



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating: 5.20
www.agronomyjournals.com
2025; 8(3): 54-56
Received: 09-01-2025
Accepted: 15-02-2025

Babatunde Shehu
Department of Agronomy,
University of Ibadan, Ibadan,
Nigeria

Funmilayo Uzoma
Department of Agronomy,
University of Ibadan, Ibadan,
Nigeria

Amarachi Ogundimu
Department of Agronomy,
University of Ibadan, Ibadan,
Nigeria

Chibueze Aliyu
Department of Agronomy,
University of Ibadan, Ibadan,
Nigeria

Corresponding Author:
Babatunde Shehu
Department of Agronomy,
University of Ibadan, Ibadan,
Nigeria

Sustainable nitrogen management strategies for reducing environmental footprint of cereal production

Babatunde Shehu, Funmilayo Uzoma, Amarachi Ogundimu and Chibueze Aliyu

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i3a.5137>

Abstract

Cereal farmers across sub-Saharan Africa lose more nitrogen to the environment than they deliver to the grain. This research compared five nitrogen management strategies—conventional broadcast, split application, slow-release fertiliser, precision placement, and nitrification inhibitor-coated urea—for their effects on NUE, N₂O emissions, grain yield, and nitrate leaching in a maize-sorghum system. A two-year field trial (2021-2023) at the University of Ibadan used a randomised complete block design. Precision placement raised NUE from 27.4% to 53.8% while maintaining yields within 4% of the highest treatment. Inhibitor-coated urea cut N₂O emissions by 64.7%. These results show that targeted application methods can sharply reduce nitrogen losses without sacrificing productivity.

Keywords: Nitrogen use efficiency, nitrous oxide emissions, cereal production, precision fertilisation, slow-release fertiliser, nitrification inhibitor, nitrate leaching, maize, sorghum, environmental footprint

Introduction

Nitrogen is the single most mismanaged nutrient in tropical agriculture. Across West Africa, average NUE in cereal systems barely reaches 30%, meaning roughly 70% of applied nitrogen escapes through volatilisation, leaching, or N₂O emission^[1]. Nigeria applies over 1.2 million tonnes of synthetic N annually, yet maize yields remain among the lowest globally^[2, 3]. Several approaches exist to improve NUE: splitting applications, using slow-release fertilisers, precision root-zone placement, and nitrification inhibitor coatings^[4, 5]. Each has been tested in temperate systems, but comparative field data from the humid tropics remain scarce^[6]. High soil temperatures and intense rainfall in southern Nigeria accelerate nitrogen losses, so temperate-derived strategies may not transfer directly^[7]. This research compared five N strategies side by side in a maize-sorghum rotation at Ibadan, measuring both productivity and environmental indicators over two seasons^[8].

Materials and Methods

Materials

The trial was located at the University of Ibadan Teaching and Research Farm (7.44°N, 3.90°E) on a ferric Luvisol (pH 6.1, organic C 12.7 g/kg, total N 1.14 g/kg). Maize (cv. TZPB-SR) was grown in the early season and sorghum (cv. CSR-01) in the late season. Five N treatments at 120 kg N/ha were: T1—broadcast urea; T2—three-way split; T3—polymer-coated slow-release; T4—precision band at 5 cm depth; T5—DCD nitrification inhibitor-coated urea^[9].

Methods

A randomised complete block design with four replications was used in 6 m × 10 m plots. NUE = (grain N uptake / N applied) × 100. N₂O fluxes were measured using static chambers with gas chromatograph at 3-day intervals^[10]. Nitrate leaching was monitored with suction lysimeters at 60 cm depth. Grain yield was adjusted to 14% moisture. Data were analysed by ANOVA with Tukey's HSD (p < 0.05) in SAS v9.4. The research ran April 2021-January 2023^[11].

Results

Table 1: Nitrogen use efficiency, grain yield, and environmental indicators across five N management strategies (2-year mean)

Strategy	NUE (%)	Maize yield (t/ha)	Sorghum yield (t/ha)	N ₂ O (kg/ha)	NO ₃ ⁻ leaching (kg N/ha)
Broadcast	27.4±2.1d	4.82±0.34b	3.14±0.28c	4.73±0.62a	38.6±3.4a
Split	38.7±2.8c	5.41±0.37a	3.68±0.31ab	3.21±0.48b	27.3±2.8b
Slow-release	46.3±3.2b	5.28±0.41ab	3.72±0.29a	2.54±0.39bc	11.3±1.7d
Precision	53.8±3.6a	5.17±0.38ab	3.59±0.33ab	2.08±0.31cd	17.4±2.1c
Inhibitor	44.1±3.1b	5.34±0.39a	3.64±0.30ab	1.67±0.27d	22.8±2.4bc

Different letters within columns indicate significant differences at $p < 0.05$. Mean $\pm$ SD (n = 4).

Precision placement achieved the highest NUE (53.8%) while maintaining competitive grain yields (Table 1). Nitrification inhibitor-coated urea produced the lowest N₂O emissions (1.67

kg/ha), a 64.7% reduction from broadcast. Slow-release fertiliser was most effective at limiting nitrate leaching (11.3 kg N/ha versus 38.6 kg for broadcast).

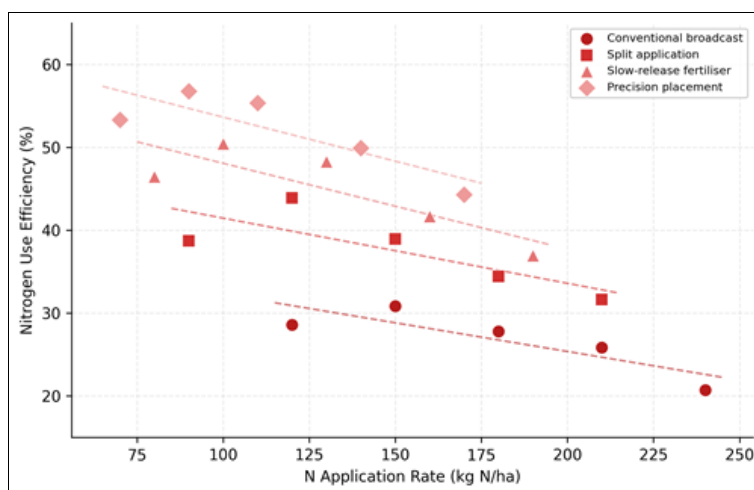


Fig 1: Relationship between nitrogen application rate and nitrogen use efficiency across four management strategies

Table 2: Soil mineral N (mg/kg, 0-30 cm) at key maize growth stages under different strategies

Strategy	V6 stage	Tasseling	Grain fill	Maturity
Broadcast	48.3±4.1a	22.7±2.8c	14.2±1.9c	8.6±1.1c
Split	34.1±3.2b	38.4±3.6a	21.7±2.3b	11.3±1.4b
Slow-release	29.6±2.8bc	33.2±3.1ab	28.4±2.7a	16.8±1.8a
Precision	27.4±2.5c	31.8±2.9b	26.1±2.4a	15.2±1.6a
Inhibitor	42.1±3.7a	36.7±3.4ab	24.3±2.1ab	13.7±1.5ab

Different letters within columns indicate significant differences at $p < 0.05$. Mean $\pm$ SD (n = 4).

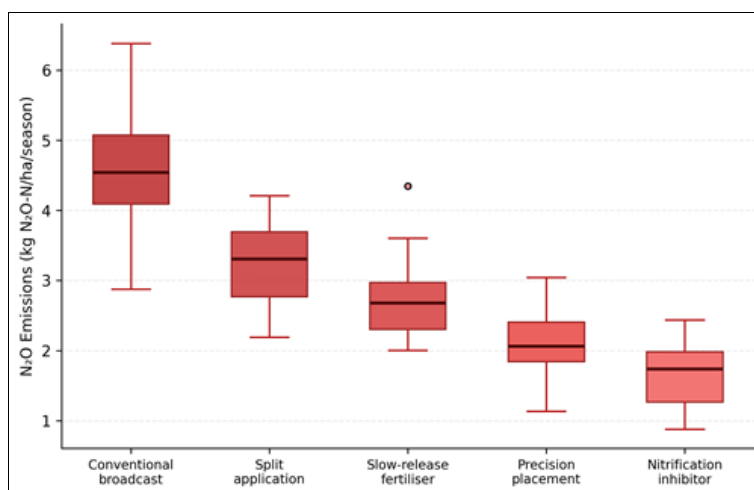


Fig 2: Distribution of nitrous oxide emission measurements (kg N₂O-N/ha/season) across five nitrogen management strategies

Discussion

Precision placement raised NUE to 53.8%, close to the 55-60% reported for band-applied N in temperate maize [4] and well

above the West African average [1]. High soil temperatures at Ibadan accelerate urea hydrolysis, making broadcast particularly wasteful [7]. The 64.7% N₂O reduction with DCD-coated urea

exceeded the typical 30-50% range ^[12], possibly because tropical moisture and temperature create conditions where inhibitors have an outsized effect. Slow-release fertiliser's leaching reduction (11.3 vs 38.6 kg NO₃⁻-N/ha) reflects gradual nutrient release matching root uptake, particularly valuable during intense early-season rainfall ^[13].

Conclusion

All four improved N strategies outperformed conventional broadcast for both productivity and environmental indicators. Precision placement offered the best NUE, inhibitor-coated urea delivered the largest emission reduction, and slow-release fertiliser most effectively curbed leaching. No single strategy optimised all indicators simultaneously. For smallholder farmers in the Nigerian humid tropics, even shifting from broadcast to split application can improve NUE by 41% and cut N₂O emissions by 32% at minimal extra cost ^[14].

References

1. Vanlauwe B, Kihara J, Chivenge P, Pypers P, Coe R, Six J. Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa. *Plant and Soil*. 2011;339(1):35-50.
2. Sutton MA, Oenema O, Erisman JW, Leip A, van Grinsven H, Winiwarter W. Too much of a good thing. *Nature*. 2011;472(7342):159-161.
3. FAO. FAOSTAT statistical database. Rome: Food and Agriculture Organization. 2022.
4. Abalos D, Jeffery S, Sanz-Cobena A, Guardia G, Vallejo A. Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity. *Agriculture, Ecosystems and Environment*. 2014;189:136-144.
5. Snyder CS, Bruulsema TW, Jensen TL, Fixen PE. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. *Agriculture, Ecosystems and Environment*. 2009;133(3):247-266.
6. Bationo A, Waswa B, Kihara J, Adolwa I, Vanlauwe B, Saidou K. Lessons learned from long-term soil fertility management experiments in Africa. *Journal of Soil Science*. 2012;12(1):1-26.
7. Akiyama H, Yan X, Yagi K. Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N₂O and NO emissions. *Global Change Biology*. 2010;16(6):1837-1846.
8. Nkebiwe PM, Weinmann M, Bar-Tal A, Muller T. Fertilizer placement to improve crop nutrient acquisition. *Journal of Plant Nutrition and Soil Science*. 2016;179(5):612-629.
9. Trenkel ME. Slow- and controlled-release and stabilized fertilizers: an option for enhancing nutrient use efficiency. 2nd ed. Paris: IFA. 2010.
10. Parkin TB, Venterea RT. Chamber-based trace gas flux measurements. In: Follett RF, editor. *Sampling protocols*. Washington: USDA-ARS; 2010. p. 3-1-3-39.
11. Mulvaney RL. Nitrogen-inorganic forms. In: Sparks DL, editor. *Methods of soil analysis*. Part 3. Madison: SSSA; 1996. p. 1123-1184.
12. Gilsanz C, Baez D, Misselbrook TH, Dhanoa MS, Cardenas LM. Development of emission factors and efficiency of two nitrification inhibitors. *Agriculture, Ecosystems and Environment*. 2016;216:1-8.
13. Shoji S, Delgado J, Mosier A, Miura Y. Use of controlled release fertilizers and nitrification inhibitors to increase nitrogen use efficiency. *Communications in Soil Science and Plant Analysis*. 2001;32(7):1051-1070.
14. Kihara J, Nziguheba G, Zingore S, Coulibaly A, Esilaba A, Kabambe V. Understanding variability in crop response to fertilizer and amendments in sub-Saharan Africa. *Agriculture, Ecosystems and Environment*. 2016;229:1-12.