 47. https://doi.org/10.1186/s40659-020-00312-4

Aziz, A., Tahir, M. A., Sabah, N. U., Adnan, M., Ahmad, M., Romman, M., Lal, R., Fahad, S., Abdel-Maksoud, M. A., Fatima, S., Al-Qahtani, W. H., & Zakria, A. M. (2025). Effects of coating agents on nitrogen dynamics and yield of wheat (*Triticum aestivum* L.) under irrigated and rainfed conditions. *Scientific Reports 15*, 35258. https://doi.org/10.1038/s41598-025-14121-w

Begho, T., Joshi, R., Nepal, B., Donovan, T., & Eory, V. (2025). Farm level drivers of nitrogen use efficiency in the Terai region of Nepal. *Discover Soil*, *2*(1), 38. https://doi.org/10.1007/s44378-025-00064-1

Bremner, J.M., & Mulvaney, C.S. (1982). Nitrogen total. In A.L. Page (Ed.), *Methods of soil analysis: part 2. Chemical and microbiological properties* (2nd ed., pp. 595-624). American Society of Agronomy. https://doi.org/10.2134/agronmonogr9.2.2ed.c31

Devkota, K. P., Devkota, M., Khadka, L., Khadka, A., Paudel, G., Acharya, S., & McDonald, A. (2018). Nutrient responses of wheat and rapeseed under different crop establishment and fertilization methods in contrasting agro-ecological conditions in Nepal. *Soil and Tillage Research*, *181*, 46-62. https://doi.org/10.1016/j.still.2018.04.001

Dotaniya, M. L., Meena, M. D., Choudhary, R. L., Meena, M. K., Meena, V. D., Singh, H., Lakaria, B. L., Jat, R. S., Rai, P. K., Kumar, K., Doutaniya, R. K., & Singh, H. (2024). Dynamics of major plant nutrients and enzymatic activities in soil influenced by application of biochar and organic waste. *PLOS ONE*, *19*(10), e0307487. https://doi.org/10.1371/journal.pone.0307487

Duan, J., Shao, Y., He, L., Li, X., Hou, G., Li, S., Feng, W., Zhu, Y., Wang, Y., & Xie, Y. (2019). Optimizing nitrogen management to achieve high yield, high nitrogen efficiency and low nitrogen emission in winter wheat. *Science of The Total Environment*, *697*, 134088. https://doi.org/10.1016/j.scitotenv.2019.134088

Ghafoor, I., Habib-ur-Rahman, M., Ali, M., Afzal, M., Ahmed, W., Gaiser, T., & Ghaffar, A. (2021). Slow-release nitrogen fertilizers enhance growth, yield, NUE in wheat crop and reduce nitrogen losses under an arid environment. *Environmental Science and Pollution Research 28*(32), 43528–43543. https://doi.org/10.1007/s11356-021-13700-4

Hafiza, B. S., Ishaque, W., Akhtar, M., Shani, M. Y., Azmat, M., Bauerle, W. L., Rahimi, M., & Ashraf, M. Y. (2025). Optimizing nitrogen management for sustainable wheat production in semi-arid subtropical environments: Impact on growth, physio-biochemical, and yield attributes. *Nitrogen*, *6*(2), 36. https://doi.org/10.3390/nitrogen6020036/s1

Herath, H.M.S.K., Camps-Arbestain, M., & Hedley, M. (2013). Effect of biochar on soil physical properties in two contrasting soils: an Alfisol and an Andisol. *Geoderma*, *209-219*, 188-197. https://doi.org/10.1016/j.geoderma.2013.06.016

Keller, L., Idowu, O. J., Ulery, A., Omer, M., & Brewer, C. E. (2023). Short-Term Biochar Impacts on Crop Performance and Soil Quality in Arid Sandy Loam Soil. *Agriculture 13*(4), 782. https://doi.org/10.3390/agriculture13040782

Khadka, U., Devkota, N., Khanal, G., Maraseni, T., & Ghimire, P. R. (2025). Enhancing agricultural productivity through improved fertilizer accessibility: Insights from a contingent valuation study in Eastern Nepal. *Agriculture & Food Security 2025*,*14*, 12. https://doi.org/10.1186/s40066-025-00532-5

Khan, M. A., Basir, A., Shah, S. T., Rehman, M. U., Hassan, M. ul, Zheng, H., Basit, A., Jamal, A., Radicetti, E., Dewir, Y. H., & Mancinelli, R. (2024). *Sustainable Soil Management in Alkaline Soils: The Role of Biochar and Organic Nitrogen in Enhancing Soil Fertility*. https://doi.org/10.20944/preprints202410.1189.v1

Lamichhane, S., Khanal, B. R., Jaishi, A., Bhatta, S., Gautam, R., & Shrestha, J. (2022). Effect of integrated use of farmyard manure and chemical fertilizers on soil properties and productivity of rice in Chitwan. *Agronomy Journal of Nepal*, *6*(1), 200–212. https://doi.org/10.3126/ajn.v6i1.47994

Li, B., Tian, X., Zhang, S., Duan, M., & Wang, L. (2023). Effects of combined application of biochar and different types of nitrogen fertilizers on rapeseed root growth and properties of purple soil in southwest China. *Agronomy*, *13*(9), 2209. https://doi.org/10.3390/agronomy13092209

MoALD, Ministry of Agriculture and Livestock Development. (2025). *Statistical Information on Nepalese Agriculture 2081/82*. https://moald.gov.np/content/500/statistics-information-on-nepalese-agriculture-2081-82

Neupane, N., & Kafle, G. (2025). Soil fertility stratification in a fragile ecosystem: Depth-wise gradients of nitrogen, phosphorus, potassium and pH in Chure hills Nepal. *Journal of Agriculture and Natural Resources*, *8*(1), 41–51. https://doi.org/10.3126/janr.v8i1.88835

Pandey, A., Jakasaniya, M. S., Inwati, D. K., Yadav, B., Singh, K., Bharteey, P. K., Kumar, R., Borah, S. R., & Bahuguna, A. (2023). Effect of Biochar and FYM and its Interaction on Soil Health Indicator under the Salt Affected Soil. *Ecology, Environment and Conservation*, *29*(November Suppl.Issue), S529–535. https://doi.org/10.53550/eec.2023.v29i06s.084

Pandit, N. R., Gaihre, Y. K., Choudhary, D., Subedi, R., Thapa, S. B., Maharjan, S., Khadka, D., Vista, S. P., & Rusinamhodzi, L. (2022). Slow but sure: the potential of slow-release nitrogen fertilizers to increase crop productivity and farm profit in Nepal. *Journal of Plant Nutrition*, *45*(19), 2986–3003. https://doi.org/10.1080/01904167.2022.2067053

Panta, S., & Parajulee, D. (2021). Integrated nutrient management (INM) in soil and sustainable agriculture. *International Journal of Applied Sciences and Biotechnology*, *9*(3), 160–165. https://doi.org/10.3126/ijasbt.v9i3.39275

Rehman, I., Riaz, M., Ali, S., Arif, M. S., Ali, S., Alyemeni, M. N., & Alsahli, A. A. (2021). Evaluating the effects of biochar with farmyard manure under optimal mineral fertilizing on tomato growth, soil organic C and biochemical quality in a low fertility soil. *Sustainability*, *13*(5), 2652. https://doi.org/10.3390/su13052652

Sheoran, S., Prakash, D., Yadav, P. K., Gupta, R. K., Al-Ansari, N., El-Hendawy, S., & Mattar, M. A. (2024). Long-term application of FYM and fertilizer N improve soil fertility and enzyme activity in 51st wheat cycle under pearl millet-wheat. *Scientific Reports*, *14*(1), 21695. https://doi.org/10.1038/S41598-024-72076-w

Singh, R., Singh, P., Singh, H., & Raghubanshi, A. S. (2019). Impact of sole and combined application of biochar, organic and chemical fertilizers on wheat crop yield and water productivity in a dry tropical agro-ecosystem. *Biochar*, *1*(2), 229–235. https://doi.org/10.1007/s42773-019-00013-6

Surekha, K., Pragnya, M., Manasa, V., Gobinath, R., & Brajendra, P. (2024). Potential agronomic and environmental benefits of neem coated urea (NCU) application in rice (*Oryza sativa* L.)-A systematic review: Benefits of NCU application in rice. *ORYZA- An International Journal of Rice*, *61*(4), 408-419. https://doi.org/10.35709/ory.2024.61.4.15

Tiwari, K. R., Sitaula, B. K., Bajracharya, R. M., & Børresen, T. (2009). Effects of soil and crop management practices on yields, income and nutrients losses from upland farming systems in the Middle Mountains region of Nepal. *Nutrient Cycling in Agroecosystems*, *86*(2), 241–253. https://doi.org/10.1007/S10705-009-9289-0

Yadav, M. (2024). Nitrogen uptake in wheat: A comprehensive study. *International Journal of Research in Agronomy*, *7*(4), 101–103. https://doi.org/10.33545/2618060X.2024.v7.i4b.535

Yimer, A. H., & Tarnawa, A. (2025). Advancing nutrient management strategies for sustainable crop productivity in a changing climate: A systematic review. *The Scientific World Journal*, *2025*, 7101060. https://doi.org/10.1155/TSWJ/7101060

Zhang, Y., Wang, J., & Feng, Y. (2021). The effects of biochar addition on soil physicochemical properties: A review. *CATENA*, *202*, 105284. https://doi.org/10.1016/j.cantena.2021.105284