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Effect of *Trichoderma asperellum* Inoculation on Mineralization of Carbon and Nitrogen during Composting of Plant and Animal Residues

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Abstract

Trichoderma spp is a genus of fungi, among many species that can be used to control phytopathogenic fungi. Having reviewed past research, there is a dearth of knowledge on the use of *Trichoderma* as an activator in the production of compost. This study was therefore carried out to determine the effect of *Trichoderma asperellum* inoculation on the mineralization of carbon and nitrogen in compost of different plant and animal materials. The experiment was carried out in the Soil Science laboratory of the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The experiment was set up in a 2 x 2 x 2 factorial combination arranged in a completely randomized design with 3 replications. The treatment consisted of two (2) types of animal wastes (poultry manure and cow dung), two (2) types of plant residues (*Panicum maximum* and *Aspilia africana*) and two (2) levels of *Trichoderma* inoculation (inoculated and uninoculated). The animal and plant residues were mixed in the ratio 3:1 and composted for twelve (12) weeks. Data were

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collected on pH, soil organic carbon, soil nitrate and ammonium content at 4, 8 and 12 weeks after inoculation. Data collected were subjected to analysis of variance and treatment means were separated using Duncan Multiple Range Test (DMRT). At the end of the study, it was observed that *Trichoderma asperellum* inoculation increased nitrogen mineralization in the compost, especially at eight (8) weeks after inoculation. Nitrate and ammonium-N levels differed significantly as *Trichoderma asperellum* inoculation favored increased nitrate-N over ammonium-N in the compost. It is therefore concluded that *Trichoderma asperellum* inoculation has the potential to enhance N mineralization thus improving the quality of compost for agricultural production.

Keywords: Compost; Trichoderma asperellum; plant residues; Inoculation; N-mineralization.

1. Introduction

Beneficial microorganisms play a crucial role in nature farming and organic agriculture by improving soil quality, enhancing crop yield, and serving as biocontrol agents and microbial activators (Wang *et al.,* 2019; El Mujtar *et al*., 2021; Fontaine *et al*., 2024). Certain microorganisms are classified as beneficial because they facilitate nutrient uptake by plants and provide protection against pathogens, although some microbes can be pathogenic. Topsoil enriched with leaf litter, particularly in forested ecosystems, serves as a reservoir for diverse microbial communities, which can be harnessed and introduced into agricultural environments to support crop growth (de Sosa *et al.,* 2023; Harman, 2006; Koning *et al*., 2000; Shukla & Cameotra, 2012).

Fungi are among the most important beneficial microorganisms in soil, playing a key role in maintaining forest ecosystem dynamics. They are efficient decomposers of organic matter, and their activity is increasingly utilised in the production of organic fertilisers to accelerate decomposition and improve the nutrient content of the final product (Bansal *et al*., 2022; Soretire & Adigun, 2026). Similarly, animal manures contain diverse bacteria and fungi that contribute to decomposition processes. In this study, a beneficial fungus isolated from carabao manure is being investigated for its potential as a microbial activator to reduce composting time and enhance the production of organic fertiliser (Bhaduri *et al*., 2022; Eldridge *et al.,* 2017). While *Trichoderma* species from other sources are widely used as commercial compost activators, this research aims to isolate an effective and low-cost alternative from carabao manure, given that the cost of microbial activators represents a major expenditure in organic fertiliser production (Adigun & Babalola, 2016; Bae *et al.,* 2011; Babalola *et al.,* 2018).

Trichoderma spp. are predominantly soil-dwelling saprophytic fungi capable of controlling phytopathogenic fungi. They exhibit rapid growth, competitive resilience against other soil microorganisms, resistance to chemical pesticides, and production of various antibiotics such as gliotoxin and viridin. Microorganisms constitute the living component of soil and drive the transformation and development of soil structure (Graham *et al*., 2017; Adigun & Babalola, 2016; Brenzinger *et al.,* 2021; Adigun & Babalola, 2017). *Trichoderma* is ubiquitous in soils and is among the most prevalent culturable fungi. Many species function as opportunistic, avirulent plant symbionts, forming mutualistic endophytic associations with various plant species, thereby highlighting their importance in biological control and soil improvement programmes (Adigun & Babalola, 2017). Microorganisms also play a pivotal role in recycling agricultural wastes. Compost produced through the bioconversion of agro-residues enhances soil fertility and health, improves biodiversity, reduces ecological risks, and contributes to sustainable agricultural productivity (Akinbola *et al.,* 2014; Harman *et al.,* 2004; Iranzo *et al.,* 2001). Such compost can serve as a carrier for bio-inoculants, disease-suppressive biocontrol agents, and materials for bioremediation. These advantages underscore the need for intensified research into novel and effective microorganisms for producing high-quality compost within shorter timeframes and developing scalable technologies for large-scale application.

2. Materials and Methods

The study was carried out in the laboratory of the Department of Soil Science and Land Management, Federal University of Agriculture, Abeokuta, Nigeria.

2.1 Sources of Materials

Soil samples were collected from the upland area of FADAMA. Organic soil amendments (poultry manure and cow dung) were sourced from a commercial livestock farm and the plant materials Elephant grass (*Panicum* *maximum)* and goat weed (*Aspilia africana*) from the Institute of Food Security, Environmental Resources and Research (IFSERAR).

2.2 Soil Preparation and Analysis

Experimental soil was air-dried, passed through 2 mm sieve and analyzed routinely for pH, Organic Carbon, Total Nitrogen, Available P, Exchangeable Bases (Na, K, Ca, Mg) and particle size distribution as follows:

2.3 Experimental Procedure

The soil sample collected was air-dried and passed through 2mm sieve. The plant materials (Elephant grass *Panicum maximum* and goat weed *Aspilia africana*) were chopped into smaller sizes. The gravimetric moisture content of the organic soil amendment (poultry manure and cow dung) was determined in order to know the amount of water present in the soil amendment by oven drying at 65^0c to a constant weight. Animal and plant residues shall be mixed in ratio 3:1 (animal residue (210 g) and plant residue (70 g) shall be weighed into a glass jar in layer with surface soil in between to make up a total weight of 500 g. Each jar was wetted with 25 ml of distilled water or 5 ml *Trichoderma* culture per jar. This was inoculated under laboratory conditions for a period of 12 weeks. Each treatment shall be turned at 4 and 8 weeks after inoculation. The experiment will be a 2 x 2 x 2 factorial combination arranged in a completely randomised design with 3 replications. The treatment shall consist of two types of animal wastes (poultry manure and cow dung), two types of plant residues (*Panicum maximum* and *Aspilia africana*) and two levels of *Trichoderma* inoculation (inoculated and uninoculated). The ratio of animal to plant residue will be 3:1.

Each treatment had the following combinations:

T1 = Soil (80g) + Pm (210g) + Soil (70g) + Aa (70g) + Soil (70g) + T (5ml)
T2 = Soil (80g) + Pm (210g) + Soil (70g) + Aa (70g) + Soil (70g) + NT
T3 = Soil (80g) + Cd (210g) + Soil (70g) + Aa (70g) + Soil (70g) + T (5ml)
T4 = Soil (80g) + Cd (210g) + Soil (70g) + Aa (70g) + Soil (70g) + NT
T5 = Soil (80g) + Pm (210g) + Soil (70g) + P (70g) + Soil (70g) + T (5ml)
T6 = Soil (80g) + Pm (210g) + Soil (70g) + P (70g) + Soil (70g) + NT
T7 = Soil (80g) + Cd (210g) + Soil (70g) + P (70g) + Soil (70g) + T (5ml)
T8 = Soil (80g) + Cd (210g) + Soil (70g) + P (70g) + Soil (70g) + NT

KEY

PM = Poultry manure; CD= Cow dung; P = *Panicum maximum;* AA = *Aspilia africana*
T = Inoculation (*Trichoderma*)*;* NT = No Inoculation

2.4 Data Collection

Data were collected on Soil pH, soil organic carbon, soil nitrate and ammonium content at 4, 8, and 12 weeks after inoculation (WAI).

2.5 Statistical Analysis

Data collected was subjected to Analysis of Variance (ANOVA) using the Statistical Analysis system version 2.2 for windows (SAS Inc., 2000) and the treatment means separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. Results and Discussion

3.1 Physical and Chemical Properties of the Soil Used for the Experiment

The soil is sandy loam. It is high in available phosphorus, low in total nitrogen and exchangeable bases. It has a neutral pH range of 7.2 with a particle size of sand- 68.9%, clay- 4.2%, and silt -26.9%. Total Nitrogen -0.216%, Available Phosphorus- 42.67 mg/kg, Exchangeable Acidity- 0.2 mEq/100g, Organic Carbon -0.678%, Organic Matter - 1.172% Exchangeable Na -0.436 cmol/kg, K - 0.651 cmol/kg, Ca -0.212 cmol/kg, Mg- 0.321 cmol/kg.

Table 1. Physical and chemical properties of the soil used for the experiment

Soil properties	Fadama
pH (H_2O)	7.2
Total N (%)	0.216
Available P (mg/kg)	42.67
Exch. Acidity (mEq/100g)	0.2
Textural class	Sandy loam
Sand (%)	68.9
Silt (%)	26.9
Clay (%)	4.2
Org. Carbon (%)	0.678
Org. Matter (%)	1.172
Exchangeable Ca (cmol/kg)	0.212
Mg (cmol/kg)	0.321
Na (cmol/kg)	0.436
K (cmol/kg)	0.651

Effect of *Trichoderma*-based compost with different plant residues on pH, Carbon and Nitrogen mineralization. The result shows that the pH status of the plant residues increases across the inoculation weeks and they were all strongly alkaline. There was no significant difference in the pH at 4^{th}, 8^{th} and 12^{th} weeks after inoculation (WAI).

The organic carbon content of the plant residues (*Panicum maximum* and *Aspilia africana*) increases across the inoculation weeks. There was also no significant difference in the organic carbon content of the plant residues but *Aspilia africana* has the highest value of 2.076 for organic carbon content at 4 WAI. At 8 WAI, *Panicum maximum* has the highest value of 2.13 for organic carbon compared to *Aspilia africana* while at 12 WAI *Aspilia africana* has the highest value of 3.27 for organic carbon.

The Nitrate Nitrogen (NO_3-N) content of the residues also increases across the inoculation weeks, in which there was no significant difference between the two plant residues (*Panicum maximum* and *Aspilia africana*) but *Aspilia africana* has the highest value of nitrate nitrogen at 4^{th}, 8^{th} and 12^{th} weeks after inoculation compared to *Panicum maximum.*

The Ammonium Nitrogen content (NH_4-N) of both plant residues increases at 4^{th}, 8th and 12^{th} WAI. *Panicum maximum* has the highest value at 4^{th} and 8^{th} WAI while *Aspilia africana* has the highest value (44.24^{a}) at 8 WAI.

Effect of *Trichoderma*-based compost with different animal residues on pH, Carbon and Nitrogen mineralization. The result shows that the pH status of the animal residues increases across the inoculation weeks. There was no significant difference in all the parameters examined across the inoculation weeks, only that the highest value for organic carbon at 8 WAI was observed. Poultry manure has the highest value for both Nitrate and Ammonium Nitrogen at 4 and 8 WAI, while cow dung has the highest value for nitrate nitrogen content at 12 WAI.

Effect of *Trichoderma asperellum* inoculation on pH, carbon and nitrogen mineralization of different plant and animal-based compost.

At 4 WAI, the pH, OC, NO_3-N and NH_4-N were not significantly different ($p<0.05$) with respect to *Trichoderma* and non-*trichoderma* inoculation. The pH were not significantly different from each other.

The organic carbon content was highest at *Trichoderma* and least at non-*trichoderma*.

The NO_3-N was highest at non-*trichoderma* and least at *Trichoderma*.

Table 2. Effect of *Trichoderma*-based compost with different plant residues on pH, Carbon and Nitrogen mineralization

	4WAI				8WAI				12WAI			
Plant Residue	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**
Panicum maximum	8.75^a	2.038^a	17.18^a	1.93^a	8.97^a	2.13^a	42.37^a	3.89^a	8.84^a	3.24^a	62.20^a	9.22^a
Aspilia africana	8.48^a	2.08^a	19.79^a	1.84^a	8.66^b	2.11^a	44.24^a	3.99^a	8.66^a	3.27^a	63.12^a	8.42^b

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY
OC = Organic Carbon; NO_3-N = Nitrate Nitrogen; NH_4-N = Ammonium Nitrogen; pH = Soil Reaction; WAI = Weeks After Inoculation

Table 3. Effect of *Trichoderma*-based compost with different animal residues on pH, Carbon and Nitrogen mineralization

	4WAI				8WAI				12WAI			
Animal Residue	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**
Cow dung	8.75^a	2.07^a	15.89^a	1.78^a	8.83^a	2.07^a	41.94^a	3.72^a	8.97^a	3.35^a	65.52^a	8.73^a
Poultry Manure	8.48^b	2.05^a	21.07^a	1.98^a	8.80^a	2.16^a	44.67^a	4.16^a	8.53^a	3.15^a	59.79^a	8.85^a

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY
OC = Organic Carbon; NO_3-N = Nitrate Nitrogen; NH_4-N = Ammonium Nitrogen; pH = Soil Reaction; WAI = Weeks After Inoculation

Table 4. Effect of *Trichoderma asperellum* inoculation on carbon and nitrogen mineralization of different plant and animal-based compost

	4WAI				8WAI				12WAI			
Inoculation	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**	**pH (2:1)**	**%OC**	**NO_3-N ($cmolkg^{-1}$)**	**NH_4-N ($cmolkg^{-1}$)**
Trichoderma	8.61^a	2.13^a	16.80^a	1.42^a	8.71^a	2.232^a	48.45^a	3.66^b	8.82^a	3.23^a	63.75^a	8.94^a
Non- *trichoderma*	8.61^a	1.98^a	20.16^a	2.35^a	8.92^a	2.01^a	38.17^b	4.22^a	8.68^a	3.27^a	61.56^a	8.70^a

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY
OC = Organic Carbon; NO_3-N = Nitrate Nitrogen; NH_4-N = Ammonium Nitrogen; pH = Soil Reaction; WAI = Weeks After Inoculation

The NH_4-N was highest at non-*trichoderma* and least at *Trichoderma*.

At 8 WAI, pH and OC were not significantly different (p<0.05) with respect to *Trichoderma* and non-*trichoderma* inoculation. The NO_3-N and NH_4-N differed significantly (P<0.05) with respect to *Trichoderma* and non-*trichoderma* inoculation. The PH was highest at non-*trichoderma* and least at *trichoderma*. The organic carbon content was highest at *Trichoderma* and least at non-*trichoderma*. The NO_3-N content was highest at *Trichoderma* and least at non- *trichoderma*. The NH_4-N content was highest at non-*trichoderma* and least at *Trichoderma.*

At 12 WAI, the pH, OC, NO_3-N and NH_4-N were not significantly different (P<0.05) with respect to *Trichoderma* and non-*trichoderma* inoculation. The pH was highest at *Trichoderma* and lowest pH was observed at non-*trichoderma inoculation.* The organic carbon content was highest at non-*trichoderma* and least at *trichoderma*. The NO_3-N content was highest at *Trichoderma* and least at non-*trichoderma.* The NH_4-N content was highest at *trichoderma* and least at non-*trichoderma.*

The interactive effect of *Trichoderma asperellum* on pH, carbon and nitrogen mineralization in different plant and animal residues-based compost at 4 WAI.

The pH, OC, NO_3-N and NH_4-N of the compost differed significantly (P<0.05) with respect to *Trichoderma* and non-*trichoderma* inoculation. The pH was highest at NT+CD+P and least at NT+CD+AA. The organic carbon content was highest at T+PM+AA and least at NT+PM+P.

The nitrate nitrogen content differed significantly with respect to *Trichoderma* inoculation and control. The nitrate nitrogen content of the compost was highest at NT+PM+AA and lowest at T+CD+P. All other treatment combinations were significantly different (P<0.05) from each other. The ammonium nitrogen content of the compost was highest at NT+PM+AA and least at T+PM+P. Other treatment combinations were significantly (P<0.05) different from each other.

Table 5. Effect of *Trichoderma asperellum* on carbon and nitrogen mineralization in different plant and animal residues-based compost at 4 weeks after inoculation (4 WAI)

Treatment	pH(2:1)	%OC	NO_3-N(cmolkg^{-1})	NH_4-N(cmolkg^{-1})
T+CD+AA	8.71^{b}	2.08^{ab}	15.18^{ab}	1.65^{abc}
T+PM+AA	8.47^{bc}	2.19^{a}	18.42^{ab}	1.39^{bc}
T+PM+P	8.50^{bc}	2.11^{a}	21.64^{ab}	1.26^{c}
T+CD+P	8.78^{b}	2.15^{a}	11.96^{b}	1.38^{bc}
NT+PM+P	8.43^{bc}	1.92^{c}	17.42^{ab}	2.63^{a}
NT+CD+P	9.30^{a}	1.97^{bc}	17.68^{ab}	2.43^{ab}
NT+PM+AA	8.52^{bc}	1.97^{bc}	26.79^{a}	2.65^{a}
NT+CD+AA	8.21^{c}	2.07^{ab}	18.75^{ab}	1.68^{abc}

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY
OC = Organic Carbon; P = Panicum maximum; NO_3-N = Nitrate Nitrogen; AA = Aspillia africana; NH_4-N = Ammonium Nitrogen; T = Inoculation (Trichoderma); pH = Soil Reaction; NT = No Inoculation; WAI = weeks after Inoculation; PM = Poultry manure; CD= Cow dung

The interactive effect of *Trichoderma asperellum* on pH, carbon and nitrogen mineralization in different plant and animal residues-based compost at 8 WAI.

The pH and NH_4-N content of the compost were not significantly (P<0.05) different with respect to *Trichoderma* and non-*trichoderma* inoculation. The pH was highest at NT+CD+AA and least at T+CD+P. The organic carbon content differed significantly (P<0.05) with respect to *Trichoderma* inoculation and control.

The organic carbon was highest at T+CD+AA and lowest at NT+CD+AA. The nitrate nitrogen content of the compost differed significantly (P<0.05) with respect to Treatment combinations. The nitrate nitrogen was highest at T+CD+P and least at NT+CD+AA.

Table 6. The interactive effect of *Trichoderma asperellum* on carbon and nitrogen mineralization in different plant and animal residues-based compost at 8 weeks after inoculation

Treatment	pH(2:1)	%OC	NO_3- N($cmolkg^{-1}$)	NH_4-N($cmolkg^{-1}$)
T+CD+AA	8.78^{a}	2.45^{a}	42.46^{ab}	3.24^{a}
T+PM+AA	8.72^{a}	2.19^{ab}	48.69^{ab}	4.12^{a}
T+PM+P	8.84^{a}	2.18^{ab}	49.57^{ab}	3.68^{a}
T+CD+P	8.53^{a}	2.14^{ab}	54.50^{a}	3.68^{a}
NT+CD+P	8.87^{a}	2.19^{ab}	41.26^{ab}	4.42^{a}
NT+PM+P	8.81^{a}	1.95^{bc}	45.09^{a}	4.21^{a}
NT+CD+AA	9.05^{a}	1.71^{c}	27.87^{c}	3.80^{a}
NT+PM+AA	8.93^{a}	2.16^{ab}	37.0^{bc}	4.37^{a}

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY: OC = Organic Carbon; P = Panicum maximum; NO_3-N = Nitrate Nitrogen; AA = Aspillia africana; NH_4-N = Ammonium Nitrogen; T = Inoculation (Trichoderma); pH = Soil Reaction; NT = No Inoculation; WAI = weeks after Inoculation; PM = Poultry manure; CD= Cow dung

The interactive effect of *Trichoderma asperellum* on carbon and nitrogen mineralization in different plant and animal residues-based compost at 12 WAI.

The pH and OC content of the compost differed significantly ($P<0.05$) with respect to *trichoderma* inoculated and un-inoculated treatments. The pH was highest at T+CD+AA and least at NT+PM+P. The organic carbon content was highest at T+CD+AA and least at NT+CD+P.

The NO_3-N and NH_4-N content of the compost were not significantly different ($P<0.05$) with respect to *Trichoderma* inoculation and control. The nitrate nitrogen was highest at NT+CD+AA and least at NT+PM+P. all other treatment combinations were not significantly different from each other. The ammonium nitrogen content was highest at T+CD+P and least at T+PM+AA. All other treatment combinations were not significantly ($P<0.05$) different from each other.

Table 7. The interactive effect of *Trichoderma asperellum* on carbon and nitrogen mineralization in different plant and animal residues-based compost at 12 weeks after inoculation

Treatment	pH(2:1)	%OC	NO_3-N($cmolkg^{-1}$)	NH_4-N($cmolkg^{-1}$)
T+CD+AA	9.22^{a}	3.80^{a}	60.05^{a}	9.46^{a}
T+PM+AA	8.58^{bc}	3.04^{b}	67.63^{a}	8.33^{a}
T+PM+P	8.78^{abc}	3.02^{b}	61.36^{a}	9.38^{a}
T+CD+P	8.76^{abc}	2.99^{b}	67.08^{a}	9.59^{a}
NT+CD+P	8.62^{bc}	2.20^{b}	69.26^{a}	8.38^{a}
NT+PM+P	8.49^{c}	3.36^{ab}	50.35^{a}	8.35^{a}
NT+PM+AA	8.52^{c}	3.45^{ab}	56.16^{a}	9.07^{a}
NT+CD+AA	9.04^{ab}	3.35^{ab}	69.36^{a}	8.00^{a}

Means followed by same alphabet along column are not different from another at 5% probability level.
KEY: OC = Organic Carbon; P = Panicum maximum; NO_3-N = Nitrate Nitrogen; AA = Aspillia africana; NH_4-N = Ammonium Nitrogen; T = Inoculation (Trichoderma); pH = Soil Reaction; NT = No Inoculation ; WAI = weeks after Inoculation; PM = Poultry manure; CD= Cow dung

3.2 Discussion

The use of *Trichoderma asperellum* to enhance mineralization in the production of compost from different materials should be encouraged because of its potential to enhance Nitrogen mineralization there by improving the quality of compost while Poultry manure should be applied at a higher rate because it has high Nitrogen content compared to cow dung (Adigun *et al*., 2023)

4. Conclusion

The study revealed that *Trichoderma asperellum* inoculation increased nitrogen mineralization in the compost, especially at 8 weeks after inoculation. Nitrate and ammonium-N level differed significantly as *Trichoderma* *asperellum* inoculation favored increased nitrate-N over ammonium-N in the compost. It is therefore concluded that *Trichoderma asperellum* inoculation has the potential to enhance Nitrogen mineralization thus improving the quality of compost for agricultural production (Babalola *et al*., 2018; Adigun *et al*., 2022; Soretire and Adigun, 2026).

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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