www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 2191-2197

www.thepharmajournal.com
Received: 16-07-2022
Accepted: 19-08-2022

Saheed Garnaik
Department of Soil Science and Agricultural Chemistry, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

PK Samant
Department of Soil Science and Agricultural Chemistry, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

J Nayak
Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

S Sahu
Department of Plant Breeding and Genetics, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
Saheed Garnaik
Department of Soil Science and Agricultural Chemistry, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Nitrogen use efficiency and micronutrient uptake under a long-term paddy production

Saheed Garnaik, PK Samant, J Nayak and S Sahu

Abstract
Nutrient management under rice-rice production became a critical issue for a tropical rice production. Rice cultivation is getting tougher over due to mismanagement of plant required nutrients. Hence, we planned to explore this area with 9 treatments and 4 replications in a long-term rice-rice production system. These were control, N, NP, PK, NPK, NPK+Zn, NPK+B+Zn, NPK+S+Zn, NPK+FYM+Lime. Different combinations of nutrients showed variation in yield, nutrient uptake and nutrient use efficiencies. Boron uptake was highest in FYM treated plots followed by boron applied plots (NPK+B+Zn). Sulphur uptake was ~8 kg ha^{-1} in NPK+FYM+Lime plots compared to control and ~59% in comparison to NPK applied plots. Boron uptake was 21.7% higher in FYM treated plots (NPK+FYM+Lime) in compared to boron supplied plots (NPK+B+Zn). Inter utilization efficiency was 16.1% higher in NPK plots compared to NPK+FYM+Lime plots. Imbalance fertilization application (N and NP) had increased the nutrient demand for crop with higher internal utilization efficiency. Physiological efficiency for P and K was 2.1 and 3.7% higher in compared to NPK. Intensive rice cultivation with proper nutrient management can improve the rice yield.

Keywords: B uptake, S uptake, acid soil, nitrogen use efficiency, acid inceptisol

Introduction
Paddy is considered as life in India. Farmers of eastern India rely on paddy for their livelihood (Dar *et al.*, 2020) [7]. Improvement in paddy production can only be achieved through effective nutrient management. Generally, rice-based cultivation practices are dominating in Indian subcontinents. However, due to imbalance fertilizer application and improper management made this important production more exhaustive and less sustainable. The increasing population put burden on improving rice production by 2050 to feed the huge population of India (Seck *et al.*, 2012) [20]. Many factors such as fertilizer, electricity, and labour cost are increasing over years that add extra burden on crop production. Climate change is a burning issue that making rice cultivation more vulnerable. Hence, the traditional method of rice cultivation requires thorough tillage followed by puddling and nursery raising (Bhatt *et al.*, 2021) [3]. In South Asia, manual transplantation is the norm and it consists of lots of labourers (Bouman *et al.*, 2007) [5]. These processes take a lot of time and effort. Hand weeding is a relatively energy-intensive job, yet it is necessary to control the crop-weed competition. By lowering the use of manual cultivation techniques, farm mechanization can increase farmers' income. Along with this, the irrigated rice system has superior capacity to improve rice production than rainfed condition (Saito *et al.*, 2013) [18]. Increasing rice production while using fewer land and agriculture inputs is now needed. Nutrient uptake and use efficiency are crucial factors in crop productivity. Superior crop output results from higher nutrient uptake relative to higher utilization of the specific nutrient (Baligar *et al.*, 2001) [2].
Hence, the shortcomings of the present cropping systems help to find out the most relevant nutrient management practice to increase the rice yield with pace. Integrated nutrient management can improve nutrient use efficiency which reduce nutrient requirement (Dwivedi *et al.*, 2016) [10]. As a result, input cost will be reduced and energy involvement could be reduced. Amid this climate change, energy requirement in a farming becomes more crucial due to its direct impact on the sustainability. The more energy efficient, the system referred to the more sustainable the farming system (Van Cauwenbergh *et al.*, 2007) [26]. The carbon sequestration, and high nutrient use efficient systems are need close addressal to sustain the future paddy production (Smith *et al.*, 2013). Also, low water use efficiency in rice critical element to save water and improve rice yield with limited water condition. Conventionally cultivated paddy requires much higher water per unit production (Adusumilli *et al.*, 2011) [1].

Nutrients such as primary (nitrogen, phosphorous, and potassium), secondary nutrients (calcium, magnesium, and sulphur), and micronutrients (iron, manganese, copper, and zinc) are essential for completion of paddy. In this context, micronutrients like boron is related to pollen fertilization (Subedi *et al*., 1997). Sulphur is associated with amino acids formation in paddy grains (Okuda *et al*., 2019).

Additionally, the ability of the rice-rice system to feed a sizable population will continue to be in question due to the improper and unbalanced application of fertilizers, which has a negative impact on both rice productivity and soil health (Singh *et al*., 2021). Therefore, the current study was conducted to comprehend cropping patterns after extensive cultivation, nutrient uptake, and use efficiency, with a focus on the utilization of secondary and micronutrients in the paddy plant system. Our research identified some improved nutrient management techniques to address yield-reducing variables and productive nutrient utilization systems. Additionally, the information gathered from this can be used as a resource by policymakers to encourage cleaner paddy production and crop diversification.

This present experiment was done to find (i) sulphur and boron uptake (ii) nitrogen phosphorous, and potassium use efficiency.

2. Materials and Methods

2.1 Experiment location

An ongoing long-term fertilizer experiment that was set up in the "E" block of the central research station (rabi season 2005–2006), OUAT, Bhubaneswar, and the land type is medium, tube well irrigation facility, underwent a field experiment. In contrast to the sandy clay-loam beneath the surface soil, it has a loamy texture. However, the soil organic carbon content is low in the surface layer to extremely low in subsurface strata. The pH is 5.30 at the surface but rises with depth. A mechanized, irrigated, and input-intensive farming area is represented by Bhubaneswar. The experimental site has a tropical and humid climate. The long-term average annual rainfall is >1500 mm, and the northwest monsoon season, which runs from July to August, accounts for about 85% of the total rainfall to September with mean annual temperature 26.6^{0}C.

2.2 Experimental layout and cultivation techniques

Using 9 treatments and 4 replications, the experiment was planned using a randomized block design (RBD) method. The 9 treatments included: i) control; ii) N (recommended dose of nitrogen); (iii) NP (recommended dose of nitrogen and phosphorous); iv) PK (recommended dose of phosphorous and potassium) v) NPK (recommended dose of N, P, and K) vi) NPK+Zn (recommended dose of N, P, K, and Zn) vii) NPK+S+Zn (recommended dose of N, P, K, S, and Zn) (viii) NPK+B+Zn (recommended dose of N, P, K, B, and Zn) (ix) NPK+FYM+Lime (recommended dose of N, P, K along with cattle farmyard manure and calcium carbonate) (Table 1). At 100% recommended dose (RD) of 80:40:60 kg ha^{-1}, urea, diammonium phosphate, and muriate of potash were employed to supply nitrogen, phosphorus, and potassium. Nitrogen was applied in three splits: 1/4th as a basal application, 1/2th at 21 days following transplanting, and 1/4th at the period of panicle initiation. Phosphorus in its whole was used as a base. Potash was applied as 1/2th at the base and 1/2th at the beginning of the panicle. Seedling root dipping with 0.4% ZnO was carried out. Final land preparation involved applying 10 t ha^{-1} of well-rotten cattle farmyard manure and 1 tonne of lime per hectare every season per crop.

2.3 Grain and straw analyses

After the crop was harvested and stored in a dry, moisture-free environment, plant sampling (for grain and straw analyses) was carried out. The samples were subsequently oven dried at 650°C for a few days to achieve a stable weight and moisture level. For error-free analysis, the samples were finely processed using a Retsch mixer mill MM 400. The CHNS analyzer was used to determine the N and S content of both grain and straw (Euro EA). Wet digestion method was used for potassium, and zinc quantification in grain and straw (using diacid mixture of HNO_3 and $HClO_4$) (Chapman, 1961) [6]. A flame photometer was used to measure potassium (Jackson, 1987) [13], respectively. Dry ashing was used to estimate the amount of boron followed by Azomethin-H method (Bingham, 1982) [4]. Using an atomic absorption spectrophotometer, the zinc concentration was determined.

2.4 Nutrient uptake and nutrient use efficiency

The amount of nutrients taken up by the crop's above-ground portions was calculated by multiplying the nutrient content of the crop's grain and straw above-ground parts by their respective yields, then adding the results (Dobermann *et al.*, 2007) [9].

$$\text{Nutrient uptake } (grain, \text{kg ha}^{-1}) = \text{Nutrient content (grain)} \times \text{Grain yield Nutrient uptake}$$

$$\text{Nutrient uptake } (straw, \text{kg ha}^{-1}) = \text{Nutrient content (straw)} \times \text{Grain yield Nutrient uptake}$$

$$\text{Total nutrient uptake } (straw, \text{kg ha}^{-1}) = \text{Nutrient uptake (grain)} + \text{Nutrient uptake (straw)}$$

Similar to this, nutrient use efficiencies can be used to measure nutrient utilization capability and transformation.

$$\text{Internal utilization efficiency } \left(\frac{\text{kg grain}}{\text{kg nutrient}}\right) = \left(\frac{\text{Grain yield}}{\text{Nutrient uptake}}\right)$$

$$\text{Internal utilization efficiency } \left(\frac{\text{kg grain}}{\text{kg nutrient}}\right) = \left(\frac{\text{Grain yield}_{treatment} - \text{Grain yield}_{control}}{\text{Uptake}_{treatment} - \text{Uptake}_{control}}\right)$$

2.5 Yield assessment

After the crop was harvested (during the kharif season), the grains and straws were both sun-dried for three to four days before being heated in an oven to maintain a constant moisture and weight (expressed in kg ha^{-1}). A portable moisture meter was used to determine the moisture content. For each treatment, the yield of grain and straw was measured. Thus, the following equation was used to calculate the above-ground biomass yield.

3. Results and Discussion

3.1 Long-term nutrition on sulphur uptake

The most relevant secondary nutrient for paddy production is sulphur, while micronutrients include boron. Although boron is only needed in trace amount, a significant impact on the metabolism of paddy plants and produce high-quality paddy grains. Sulphur uptake was observed highest in NPK+FYM+Lime plots (9.49 kg ha^{-1}) whereas lowest in control plots (1.72 kg ha^{-1}) in kharif 2020. Sulphur applied plots (NPK+S+Zn) showed similar results of sulphur uptake as NPK+FYM+Lime plots (Fig. 1). Comparing NPK+Zn, ~45% higher sulphur uptake was observed with integration of sulphur and zinc with NPK (NPK+S+Zn). Zinc and boron application with NPK (NPK+Zn and NPK+B+Zn) showed similar sulphur uptake (~6.5 kg ha^{-1}) (Fig. 1). Also, N, NP, and PK showed no significant variation in sulphur uptake in kharif season (2020). Sulphur is essential for methionine, cysteine, and cystine synthesis. Also, plant hormones such as thiamine and biotin (De Datta, 1981) [8]. Sulphur availability is affected by water logged paddy soil as sulphur was reduced to sulphide and it reduced the paddy growth (Rahman *et al.*, 2007) [17]. Sulphur application with NPK increased sulphur availability as well as sulphur uptake in paddy plants. FYM addition increased sulphur uptake as organic matter provided inherent sulphur (Tripathi *et al.* 2018) [25].

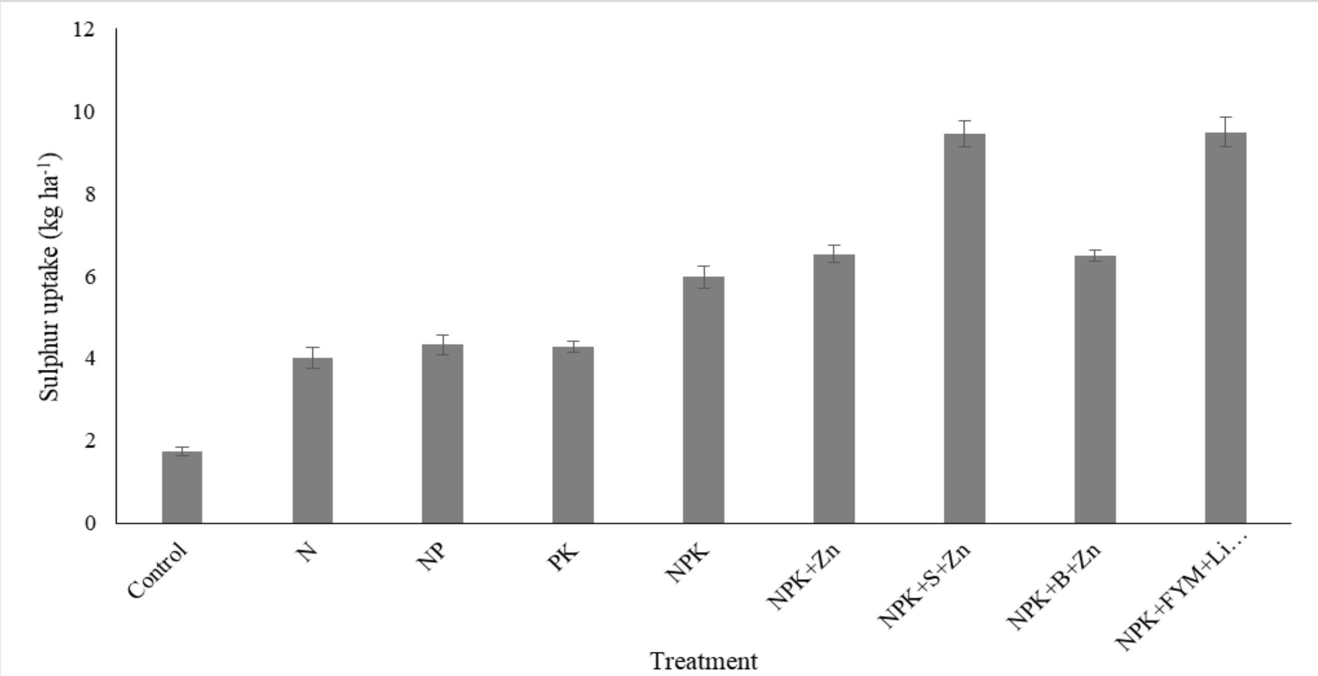

Fig 1: Long-term effect of fertilizers and manures on sulphur uptake

3.2 Long-term nutrition on boron uptake

Boron uptake was varied across the treatments from control plots to NPK+FYM+Lime plots. Boron uptake was recorded highest in NPK+FYM+Lime (0.28 kg ha^{-1}) and least in control plots (0.07 kg ha^{-1}). Boron applied treatments showed significant results in relation to no boron applied plots. Boron uptake was 27.8% higher in boron supplied plots (NPK+B+Zn) compared to NPK plots. Addition of farmyard manure increased boron uptake by 55.6% in NPK+FYM+Lime plots in comparison to NPK plots (Fig. 2). Comparing control plots with boron applied plots (NPK+B+Zn), ~229% higher boron uptake was observed in boron applied plots.

Significant nutrient uptake in NPK+B+Zn plots could be ascribed to the continuous supply of the specific nutrient. The boron addition through farmyard manure improved boron uptake in NPK+FYM+Lime plots (Fig. 2). Along with this, farmyard manure improved root rhizosphere that indirectly improve the physical, chemical, and biological health of soil. This condition helps in absorbance of boron by paddy roots. Also, under a transplanted paddy condition, neutral soil pH is achieved due to waterlogged condition. This neutral soil reaction helps in increase in availability of nutrients. As boron is required in trace amount, the uptake is highly dependent upon external nutrient supply other than inherent soil supply. Farmyard manure is a good contributor of all sorts of nutrients. So, high boron uptake in farmyard manure plots (NPK+FYM+Lime) could be referred to the boron supplying capacity of farmyard manure. Previous findings by (Sarkar *et al.*, 2020) [19] positive relationship between boron and organic manure.

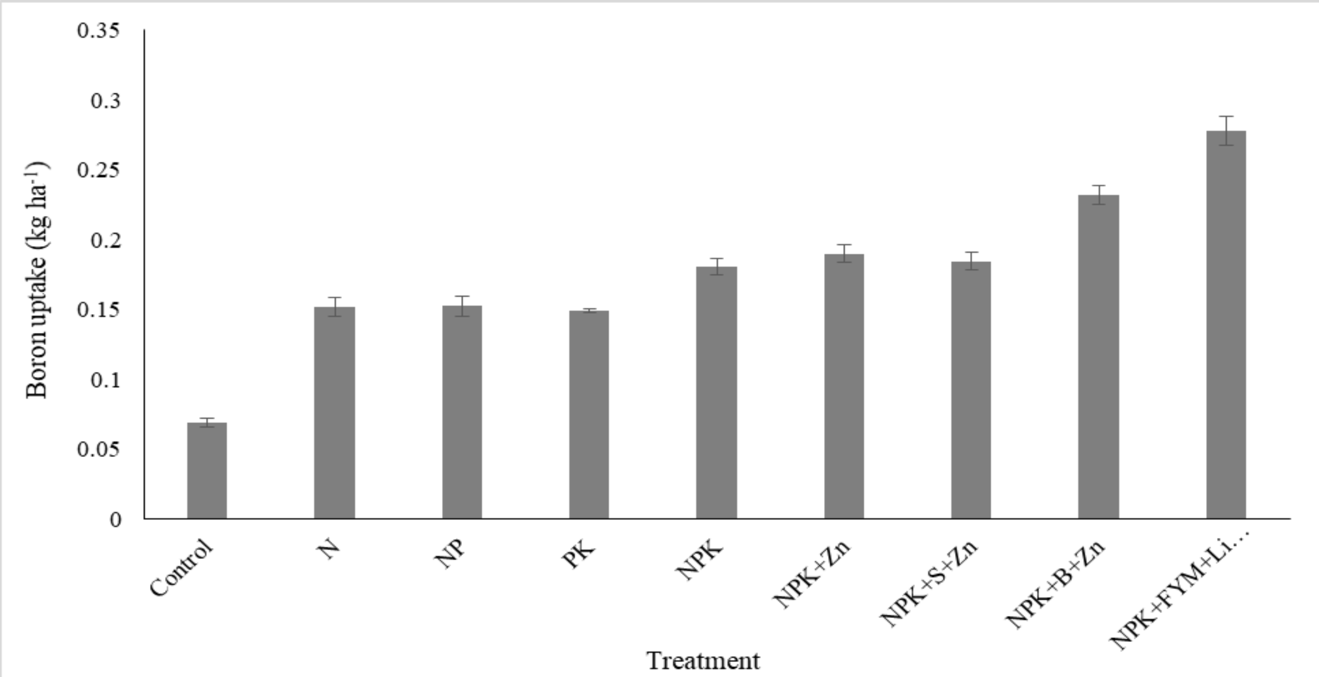

Fig 2: Long-term effect of fertilizers and manures on boron uptake

3.3 Long-term nutrition on internal use efficiency for nitrogen

Various management systems affected differently on nitrogen use efficiency to explain the uptake and utilization by rice plant. Most important efficiencies viz., internal nitrogen utilization efficiency (INUE) and physiological nitrogen efficiency (PEN) clearly depicted the nutrient utilization between applied nitrogen and grain (Table 4). Internal N utilization efficiency (INUE) in kharif season varied from 49.45 kg grain kg N uptake^{-1} to 91.10 kg kg-N uptake^{-1} under in BInOF system and control system, respectively.

Continuous supply of fertilizers and manures under various nutrient management systems significantly affected nutrient use efficiencies. INUE represents plant capacity of transforming nutrients into grain yield. INUE generally evaluates the genotype trait in rice plant. INUE values between 55-65 is considered as optimum for nutrient transformation to produce optimum economic yield. High INUE values under control system could be ascribed to low nitrogen level in soil as no fertilizer had been added into soil in past 15 years. Contrarily, low internal utilization efficiency values under NPK+FYM+Lime plots due to significant nutrient uptake due to continuous addition of nitrogen through fertilizer and manure. Previous researches from Hossain *et al.* (2005) [11], Dobermann (2007, 30-90 kg kg^{-1}), and Zhang *et al*. (2019) [27] reported similar internal N utilization efficiency (50 to 80 kg kg^{-1}).

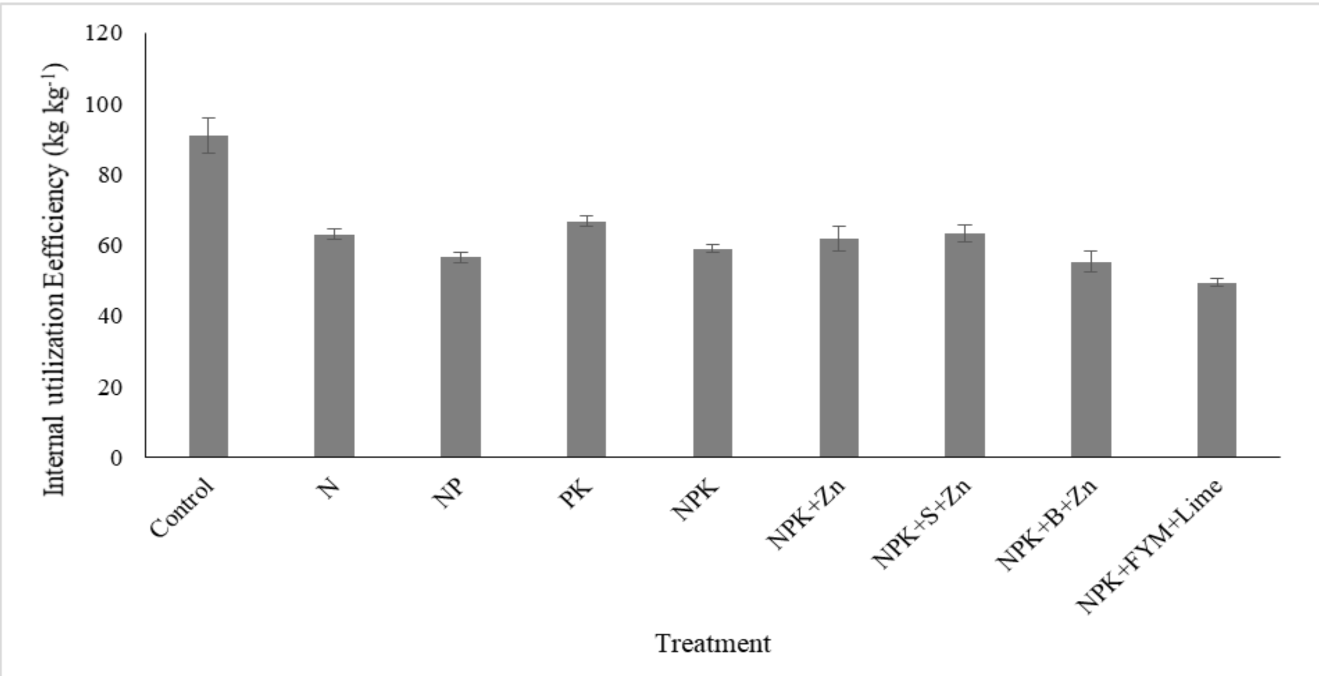

Fig. 3. Long-term effect of fertilizers and manures on internal utilization efficiency for nitrogen

3.4 Long-term nutrition on physiological efficiency

Physiological efficiency ranged from 41.95 to 53.55 in NPK+FYM+Lime and NPK+S+Zn plots, respectively for nitrogen. Similarly, micronutrient application plots showed significant physiological efficiency and varied between 44.45 to 53.55% in zinc, boron applied plots (NPK+Zn, NPK+S+Zn, and NPK+B+Zn plots) (Fig. 4). Zhang *et al*. (2019) found similar results physiological efficiency for nitrogen. In case of potassium, physiological efficiency varied between 40.16 to 50.95 kg grain kg nutrient^{-1} (Fig. 5). Potassium fertilized plots showed the physiological efficiency around ~38 to 40 kg grain kg nutrient^{-1}. Lowest physiological efficiency was observed in FYM treated plots (PK plots, 38.20). No potassium fertilization plots such as N and NP plots showed physiological efficiency of ~50 kg kg^{-1} (Fig. 5).

Physiological efficiency (PE) explains the increase in yield in relation to uptake in above ground portion of rice crop. It is related to increase in grain yield excluding control yield to uptake through fertilizer source only. Physiological suggested the effectiveness of the unit nutrient fertilization to produce unit grain yield. Here, crop physiology is responsible for utilization of nitrogen. Higher utilization of nitrogen inferred low physiological efficiency while higher physiological efficiency values suggested reduction in uptake from the fertilizer source. So, low physiological efficiency in NPK+FYM+Lime plots and NPK plots, indicated no factor other than significant nitrogen nutrition was responsible for improvement in physiological efficiency. These findings were consistent with Ladha *et al.* (2005) [14] and Singh *et al*. (2021) [21]. Similarly, Islam *et al.* (2015) [12] reported similar physiological efficiency of ~47 kg kg^{-1}.

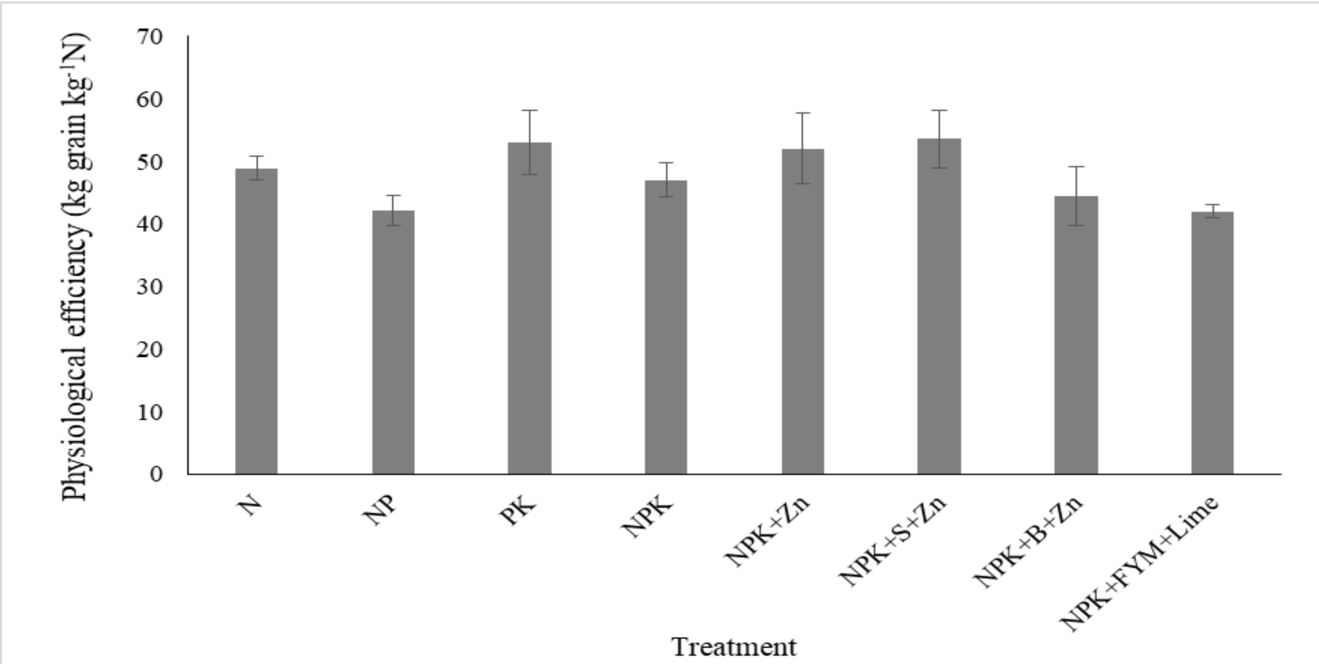

Fig 4: Long-term effect of fertilizers and manures on physiological efficiency for nitrogen

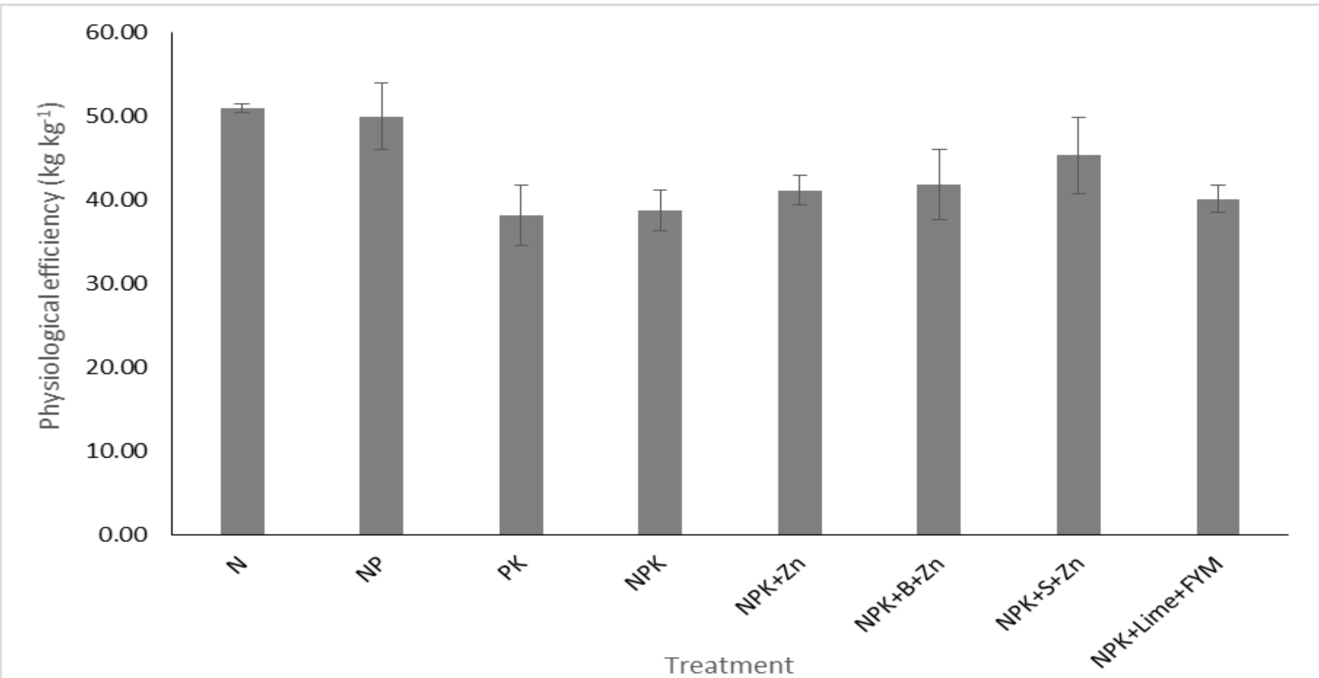

Fig 5: Long-term effect of fertilizers and manures on physiological efficiency for potassium

4. Conclusion
Diversified nutrient application directly and indirectly affected the nutrient uptake and nutrient use efficiency. For an effective paddy production, nitrogen use efficiency played great role in comparison to other nutrients. Hence, the internal utilization efficiency and physiological efficiency are involved nitrogen utilization in plant to produce paddy. Over the years due to continuous paddy cultivation. Boron and sulphur application increased their uptakes and farmyard manure application also improved uptake. The most relevant nutrient management plots were 100%NPK+FYM+Lime plots in relation to sulphur and boron uptake. Highest nitrogen utilization in the form of internal utilization efficiency and physiological efficiency was in FYM applied plots (100%NPK+FYM+Lime). The most important nutrient management technique that effectively maintained paddy production and made efficient use of the nutrients was 100%NPK+FYM+Lime. Together with NPK, farmyard manure improved the yield-related indicators by increasing the use efficiency of nitrogen and micronutrient uptake. Therefore, integrating organic and inorganic fertilization should be the future strategy to increase biological rice yield by improving micronutrient uptake and use.

5. Acknowledgment
For all laboratory work, the authors are grateful to the Department of Soil Science and Agricultural Chemistry at the Odisha University of Agriculture and Technology in Bhubaneswar, Odisha. Additionally, ICAR's AICRP on Long-Term Fertilizer Experiment is highly commended for supporting the execution of this study. The first author acknowledges UGC for UGC-JRF. The department of Soil Science and Agricultural Chemistry's research personnel and laboratory staff provided valuable assistance to the authors during chemical analysis and laboratory work for the experiment. Sincere thanks go out to Dr. AK Pal, Dr. MR Pattanaik, Dr. RK Nayak, and Dr. KK Rout for starting and maintaining this lengthy trial. Dr. RH Wanjari, Dr. Mitali Mandal, and Dr. Debadatta Sethi are thanked by Saheed Garnaik for their kind help.

6. References
1. Adusumilli R, Bhagya Laxmi S. Potential of the system of rice intensification for systemic improvement in rice production and water use: the case of Andhra Pradesh, India. Paddy and Water Environment. 2011;9(1):89-97.
2. Baligar VC, Fageria NK, He ZL. Nutrient use efficiency in plants. Communications in soil science and plant analysis. 2001;32(7-8):921-950.
3. Bhatt R, Singh P, Hossain A, Timsina J. Rice–wheat system in the northwest Indo-Gangetic plains of South Asia: Issues and technological interventions for increasing productivity and sustainability. Paddy and Water Environment. 2021;19(3):345-365.
4. Bingham FT. Boron, IN A.L. Page (ed.) Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI, 1982, 431-448.
5. Bouman BAM. Water management in irrigated rice: coping with water scarcity. Int. Rice Res. Inst, 2007.
6. Chapman H, Prat P. Methods of analysis for soil plant & water, USA: Division of Agriculture Science. University of California: Riverside. CA, 1961, 1188.
7. Dar MH, Waza SA, Shukla S, Zaidi NW, Nayak S, Hossain M, *et al.* Drought tolerant rice for ensuring food security in Eastern India. Sustainability. 2020;12(6):2214.
8. De Datta SK. Principles and practices of rice production. Int. Rice Res. Inst, 1981.
9. Dobermann A. Nutrient use efficiency–measurement and management, 2007.
10. Dwivedi BS, Singh VK, Meena MC, Dey A, Datta SP. Integrated nutrient management for enhancing nitrogen use efficiency. Indian J Fertil. 2016;12:62-71.
11. Hossain MF, White SK, Elahi SF, Sultana N, Choudhury MHK, Alam QK, *et al*. The efficiency of nitrogen fertiliser for rice in Bangladeshi farmers' fields. Field Crops Research. 2005;93(1):94-107.
12. Islam SMM, Khatun A, Rahman F, Hossain AS, Naher UA, Saleque MA. Rice response to nitrogen in tidal flooded non-saline soil. Bangladesh Rice Journal. 2015;19(2):65-70.
13. Jackson KT. Crabgrass frontier: The suburbanization of the United States. Oxford University Press, 1987.
14. Ladha JK, Pathak H, Krupnik TJ, Six J, Van Kessel C. Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. Advances in agronomy. 2005;87:85-156.
15. Lüdecke D, Ben-Shachar MS, Patil I, Waggoner P, Makowski D. Performance: An R package for assessment, comparison and testing of statistical models. Journal of Open-Source Software, 2021, 6(60).
16. Okuda M, Isogai A, Joyo M, Goto-Yamamoto N, Mikami S. Influence of sulfur and nitrogen content of rice grains on flavor in stored sake. Cereal chemistry. 2009;86(5):534-541.
17. Rahman MN, Sayem SM, Alam MK, Islam MS, Mondol ATMAI. Influence of sulphur on nutrient content and uptake by rice and its balance in old Brahmaputra floodplain soil. Journal of Soil Nature. 2007;1:05-10.
18. Saito K, Nelson A, Zwart SJ, Niang A, Sow A, Yoshida H, Wopereis MC, 15 Towards of Biophysical Determinants of Yield Gaps and the Potential for Expansion of the Rice Area in Africa. Realizing Africa's rice promise, 2013, 188.
19. Sarkar A, Devi NS. Effect of boron and farmyard manure application on boron concentration and dry matter yield of paddy. IJCS. 2020;8(1):1374-1376.
20. Seck PA, Diagne A, Mohanty S, Wopereis M. Crops that feed the world 7: Rice. Food security. 2012;4(1):7-24.
21. Singh P, Benbi DK, Verma G. Nutrient management impacts on nutrient use efficiency and energy, carbon, and net ecosystem economic budget of a rice–wheat cropping system in Northwestern India. Journal of Soil Science and Plant Nutrition. 2021;21(1):559-577.
22. Singh P, Benbi DK, Verma G. Nutrient management impacts on nutrient use efficiency and energy, carbon, and net ecosystem economic budget of a rice–wheat cropping system in Northwestern India. Journal of Soil Science and Plant Nutrition. 2021;21(1):559-577.
23. Smith P, Gregory PJ. Climate change and sustainable food production. Proceedings of the Nutrition Society. 2013;72(1):21-28.
24. Subedi KD, Budhathoki CB, Subedi M, Gc YD. Response of wheat genotypes to sowing date and boron fertilization aimed at controlling sterility in a rice-wheat rotation in Nepal. Plant and soil. 1997;188(2):249-256.
25. Tripathi LK, Ghosh SK, Patra PK, Gupta AK. Efficacy of

organic and inorganic amendments on Sulphur availability in relation to growth and yield of rice in an Alfisol soil. IJCS. 2018;6(2):2992-2997.
26. Van Cauwenbergh N, Biala K, Bielders C, Brouckaert V, Franchois L, *et al*., SAFE: A hierarchical framework for assessing the sustainability of agricultural systems. Agriculture, ecosystems & environment. 2007;120(2-4):229-242.
27. Zhang H, Hou DP, Peng XL, Shao SM, Jing WJ, Gu J.F., *et al.*, Optimizing integrative cultivation management improves grain quality while increasing yield and nitrogen use efficiency in rice. Journal of Integrative Agriculture. 2019;18(12):2716-2731.