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Enhancing Nutrient Use Efficiency in Semi-arid Lowland Rice through Deep Placement of NPK Briquettes

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SA, OJ and YL designed the study, performed the statistical analysis, wrote the protocol, and drafted the first version of the manuscript. Authors SA and ONM supervised the field trial implementation, contributed to data collection. Author SI contributed to the interpretation of results. Author NI participated in data curation. All authors read and approved the final manuscript.

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Abstract

Background: Global food security remains under increasing pressure due to rapid population growth and limited natural resources, particularly in developing regions reliant on staple crops such as rice. In Burkina Faso, low soil fertility, inefficient fertiliser use, and climate variability significantly constrain rice productivity, highlighting the need for more efficient nutrient management strategies such as deep fertiliser placement.

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Aims: This study aimed to evaluate the effect of deep placement of NPK briquettes on nitrogen and phosphorus use efficiency in lowland rice systems under semi-arid conditions in Burkina Faso.
Study Design: A completely randomized experimental design with three replications was used to compare different fertilizer management practices.
Place and Duration of the Study: The experiment was conducted in a lowland rice production area in the semi-arid zone of Burkina Faso during the 2022–2023 cropping season.
Methodology: Five fertilizer treatments were tested: (i) control without fertilizer; (ii) farmer's practice (150 kg ha^{-1} NPK + 100 kg ha^{-1} prilled urea); (iii) 150 kg ha^{-1} NPK + 1.8 g urea super granule (USG); (iv) two 1.8 g NPK super granules (SG-NPK); and (v) two 1.8 g SG-NPK + 100 kg ha^{-1} prilled urea. Agronomic efficiency (AE), internal efficiency (IE), physiological efficiency (PE), and partial factor productivity (PFP) were calculated for each treatment. Data were analyzed using ANOVA in GenStat (12th edition).
Results: The combination of two SG-NPK with 100 kg ha^{-1} prilled urea increased internal and physiological nitrogen use efficiency by 32.86% and 203.58%, respectively, compared with the farmer's practice. The highest phosphorus agronomic efficiency (38.45 kg paddy kg^{-1} P applied) was obtained with 150 kg ha^{-1} NPK + 1.8 g USG. This treatment also produced the highest partial factor productivity (61.09 kg paddy kg^{-1} N and 119.03 kg paddy kg^{-1} P applied).
Conclusion: Deep placement of NPK briquettes significantly improves nutrient use efficiency in lowland rice under semi-arid conditions, suggesting its potential as an effective strategy for optimizing nitrogen and phosphorus management.

Keywords: NPK briquettes; deep placement; nutrient use efficiency; agronomic efficiency; lowland rice; Burkina Faso

1. Introduction

Global food security remains a major challenge today, with a constantly growing world population and limited natural resources (FAO, 2020). Rice, a major staple crop, plays a critical role in providing calories and nutrients to millions worldwide (McDermid et al., 2023). In Burkina Faso, a landlocked country in West Africa, agriculture remains the backbone of the economy and food supply. Rice production is particularly important for meeting the dietary needs of its growing population; however, domestic output still falls short of demand, leading to substantial imports (AGRA, 2023). However, rice cultivation in Burkina Faso, especially in semi-arid lowland systems, is constrained by several factors, including inherently low soil fertility, inefficient nutrient management practices, inefficient nutrient management practices, irregular water availability, and the impacts of climate variability (MAAHA, 2020; Koutou et al., 2021). Conventional fertilizer practices, which rely heavily on broadcast application of prilled urea and compound NPK fertilizers, result in low nutrient use efficiency. Under such conditions, nitrogen recovery by rice plants is often only 30-40 %, with losses reaching 60-70 % through ammonia volatilization, denitrification, leaching, and runoff (IFDC, 2017). Therefore, it would be worthwhile to consider a more efficient alternative by adopting deep fertilizer placement. Studies conducted in Bangladesh, Senegal, and Benin have shown that deep placement of urea significantly reduces the amount used on rice and cotton, with an average efficiency of 24.50 kg paddy kg^{-1} of N. It also significantly improves nitrogen recovery rates by 70% for rice, increases paddy yields by 31.07%, and raises the marginal rate of return to over 100% for cotton and rice (Aliou et al., 2014; Khalequzzaman et al., 2014; Rahman et al., 2016; Faye et al., 2020). In Burkina Faso, deep placement of urea has been tested for several years, particularly in rice plains and lowlands. These studies have shown the agronomic superiority of super granules of urea over prilled urea applied to smallholder plots, with yield gains of approximately 12–20% (Yaméogo et al., 2013; Bandaogo et al., 2015; Sawadogo et al., 2025; Lu et al., 2020). These percentages indicate that nitrogen fertilization was well controlled. However, this was not the case for the other major elements, particularly phosphorus (P) and potassium (K). Deep placement of NPK can improve the efficiency of phosphorus use, which is one of the most limiting nutrients in rice production. It should also be noted that few studies have examined the effect of this technology on lowland rice cultivation. Therefore, this study aimed to assess the effects of deep placement of NPK briquettes on nitrogen and phosphorus use efficiency in lowland rice under semi-arid conditions in Burkina Faso.

2. Material and Methods

2.1 Presentation of the Study Area

This study was conducted in the rural commune of Kindi, specifically in the village of Nassoulou. Located in the Centre-West region of Burkina Faso, the commune of Kindi covers an area of 282 km^2, i.e. 6.8% of the province of Boulkiemdé to which it belongs. It is located 70 kilometers from Ouagadougou by the National Road (RN 2) and 45 kilometers from Koudougou by the Departmental Road. The village of Nassoulou is 15 km from Kindi-Centre (capital of the commune) more precisely at 2° 10' west longitude and 12°19' north latitude. The climate is Sudano-Sahelian with two predominant seasons: the wet season of 3 to 4 months and the dry season of 8 to 9 months. The Kindi relief is flat, with rocky outcrops. There are three (3) categories of soils according to their texture in the commune of Kindi: sandy soils, approximately 60%; gravel soils, approximately 30%; and loamy soils located in the lowlands, approximately 10%. The physicochemical parameters of the surface horizon (0–20 cm) are presented in Table 1. The physicochemical parameters of the surface horizon (0-20 cm) are summarized in Table 1.

Table 1. Characteristics of the soil of the experimental site

Parameters	pH	Organic Carbon	Total Nitrogen	Available Phosphorus (mg kg^{-1})	Clay (%)	Silt (%)	Sand (%)
Values	6.9	0.53	0.046	190	36.5	34.75	29

2.2 Experimental Design

The experimental design used was a completely randomized block with three repetitions and five treatments. The test measures 27 m x 14 m. The experimental unit was a plot measuring 5 m × 4 m. The plots were separated by boundary bunds to prevent the passage of nutrients from one plot to another plot. A 1 m aisle was left between repetitions and 0.5 m between treatments.

2.3 Fertilizers Used

For the plots with treatments, four types of mineral fertilizers were applied.

- ✓ **NPK 14-23-14-6S-1B**
  The compound fertilizer was used as a basal application to supply nitrogen, phosphorus, and K.
- ✓ **Prilled Urea (PU)**
  Prilled urea containing 46% nitrogen (N) was used as a cover manure to supply nitrogen, depending on the treatment.
- ✓ **Super Granule Urea (USG)**
  Super-granulated urea (SGU) is produced by physically modifying prilled urea. USG contained 46% N, similar to prilled urea. The weight of each granule was 1.8 g.
- ✓ **NPK Super granule (SG-NPK)**
  This is NPK 16-26-12 which has been compacted from a machine to form granules. The weight of a pellet can vary from 1 to 3 g, but the experiment focused on 1.8 g pellets.

Table 2. Summary table of doses, types of fertilization (g/elementary plot) the amount of nutrients (kg ha^{-1}) N, P and K provided by each treatment

Treatment	Urea Super Granule (USG)	Prilled Urea (PU)	NPK Super Granule	Prilled NPK	N rate (kg/ha)	P_2O_5 dose (kg ha^{-1})	K_2O rate (kg ha^{-1})
2 SG-NPK	-	-	450	-	36	58.5	27
FP	-	200	-	300	67	34.5	21
150 kg NPK + USG	225	-	-	300	72.98	34.5	21
2 SG-NPK + PU	-	200	450	-	82	58.5	27
Control	-	-	-	-	-	-	-

SG-NPK: NPK Super Granule; USG: Super Granulated Urea; FP: Famer's practice; PU: Prilled Urea

2.4 Plant Sampling and Analysis

Grain and straw samples were collected from each elementary plot after harvest to analyze the N and P contents. This sampling was conducted in the same square used to evaluate the performance of the components. This biomass was dried in the shade under open air, and a 50 g sample was stored in labelled plastic bags for analysis. Nitrogen is determined by the Kjeldhal method developed by Hillebrand et al., (1953), phosphorus is assimilable by the Bray I method.

2.5 Agronomic Indices for Assessing Nutrient Efficiency

Indices such as physiological efficiency (PE), internal nutrient use efficiency (EI), agronomic efficiency (EA), and partial applied nutrient productivity factor (PFP) were calculated for nutrient efficiency assessment. The formulas of Doberman (2007) were used for this purpose:

Table 3. Agronomic indices used to evaluate nutrient use efficiency

Agronomic index	Formula
Physiological efficiency (PE)	$(GYi - GY_0) / (Ui - U_0)$
Agronomic efficiency (AE)	$(GYi - GY_0) / F$ or $AE = RE \times PE$
Internal efficiency (IE)	GY / U
Partial factor productivity (PFP)	GYi/For (GY/U) +AE

F: dose of the nutrient applied (kg ha^{-1}); GYi: Grain yield obtained for a dose i of nutrient applied (kg ha^{-1}); GYo: Grain yield obtained without fertilizer application (kg ha^{-1}); Ui: Total export of the nutrient through grain and straw for a dose i of this nutrient applied (kg ha^{-1}); U_0: Total export (grain + straw) obtained without fertilizer (kg ha^{-1})

2.6 Data Processing and Analysis

The data collected were entered into the Excel spreadsheet version 2019 and subjected to an analysis of variance at the 5% level using the statistical software GenStat 12th Edition. The Student–Newman–Keuls test was used to compare the means when the differences were significant.

3. Results and Discussion

3.1 Results

3.1.1 Effect of Mineral Fertilization Types on Nitrogen and Phosphorus Export

Table 4 shows the effects of the treatments on nitrogen and phosphorus nutrient export.

Table 4. Effect of mineral fertilization types on nitrogen and phosphorus export

Treatment	Paddy Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Total N Uptake (kg ha^{-1})	Total P Uptake (kg ha^{-1})
2 SG-NPK	3683^{c}	3550^{b}	70.80^{b}	13.71^{b}
FP	4033^{ac}	3992^{ab}	84.38^{a}	14.68^{b}
150 kg NPK + USG	4458^{ab}	3917^{b}	80.77^{ab}	16.64^{a}
2 SG-NPK + PU	4540^{a}	4333^{a}	71.77^{c}	17.65^{a}
Control	3132^{d}	2650^{c}	43.79^{d}	10.32^{c}
CV (%)	5.5	6	6.7	5.1
Probability (p-value)	<0.001	<0.001	<0.001	<0.001
Significance	***	***	***	***

The assigned values of the same letters in the same column are not significantly different at the 5% probability threshold.: SG-NPK: NPK Super Granule; FP: Farmer's Practice; USG: Super Granulated Urea; PU: Prilled Urea; HS: Highly significant; CV: coefficient of variation

The analysis of this table revealed that the total uptake (by rice grains and straw) was affected by the different treatments. The highest nitrogen uptake was recorded under the farmer's practice (84.38 kg ha^{-1}), followed by the combination of 150 kg ha^{-1} NPK + USG (80.77 kg ha^{-1}). The analysis of variance also showed a highly significant difference between the treatments. The highest total phosphorus uptake was recorded with the combination of 2 SG-NPK + PU combination. This treatment increased phosphorus uptake by 20.23% compared with FP and by 6% compared with 150 kg NPK + USG. Analysis of variance also revealed significant differences between the treatments. However, the Student Newman-Keuls test revealed that the treatments 2 SG-NPK + PU and 150 kg ha^{-1} NPK + USG were identical in terms of phosphorus uptake.

3.1.2 Effect of Different Types of Mineral Fertilization on Nitrogen and Phosphorus use Efficiency

An analysis of Table 5 reveals that the highest internal nitrogen use efficiency (INUE) was recorded for the control (72.18 kg grain kg^{-1}N). Optimal values were recorded for the 150 NPK + USG (55.25 kg grain kg^{-1}N absorbed) and 2 SG-NPK + PU (63.64 kg grain kg^{-1}N absorbed) treatments. These values show a 15.18% improvement in IUE for NPK briquettes compared with USG. ANOVA also highlighted the significant effect of the treatments on NIE (P= 0.002). Furthermore, the treatments using SG-NPK were statistically different from USG and the farmer's practice. The table also shows that internal phosphorus use efficiencies (IPUE) ranging from 257.7 to 306.2 kg grain kg^{-1}P were obtained by the treatments. However, ANOVA did not reveal a significant effect of the type of mineral fertilization on IPUE. Regarding physiological efficiency (PE), the results showed that treatment 2 (SG-NPK + PU) was the most efficient for nutrient N (100.79 kg kg^{-1}N). The increase in PE due to this treatment was 203.58% compared with FP and 72.67% compared with the 150 kg NPK + USG treatment. ANOVA showed a significant effect of the different treatments on the PE of N. Furthermore, the combination 2 SG-NPK + PU differed statistically from the other treatments, which were similar. However, the effect of these fertilizers was not significant for the EP of P.

Table 5. Effects of fertilizer types on nitrogen and phosphorus uptake and use efficiency

Treatment	Internal Efficiency - Nitrogen (kg kg^{-1})	Internal Efficiency - Phosphorus (kg kg^{-1})	Physiological Efficiency - Nitrogen (kg kg^{-1})	Physiological Efficiency - Phosphorus (kg kg^{-1})
Control	72.18^{a}	306.2		
2 SG-NPK	52.04^{c}	269.4	45.34^{b}	218.8
FP	47.90^{c}	274.5	33.20^{b}	215
150 kg NPK + USG	55.25^{bc}	268.3	58.37^{b}	211.8
2 SG-NPK + PU	63.64^{de}	257.7	100.79^{a}	203.7
CV (%)	8.5	9.9	32.7	40
p-value	0.002	0.32	0.023	0.99
Significance	**	NS	*	NS

The assigned values of the same letters in the same column are not significantly different at the 5% probability level. SG-NPK: Super NPK Granule; FP: Farmer's Practice; USG: Super Granulated Urea; PU: Prilled Urea; HS: Highly significant; NS: Not significant; CV: coefficient of variation

3.1.3 Correlation between Rice Yield, Nutrient Uptake, and Nutrient use Efficiency Indicators

Correlation analysis (Fig. 1) revealed strong relationships among rice yield, nutrient uptake, and nutrient use efficiency indicators. Paddy yield was strongly and positively correlated with straw yield (r = 0.87), total nitrogen uptake (r = 0.76), and total phosphorus uptake (r = 0.90), indicating that higher biomass production and nutrient acquisition contributed to increased grain yield. Straw yield was also strongly and positively correlated with total phosphorus (r = 0.92) and nitrogen (r = 0.78) uptake. In contrast, the internal efficiencies for nitrogen and phosphorus (IEN and IEP) were negatively correlated with yield and nutrient uptake variables (r = −0.83 between IEN and total N uptake), suggesting dilution effects with increasing nutrient uptake. The physiological efficiency of nitrogen (PEN) was positively associated with paddy yield (r = 0.83) and straw yield (r = 0.80), highlighting the role of efficient nutrient conversion into biomass. Overall, rice productivity in this system appears to be primarily driven by nutrient uptake and physiological efficiency, rather than internal efficiency alone.

Table 6 presents the agronomic efficiency (AE) and partial productivity factor (PPF) of phosphorus and nitrogen according to the treatments. Analysis of this table revealed that the combinations 150 kg NPK + USG (18.18 kg kg^{-1} N) and 2 SG-NPK + PU (17.17 kg kg^{-1} N) yielded the best agronomic efficiencies of nitrogen fertilizer (AEN). However, statistical analysis showed that the treatments had no significant effect on the AEN. The agronomic efficiency of P (AEP) ranged from 9.43 to 38.45 kg kg^{-1}P. The most effective treatments were 150 kg NPK + USG (38.45 kg kg^{-1}P) and FP (26.14 kg kg^{-1}P). Analysis of variance showed a significant effect of different types of mineral fertilization on EAP (P= 0.007). The Student–Newman–Keuls test also detected highly significant differences between the treatments. Table 6 also shows the effects of the different treatments on the PFP of both phosphorus and nitrogen. This index highlights the improvement in the yield per kilogram of fertilizer applied. The analysis of this table revealed a decrease in the PFP of N (PFPN) as its application rate increased, except for FP. The highest PFPN was recorded for treatment 2 SG-NPK (102.31 kg of grain kg^{-1}N applied), followed by 150 kg NPK + USG (61.09 kg of grain kg^{-1}N applied). ANOVA also revealed a significant effect of the treatments on PFPN. However, the treatments were similar, except for Treatment 2 (SG-NPK). The same trend was observed for P PFP (PFPP). The highest PFPP was obtained with the 150 kg NPK + USG treatment (119.03 kg grain kg^{-1} P applied), and the lowest PFPP was recorded with 2 SG-NPK (68.55 kg grain kg^{-1} P applied). Statistical analysis also showed a significant effect of the treatments on phosphorus PFP. Furthermore, NPK briquettes were statistically different from FP and 150 kg NPK + USG.

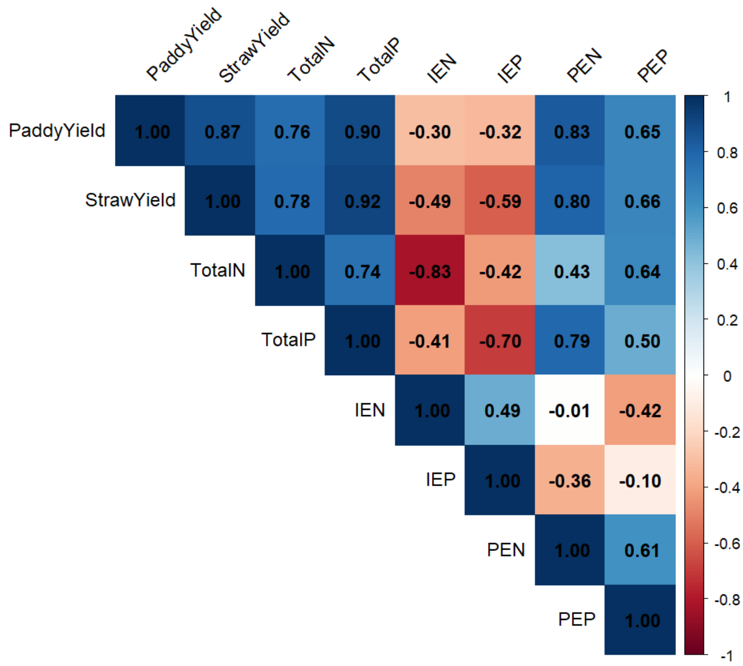

Fig. 1. Effect of mineral fertilization types on agronomic efficiency and partial nutrient productivity factor

Table 6. Effect of fertilizer types on agronomic efficiency and on the partial productivity factor of nitrogen and phosphorus

Treatment	Agronomic efficiency N (kg kg^{-1})	Agronomic efficiency P (kg kg^{-1})	Partial factor productivity N (kg kg^{-1})	Partial factor productivity P (kg kg^{-1})
Control	–	–	–	–
2 SG-NPK	15.32	9.43c	102.31a	68.55b
FP	13.46	26.14b	60.20b	116.91a
150 kg NPK + USG	18.18	38.45a	61.09b	119.03a
2 SG-NPK + PU	17.17	24.07	55.37b	72.93b
CV (%)	20.5	24.9	5.1	5.6
p-value	0.38	0.007	<0.001	<0.001
Significance	NS	***	***	***

The assigned values of the same letters in the same column are not significantly different at the 5% probability threshold. SG-NPK: Super NPK Granule; FP: Farmer's Practice; USG: Super Granulated Urea; PU: Prilled Urea; HS: Highly significant; NS: Not significant; CV: coefficient of variation

4. Discussion

The analysis of the results on nutrient uptake showed that the technology of deep placement of the briquette fertilizer is not statistically superior to the farmer's practice for the nutrient N. However, the combination of 2 SG-NPK + PU resulted in better absorption of the nutrient P. Our results partially confirm the conclusions drawn by Bandaogo et al., (2015); Miah et al., (2016); Sharna et al., (2021). These authors showed that deep placement of briquettes significantly improved nutrient uptake compared to the application of Prilled urea. Lack of water control in lowland rice cultivation could slightly affect the performance of urea granules. Wang et al., (2020) also reported the effect of SG-NPKs on P uptake by corn kernels. This absorption of P could be explained by its availability by NPK briquettes according to the needs of the rice plants (Akassimadou et al., 2017) thus reducing its fixation by aluminum and iron oxides (Ebbisa, 2022). The results of P uptake show a relationship between phosphorus content at maturity and grain yield. This relationship is stronger than that between the uptake of P by the straw and the straw yield; effectively confirming the migration of P from the oldest to the youngest leaves, and its accumulation, ultimately, in the grains. These results confirm the findings of omission trials that a good dose of N increases P uptake (Akassimadou et al., 2017; Read et al., 2020).

The treatments also had a significant impact on the internal and physiological use efficacy of N. The highest internal nitrogen efficiency was recorded by the control (72.18 kg grain kg^{-1}N absorbed). This result could be explained by a deficiency of this macro-element in the soil (Dobermann, 2007; Fixen et al., 2014; Baligar & Fageria, 2015; Bihari et al., 2022). Optimal internal nitrogen efficiencies were achieved by the 150 kg NPK + USG treatment (55.25 kg paddy kg^{-1}N absorbed) and 2 SG-NPK + PU (63.64 kg grain kg^{-1}N absorbed), according to the range established by Fixen et al., (2014) and Dobermann (2007). Observations made by Bandaogo et al., (2015) have also shown significant results of briquettes on the internal and physiological efficiency of nitrogen. However, multi-nutrient briquettes did not significantly affect the internal use efficiency of P. These results can be explained by their wide availability, which also leads to luxury consumption. Similar results were obtained by Ouédraogo et al., (2022).

The highest agronomic efficiency of N was recorded with the 150 kg NPK + USG treatment (18.18 kg kg^{-1} N), followed by the 2 SG-NPK + PU treatment (17.17 kg kg^{-1} N). Yaméogo et al. (2013) and Bandaogo et al. (2015; 2016) observed different results. These authors obtained significant effects of super granules on the agronomic efficacy of N. This divergence can be attributed to differences in rice ecology. According to Nishigaki et al. (2019), in rainfed production systems, the instability of hydrology limits grain yield and the response of rice to fertilizer input, thus impacting the agronomic efficiency of N.

The highest partial productivity factor for N was obtained with the 2 SG-NPK treatment (102.31 kg of grains kg^{-1} N applied), while the highest agronomic efficiency of P and the partial productivity factor of P were observed with the 150 kg NPK + USG treatment (38.45 kg kg^{-1} P and 119.06 kg of grains kg^{-1} P applied, respectively). According to Fixen et al., (2014), it is desirable to have higher efficiencies so that more grain yield can be produced per unit of its application, which not only contributes to food safety but also reduces the environmental risks associated with excess nutrients. The high values of the partial productivity factor of N held by the SG-NPKs and the partial productivity factor of P and its agronomic efficiency held by the USGs can be attributed to a reduction in the loss of these nutrients in different forms, which usually occurs with the diffusion of prilled fertilizers (Wang et al., 2017). This efficiency can also be explained by synchronization in time and space with the contribution of N and P from soil labile reserves and treatment (Dwivedi et al., 2016). Consistent with these findings, previous studies have reported a higher agronomic use efficiency of P (25-42 kg $kg^{-1}P^{)}$ compared to the farmer's practice using a combination of USG and increasing doses of P (Bandaogo et al., 2016). Several scales have been established for the interpretation of partial productivity factors. A higher partial factor value in plots treated with mineral fertilizers suggests suboptimal use of this element in these treatments or nutrient supply that likely limits productivity, whereas a lower level suggests less reactive or excessive nutrient application (Dobermann, 2007; Fixen et al., 2014). Our results, and in accordance with the range established by Fixen et al., (2014), indicate that the 150 kg NPK + USG treatment is the best management practice for N and P element. However, this treatment was not statistically better than the 2 SG-NPK+PU for N management or the farmer's practice for P management. However, according to Devkota et al., (2019), P fertilization was not required because the partial productivity factor of P was less than 150 kg of grain per kg of phosphorus applied. Therefore, there is an imbalance between inputs and outputs, which can lead to excessive enrichment of soil P (Singh & Singh, 2017). This variation in results is due to the fact that the partial productivity factor varies between cropping systems, as crops differ in their nutrient and water requirements (Baligar & Fageria, 2015)

5. Conclusion

A study on the impact of different fertilization approaches on nitrogen and phosphorus use efficiency in lowland rice cultivation in the semi-arid zone of Burkina Faso highlights the crucial importance of choosing appropriate fertilization strategies to maximize crop yields while minimizing nutrient losses. The results showed that the combination of two Super Granules of NPK at 1.8 g (SG-NPK) + 100 kg ha^{-1} of prilled urea improved internal and physiological nitrogen use efficiency by 32.86% and 203.58%, respectively, compared to the farmer's practice. The best agronomic efficiency of phosphorus (38.45 kg paddy kg^{-1}P applied) was recorded with the combination of 150 kg ha^{-1} NPK + 1.8 g Super Granulated Urea (USG). This combination also allowed for optimal nitrogen and phosphorus management (61.09 kg paddy kg^{-1}N and 119.03 kg paddy kg^{-1}P, respectively). Despite these promising results, further investigation is required to refine these strategies and assess their economic viability on a larger scale. In conclusion, this study provides valuable insights to guide resource management decisions in the specific context of lowland rice cultivation in semi-arid areas.

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.

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Competing Interests

Authors have declared that no competing interests exist.

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