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Effect of Amendments on Soil and Growth Characteristics of Rice (*Oryga sativa*) in Lateritic and Coastal Wetland Soils

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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

Wetland ecosystems of Kerala play a crucial role in sustaining rice production, yet their productivity is increasingly constrained by poor soil fertility and adverse physicochemical properties. Understanding nutrient dynamics and the impact of soil amendments in distinct agroecological units is essential for developing effective management strategies to enhance soil fertility and rice yield. A pot culture experiment was conducted to study the effect of amendments on the soil nutrient dynamics of both lateritic and coastal wetland soils at College of Agriculture, Padannakkad, Kasaragod from October 2023 to January 2024. Experiment was conducted with 2 types of soils (coastal sandy and lateritic alluvial wetland) under 5 levels of treatments using completely randomized design (CRD) using paddy as the test crop. From the experiment, yield limiting factors were found to be available Mg and B status in both the soil types. The results of the experiment revealed that application of Soil Test Based Fertilizers (STBF) and STBF combined with lime / dolomite significantly improved growth parameters such as productive tillers, grains per panicle, and test weight and ultimately leading to higher yield potential. The incorporation of liming materials not only ameliorated soil acidity but also enhanced the availability of essential nutrients. Thereby Soil Test Based

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Fertilizers (STBF) combined with lime / dolomite by significantly improving soil nutrient availability, plant nutrient uptake, and yield attributes in both soil types and proved to be the best management practice in both the soil types.

Keywords: Lateritic wetland; coastal wetland; $MgSO_4$; Borax; STBF.

1. Introduction

Wetlands of Kerala are highly significant in their role in the production of rice. Rice is the most important food crop of the developing world, the staple food of more than half of the world's population, and an important residue producing crop in Asia (Swaminathan, 1984). India ranks second in rice production after China, covering 46.37 million hectare, with a production of 130.29 million tonnes and productivity of 2809 kg ha^{-1} in 2021-22 (GOI, 2022). The area, production and productivity of rice in Kerala is 1.94 lakh ha, 5.59 lakh t and 2884 kg ha^{-1} respectively in 2021-22 registering a decrease of 10.7 % in production and 7.1% in productivity over 2020-21 (GOK, 2022).

The two agroecological units selected for the study are AEU 2 and AEU 11. AEU 11 comprises of northern laterites and is delineated to represent midland laterite terrain with longer dry period than its southern counterpart. The climate is tropical humid monsoon type with mean annual temperature of 27.3 °C and rainfall of 3217 mm. Moisture stress is experienced for a period of 4 to 6 months. AEU 2 represents the northern coastal plain having a rainfall of 3133 mm and mean annual temperature of 28 °C.

Coastal wetland soils in many situations are constrained by factors *viz*., low organic matter, low cation exchange capacity, low water holding capacity etc. Lateritic wetland soils are abundant in aluminium and iron, formed in humid and hot tropical areas. They are leached soils and are acidic in nature and coarse and crumbly in texture. Lack of nitrogen, potassium and organic matter make these soils unsuitable for cultivation. Use of appropriate management practices can increase the productivity of these wetlands.

The uniqueness in soil forming and development processes under the humid tropical climate dictates the dynamic equilibrium of different nutrient ions existing in solid and solution phase. The understanding of nutrient dynamics of these wetland soils (AEU 2 and AEU 11) is important in managing the soil fertility at precise level. Proper assessment of nutrient dynamics is a pre-requisite for soil fertility evaluation, correct interpretation and appropriate use of amendments. The effect of different amendments on the soil nutrient dynamics also need to be studied for evolving suitable management strategies for maintaining or enhancing the fertility of these soils.

Hence, an attempt to study the effect of amendments on the soil nutrient dynamics of both lateritic and coastal wetland soils was done using a pot culture experiment to evolve the suitable management strategies for enhancing the fertility of these soils.

2. Methodology

Pot culture experiment was conducted by growing paddy as test crop at a farm plot in College of Agriculture, Padannakkad, Kasaragod from October 2023 to January 2024. With two types of soils (coastal sandy and lateritic alluvial wetlands) under five levels of treatments, the experiment was conducted using Completely Randomized Design. Soil required for filling 15 pots (12inch size) was collected were collected from representative areas of each wetland under AEU 2 and AEU 11 for conducting pot culture experiment.

The experiment was done using paddy as test crop, and the variety used was Uma (MO 16). It was developed by Rice Research Station, Moncompu of Kerala Agricultural University. Treatment combinations were T_1 (KAU POP (2016) based fertilizers + lime), T_2 (Soil test based fertilizers), T_3 (Soil test based fertilizers and lime), T_4 (KAU organic POP based FYM + Lime) and T_5 (Soil test based fertilizers and dolomite)

After clearing the field of stubble and weeds, the experiment site was prepared by placing a total of 30 pots as per the experimental layout. Each pot was filled with the soil (approximately 10 kg per pot) collected from the two wetlands (northern coastal and northern lateritic wetland).

Soil test based lime and dolomite was applied initially. FYM was applied 10 days before sowing for proper incorporation. Inorganic fertilizers (Urea, MOP, NPK complex fertilisers, $MgSO_4$ and borax) were applied 3 days prior to sowing as basal application as per the treatment requirement. It was uniformly spread on the pots and lightly incorporated into the soil manually.

Seeds were soaked overnight prior to planting for faster germination. The seeds were then planted directly in the pots at 3 seeds per pot. Plants were thinned to one per pot at 25 days after sowing and maintained under submerged condition. The second dose of lime and dolomite was given at 1 month after sowing as per treatments. One third dose of N was given at active tillering stage as per treatment. At panicle initiation stage, the balance doses of N and potash were given as per treatment.

Soil samples for laboratory analysis were collected from all the treatments at three stages of rice cultivation (maximum tillering, flowering and harvest). Total plant samples collected after harvest were dried, powdered and analysed separately.

Table 1. Properties of initial soil sample

Parameter	Lateritic wetland soil	Coastal wetland soil
pH	5.48	6.1
EC (dS/m)	0.08	0.17
Organic carbon (%)	1.08	0.84
Available N (kg/ha)	137.98	112.89
Available P (kg/ha)	43.68	62.72
Available K (kg/ha)	102.25	82.54
Available Ca (mg/kg)	280	240
Available Mg (mg/kg)	108	84
Available B (mg/kg)	0.172	0.084

Table 2. Quantity of inputs applied in different treatments

Type of soil	Treatment	Quantity of inputs (gram per pot)							
		Lime	Dolomite	Urea	NPK	MOP	Borax	FYM	$MgSO_4$
Lateritic wetland soil	T_1	4.26	0	0.69	1.67	0	0	35.3	0
	T_2	0	0	1.16	0	0.56	0.07	0	0.56
	T_3	1.38	0	1.16	0	0.56	0.07	0	0.56
	T_4	4.26	0	0	0	0	0	35.3	0
	T_5	0	2.27	1.16	0	0.56	0.07	0	0.56
Coastal wetland soil	T_1	4.26	0	0.69	1.67	0	0	35.3	0
	T_2	0	0	1.08	0	0.56	0.07	0	0.56
	T_3	0.39	0	1.08	0	0.56	0.07	0	0.56
	T_4	4.26	0	0	0	0	0	35.3	0
	T_5	0	0.64	1.08	0	0.56	0.07	0	0.56

3. Results and Discussion

3.1 Soil Analysis

In lateritic wetland soils, at flowering the highest organic C content was observed in T_1 and after harvest, the highest organic C content was observed in T_1 which was on par with T_4. In coastal wetland soils, at flowering and after harvest stages, significantly highest organic C content was observed in T_1 which was on par with T_4.

This result corroborates with the findings of Dutta et al., (2022) who reported that combination of FYM and inorganic fertilizers in rice cultivation can significantly boost SOC content and carbon sequestration ensuring sustainable productivity.

Table 3. Effect of treatments on organic carbon (%), P and K (kg ha^{-1}) in soil

Type of soil	Treatments	Organic carbon (%)			Available N (kg ha^{-1})			Available K (kg ha^{-1})		
		Maximum tillering	Flowering	After harvest	Maximum tillering	Flowering	After harvest	Maximum tillering	Flowering	After harvest
Lateritic wetland soil	T_1	0.96	1.06^{a}	1.20^{a}	259.24^{a}	213.25^{a}	156.8	139.22^{b}	138.24^{b}	111.59
	T_2	0.79	0.66^{c}	0.90^{bc}	234.15^{a}	188.16^{b}	137.98	142.91^{ab}	142.05^{ab}	117.52
	T_3	0.76	0.64^{c}	0.85^{c}	246.69^{a}	200.7^{ab}	150.53	151.87^{a}	149.67^{a}	125.03
	T_4	0.90	0.88^{b}	1.06^{ab}	171.43^{b}	163.07^{c}	119.17	114.35^{c}	119.65^{c}	105.09
	T_5	0.85	0.60^{c}	0.88^{bc}	240.42^{a}	194.43^{ab}	144.25	141.79^{ab}	143.06^{ab}	120.99
	SE(m)	0.05	0.03	0.18	14.63	7.24	9.58	3.60	2.92	4.54
	CD (0.05)	NS	0.095	0.058	46.110	22.820	NS	11.345	9.188	NS
Coastal wetland soil	T_1	0.89	0.93^{a}	0.91^{a}	194.43	190.25^{a}	173.52	105.02^{b}	108.60^{b}	98.15^{a}
	T_2	0.74	0.57^{b}	0.73^{b}	156.8	152.62^{bc}	154.71	108.83^{ab}	116.22^{ab}	99.27^{a}
	T_3	0.75	0.55^{b}	0.69^{c}	169.34	165.16^{ab}	167.25	114.43^{a}	124.84^{a}	105.09^{a}
	T_4	0.87	0.79^{a}	0.88^{a}	131.71	127.53^{c}	110.8	83.74^{c}	84.29^{c}	78.44^{b}
	T_5	0.73	0.6^{b}	0.67^{c}	163.07	158.89^{abc}	160.98	111.18^{ab}	121.93^{a}	100.72^{a}
	SE(m)	0.05	0.06	0.01	13.05	11.64	13.71	2.53	3.68	4.85
	CD (0.05)	NS	0.190	0.040	NS	36.680	NS	7.71	11.590	15.290

SE (m)- Standard Error of the Mean, CD (0.05) - Critical Difference at a 5% level of significance, NS – Non significant

Table 4. Effect of treatments on available Mg (kg ha^{-1}) and B (mg kg^{-1}) in soil

Type of soil	Treatments	Available Mg (mg kg^{-1})			Available B (mg kg^{-1})		
		Maximum tillering	Flowering	After harvest	Maximum tillering	Flowering	After harvest
Lateritic wetland soils	T_1	92^{b}	101^{c}	84	0.169^{c}	0.161^{b}	0.097
	T_2	160^{a}	141^{ab}	132	0.199^{b}	0.176^{ab}	0.115
	T_3	172^{a}	159^{a}	144	0.237^{a}	0.189^{a}	0.119
	T_4	100^{b}	105^{bc}	96	0.180^{bc}	0.157^{b}	0.097
	T_5	166^{a}	153^{a}	150	0.227^{a}	0.185^{a}	0.119
	SE(m)	18.24	11.56	18.33	0.01	0.01	0.01
	CD (0.05)	57.48	36.44	NS	0.026	0.019	NS
Coastal wetland soils	T_1	107^{bc}	100^{b}	93^{bc}	0.137	0.119^{bc}	0.073
	T_2	131^{ab}	160^{a}	141^{ab}	0.152	0.142^{ab}	0.088
	T_3	149^{a}	166^{a}	153^{a}	0.162	0.147^{a}	0.093
	T_4	95^{c}	88^{b}	81^{c}	0.134	0.111^{c}	0.080
	T_5	143^{a}	160^{a}	147^{a}	0.161	0.146^{a}	0.094
	SE(m)	11.11	14.00	16.91	0.01	0.01	0.01
	CD (0.05)	35.02	44.11	53.31	NS	0.026	NS

SE (m)- Standard Error of the Mean, CD (0.05) - Critical Difference at a 5% level of significance, NS – Non significant

In both the wetland soils, the highest available N was recorded in T_1 (KAU POP based fertilizer and lime application). Soil available N increased when N was supplied through both fertilizers and FYM (Behera and Pany, 2021).

The highest available K content was observed in treatment T_3 (STBF and lime application) in both the wetland soils. This might be due to the higher dose of K fertilizer given in T_3 and the effect of lime. The higher the dose of K fertilizer applied, the greater the amount of available K in the soil (Hartati *et al*, 2018). The addition of gypsum, calcium hydroxide, and calcium carbonate to acidic soils through liming increases the availability of K, thereby improving crop productivity and profitability more effectively compared to other materials like Cement Kiln Dust, dolomite, and wood ash (Enesi *et al.,* 2023).

In lateritic wetland soils, highest available Mg content was recorded in T_3 which was on par with T_5 and T_2 at maximum tillering and flowering stages. In coastal wetland soils, highest available Mg value was recorded in T_3 which was on par with T_5 and T_2 at maximum tillering, flowering and after harvest stages.

In lateritic wetland soils, highest available B value was recorded in T_3 which was on par with T_5 at maximum tillering. The highest available B value was recorded in T_3 which was on par with T_5 and T_2 at flowering, In coastal wetland soils. highest available B value was recorded in T_3 which was on par with T_5 and T_2 at flowering stage.

Applying $MgSO_4$ (Kieserite) increases the availability of Mg in soils, thereby enhancing Mg availability for paddy cultivation and potentially leading to benefits in terms of yield and nutrient uptake (Hardter *et al*., 2005). The results showed that available B was highest in the treatments (T_3 and T_5) in both the wetland soils where both borax and lime/dolomite was applied as soil amendments. This also corroborates with the findings of Caballero *et al*. (2016) that the application of liming material increases available boron in acidic soil.

3.2 Plant Analysis

Highest plant N content was recorded in treatment T_1 (KAU POP (2016) based fertilizers + lime) which was on par with T_3 and T_5 treatments. This might be due to the combined application of FYM and inorganic fertilizers which resulted in increased nutrient availability and higher meristematic activities in the above ground and roots of the plant leading to high absorption of N from the soil. These results were in conformity with the findings of Pallavi et al. (2016).

Highest plant K content was recorded with the application of STBF and lime (T_3) in lateritic wetland soils while it was maximum in treatment T_3 which was on par with T_5 in coastal wetland soils. This might be due to the higher available K content in soil for treatment T_3 due to the higher dose of K fertilizer given in this treatment along with the effect of lime. Increased soil available K increases plant K content in rice (Isnaini and Rivaie, 2023).

Highest plant Ca content was recorded in treatment T_1 (KAU POP (2016) based fertilizers + lime) which was on par with T_4 treatment. This is in line with the findings of Sharma and Chetani (2017) who reported that the combined application of organic and inorganic fertilizers synergistically increases Ca levels in soils, thereby enhancing the Ca content in plants. Highest Mg content was recorded in treatment T_3 which was on par with T_5 and T_2 treatments. Application of Mg fertilizer increases Mg content in rice plants (Ahmed *et al*., 2020).

Plant B content was maximum in T_3 which was on par with T_5 treatment. Soil application of boron fertilizer, such as borax, increases total boron uptake in rice plants (Songsriin *et al.,* 2023). This might also be also due to the effect of liming which increases extractable B in acidic soils.

3.3 Growth and Yield Characters

Treatments have no significant effect on plant height in both the wetland soils. In lateritic wetland soils, highest number of productive tillers was recorded in treatment T_5 which was on par with T_3 and T_2 treatments. Highest number of grains per panicle was recorded in T_3 which was on par with T_5 and T_2 treatments. In coastal wetland soils, number of productive tillers was maximum in treatment T_3 which was on par with T_5 and T_2 treatments. Number of grains per panicle was maximum in T_5 which was on par with T_3 and T_2 treatments.

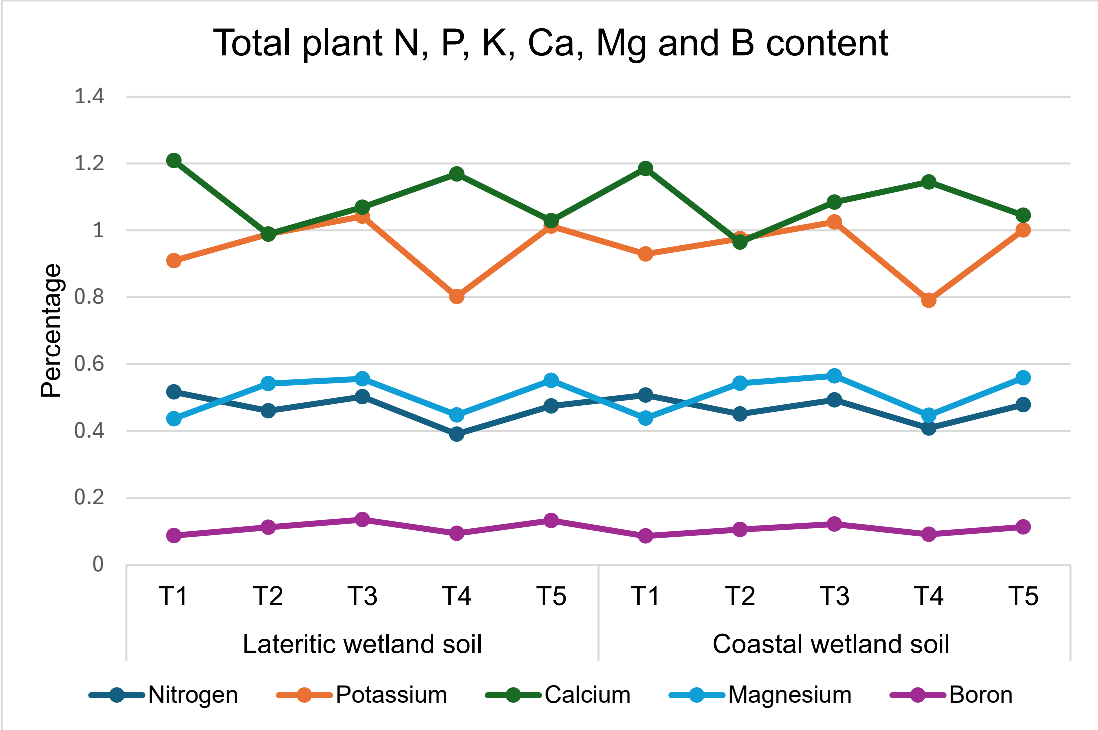

Fig. 1. Effect of treatments on total plant N, P, K, Ca, Mg and B content

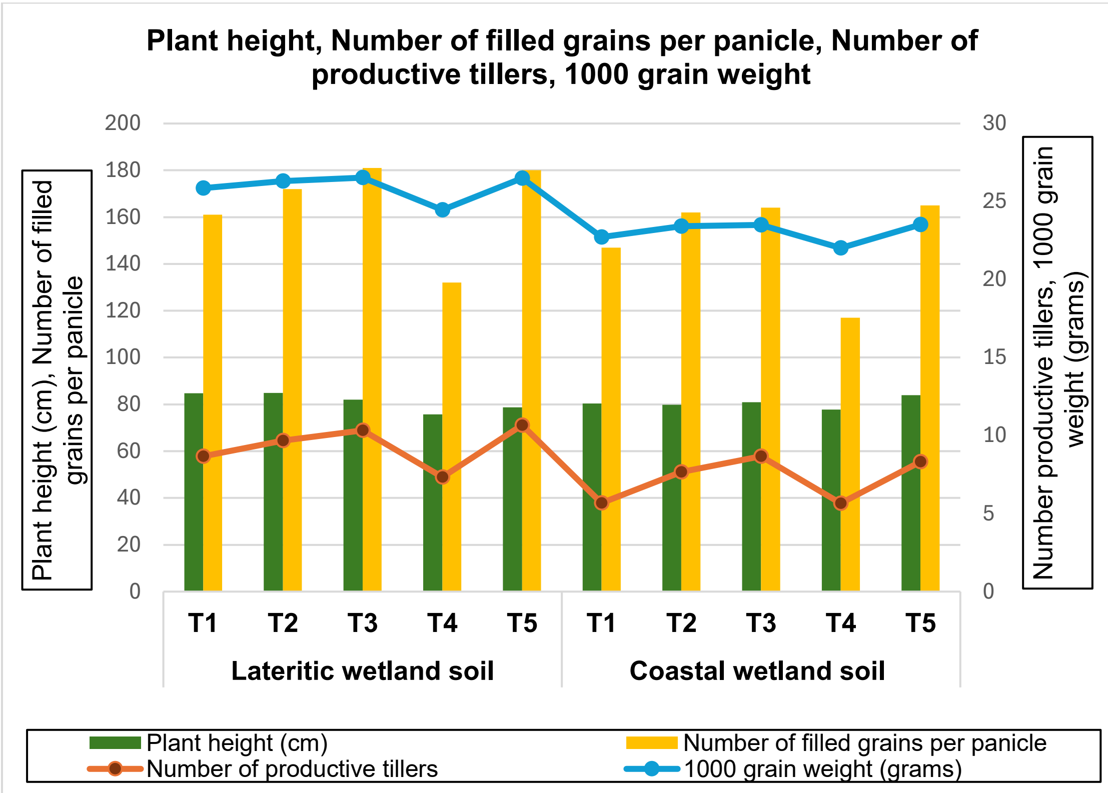

Fig.2. Effect of treatments on plant height, number of productive tillers, number of grains per panicle and 1000 grain weight

This might be due to the addition of limiting nutrients such as Mg as $MgSO_4$, B as borax in T_3, T_5 and T_2 treatments. This is also in line with the findings of Biswas *et al.* (2013) who reported that application of $MgSO_4$ increased number of grains per panicle in rice. Boron is crucial for increasing grains per panicle in rice (Yeo *et al.,* 2014).

In lateritic wetland soils, highest 1000 grain weight was recorded in T_3 which was on par with T_5 treatment while in coastal wetland soils, highest value was recorded in T_5 which was on par with T_3 treatment. The application of Mg results in the early completion of flowering, aiding in the uniform ripening of grains and consequently increasing the grain weight. Test weight increased compared to the control when the nutrients Mg and B were applied individually or together, either in soil or on foliage (Preman *et al*., 2016). This results also corroborates with the findings of Dash *et al*. (2015) who reported that decrease in yield in the absence of B was more significant compared to the reduction in yield due to the absence of N, P, or K alone or in combination.

4. Conclusion

The results of the pot culture experiment demonstrated that both lateritic and coastal wetland soils were deficient in available magnesium (Mg) and boron (B), which acted as major yield-limiting nutrients for paddy cultivation. Application of soil test-based fertilizers (STBF), particularly when combined with lime or dolomite, significantly improved soil nutrient availability, plant nutrient uptake, and yield attributes in both soil types.

Among the treatments, STBF combined with lime (T_3) and STBF combined with dolomite (T_5) consistently performed better in enhancing available Mg and B, improving growth parameters such as productive tillers, grains per panicle, and test weight, ultimately leading to higher yield potential. The incorporation of liming materials not only ameliorated soil acidity but also enhanced the availability of essential nutrients.

Therefore, the study highlights that balanced nutrient management based on soil testing, along with the application of Mg and B through appropriate amendments, is essential for improving the productivity and sustainability of lateritic and coastal wetland soils. These findings provide a practical and effective nutrient management strategy for rice cultivation in such challenging soil environments.

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 they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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