


**COMPARATIVE EVALUATION OF BIOCHAR AND PADDY SOIL
AS SUBSTRATES FOR RICE (*ORYZA SATIVA* L.) SEEDLING
GROWTH AND DEVELOPMENT**

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ABSTRACT

Rice (*Oryza sativa* L.) is an important cereal crop that feed more than half of the global population, making its production vital for food security. Seedling development is a fundamental stage of rice growth that determine the vigor, establishment and ultimate productivity of the crop in the field. The experiment was conducted at Egerton University teaching and research field to determine the performance of substrate with different percentage of soil and rice husk biochar on growth and development of rice seedlings. The substrates were: S100B0 (100% soil and 0% biochar), S75B25 (75% soil and 25% biochar), S50B50 (50% soil and 50% biochar, S25B75 (25% soil and 75% biochar), S0B100 (0% soil and 100% biochar). Data collected were emergence at 7 and 14 days after sowing, plant height, soil plant analysis development (SPAD) both collected weekly from 14 to 35 days after sowing, biomass weight at 35 days after sowing, tissue nitrogen and tissue phosphorus was analyzed from the harvested seedlings at 35 days after sowing. ANOVA was conducted by use of R. software version 4.4.4 and general linear model (GLM) technique. Pearson's correlation was used to analyze the correlation between growth and nutrient. The treatments mean was compared using Fisher's Least Significant Difference (LSD) at $P \leq 0.05$ level of significance. The highest percent emergence was recorded from S0B100 and the tallest seedlings 4.9 cm were produced at S75B25. Tissue nitrogen and SPAD were affected highly by S75B25 with 5.1% and 25.0 for tissue nitrogen and SPAD respectively. The highest percentage of tissue phosphorus was 0.48% recorded from S0B100 and the least 0.32 % from S75B25. Use of appropriate substrate is important as it can influence germination, crop vigor, nutrient uptake as well as plant health in general. The choice of nursery substrate influences not only germination rates but also root architecture, nutrient uptake, and the ability to withstand transplanting shock.

Keywords: Biochar; Rice Seedling; Soil; Substrate

INTRODUCTION

Rice (*Oryza sativa* L.) is an important cereal crop consumed by more than half of the global population, making its production vigorous for food security. In sub-Saharan Africa and Asia dominated by developing countries, cultivation of rice is a food source as well as a key economic activity for millions of smallholder farmers. Seedling development is a fundamental stage of rice growth that determine the vigor, establishment and ultimate productivity of the crop in the field (Mahender et al., 2023). The choice of nursery substrate influences not only germination rates but also root architecture, nutrient uptake, and the ability to withstand transplanting shock. To support healthy seedling growth and subsequent crop performance, the selection of a suitable substrate for nursery management is essential. Traditionally, rice seedlings are grown in paddy soil beds under waterlogged conditions, which support early root enlargement and ease transplanting. Yet, the continual use of native paddy soil as a nursery medium poses challenges (Moldenhauer et al., 2025). Reduced seedling vigor is experienced due to long term cultivation of one crop that depletes soil fertility. Furthermore, sustainable alternatives that can enhance seedling quality without degrading the land is demanded due environmental concerns such as nutrient runoff, erosion and deterioration of soil structure (Akay et al., 2021). The increasing demand for sustainable and efficient rice production calls for alternative substrates to traditional paddy soil. Biochar, a stable carbon-rich product obtained through the pyrolysis of organic materials such as crop residues or animal waste, has emerged as a promising soil amendment and growing medium. It improves soil structure, enhances nutrient retention, and supports microbial activity, while also serving as a means of carbon sequestration (Namuco et al., 2019). Studies have reported positive impacts of biochar on crop growth and soil health, suggesting it could be an effective alternative to conventional substrates. Using biochar either alone or in combination with paddy soil may enhance rice seedling development and easy to uproot. However, the effectiveness of biochar as a substrate varies with feedstock type, pyrolysis conditions, and application rates (Ros et al., 2023). Therefore, empirical data are required to evaluate its potential as a nursery medium, particularly in tropical and subtropical rice-growing regions. Biochar may offer a viable solution, but its effectiveness as a substrate for rice seedlings remains underexplored in many rice-growing regions. This study aims to compare biochar and paddy soil as substrates for rice seedlings and identify the best composition for sustainable seedling production.

Hence there is huge production of rice husk farmers can easily utilize it at no cost to process into biochar. Therefore, adopting the combined substrates in real nursery is ideal because it enhance seedling uprooting and disease suppression. The substrates contribute to higher profitability in rice production as they improved seedling fast establishment after transplanting that reduce seedling loss and increase final yield due to seedling vigour. Biochar can reduce environmental pollutions

as it uses recycles farm waste, it also improves water retention and soil structure in the nursery. Biochar helps in boosting soil fertility when seedlings are transplanted to the field and this results in sustainable benefits as biochar remain in soil for long time.

MATERIAL AND METHODS

Site and Experiment Procedure Description

The experiment was conducted at Egerton University teaching and research field 7 in a shade net structure. Egerton University is located in Njoro, Nakuru County with the coordinate 35° 35' E longitude, latitude of 0° 23' S (Bulitia, 2019). The tested rice variety is IR2793-80-1, a product of IRRI in collaboration with KARLO Kisumu. Its attributes include high yields, 6-7 t ha⁻¹, 20-25 tillers per plant, plant height 80-85cm, duration of 120 days, thin long grain and none aromatic. The genotype was tested for response to different growth substrates of paddy soil and plain rice husk biochar combination. Nursery tray of 200 planting holes was used which were filled with their respective planting substrate. The different substrates were formulated from paddy soil from Ahero paddy rice field and plain rice husk biochar from Safi Organic Company Ltd. at 100% soil, 100% biochar, 25% soil + 75% biochar, 25% biochar + 75% soil, and 50% soil + 50% biochar. The rice seeds were first soaked in water to remove the empty seeds and was left to sit for 24 hours after which were air dried under the shade to reduce the moisture for easy handling during sowing. The prepared trays were sown 1 seed per hole. The experiment was monitored and watered twice daily all through the period. The experiment was laid in randomized complete block design (RCBD) with 3 replications. The trays we separated 60 cm between blocks and 30 cm between trays withing the same block.

Data Collection and Analysis on Percentage Emergence and Growth of Rice Seedlings

Percentage emergence was counted on the seventh and fourteenth day after sowing (DAS). Growth parameters collected include: plant height and number of leaves per seedling weekly from week 2 to week 5 after sowing. Plant height was measured using a ruler from the base to tip of last leaf sheath. Chlorophyll content was measured weekly using a chlorophyll meter (SPAAD) meter (TYS-A) from week 2 to week 5 after sowing. The rice seedlings were uprooted and the below ground part removed, above ground biomass was oven dried at 65°C for 48 hours and weighed using electronic scale. The dry seedlings were ground using an electronic grinder and sieved with a 1mm mesh to obtain a better surface area for analysis.

Tissue Analysis

Kjeldahl Digestion Method was used to determine total nitrogen. 0.1 g of the sample was weighed into Kjeldahl tube and 2.5 ml of digestion mixture was added. The solution was heated for an hour after which 3 ml of hydrogen peroxide (H₂O₂) was added in sequence and heating continued until

the sample become clear. After cooling, the solution was diluted using deionized water and transferred to a 50 ml volumetric flask and top to the mark. An aliquot of 10 ml was taken into distillation tube and was neutralized with 10 ml of 40% of NaOH. The solution was steam distilled in a conical flask containing 5 ml of boric acid and mixed indicator developing a green colour. The distillate received was titrated using 0.1/140 HCl till the end point transiting from green to pink. To obtain the amount of total nitrogen present in rice plant tissue, the following formula was applied:

$$\%TN = \frac{Vol \times 0.1 \times vol \text{ of digest}}{1000 \times sw \times al} \times 100 \dots \dots \dots \text{equation 1}$$

Where:

Vol: volume used in titration, 0.1: molarity of titrant, sw: sample weight of the sample, al: aliquot from the digested sample

Total phosphorus was determined through wet acid digestion and quantified using molybdenum colorimetric method. 0.3 g from the grounded sample was weighed into the Kjeldahl tube. The tubes were heated after adding 2.5 ml of digestion mixture and subsequently added 3 ml of hydrogen peroxide in sequence and further heated until the solution became clear. The digested solution was cooled and diluted with deionized water and top to the mark of a 50 ml volumetric flask. A mixture of 2 ml pipetted from the sample solution and 5 ml of ascorbic acid was left to stand for an hour for colour development. The spectrophotometer at 880 nm was used to measure the absorbance which were used to calculate the concentration. The formula below was used to calculate the total phosphorus in the tissue:

$$TP = \frac{C \times vol \times DF}{sw} \dots \dots \dots \text{equation 2}$$

TP: Total phosphorus, C: The concentration of phosphorus in sample, Vol: Total Volume after topping to the mark, DF: Dilution factor

Data Analysis

Data was tested for normality with Shapiro Wilk test. ANOVA was conducted by use of R. software version 4.4.4 and general linear model (GLM) technique. Pearson’s correlation was used to analyze the correlation between growth and nutrient uptake to give the insights into how treatments affected rice seedling growth and chlorophyll content. The treatments mean was compared using Fisher’s Least Significant Difference (LSD) at $P \leq 0.05$ level of significance.

RESULTS

Effects of Substrates on Percent Emergence and Rice Seedling Height

The substrates have significance difference on emergence of seedling at 14 days after sowing. The highest percent emergence is 94.4% for 50% soil and 50% biochar (S50B50%) then 100% biochar (S0B100). The least percent emergence was 81.6% recorded at 100% paddy soil (S100B0) Table 1.

There was significance difference on plant height at different growing period (days after sowing) among substrates. At seven days after sowing, the tallest plant of 1.9 cm was measured from the substrate composition of 100% soil and 0% biochar (S100B0) while the shortest was 1.5 cm from 0% soil and 100% biochar (S0B100). At 14 and 21 days after sowing, 100% soil and 0% biochar (S100B0) still maintained taller plants as 0% soil and 100% biochar (S0B100) recorded the shortest. The tallest plant at 35 days after sowing was recorded from the combination of 75% soil and 25% biochar with average plant height of 4.6 cm followed by 50% soil and 50% biochar with 4.4 cm and the shortest was 3.3 cm recorded from 0% soil and 100 biochar Table 1.

Table 1: Effects of Substrates on Percentage Emergence and Rice Seedling Height

Treatments	Percentage Emergence (%)		Seedling Height (cm)			
	7 Days After Sowing	14 Days After Sowing	14 Days After Sowing	21 Days After Sowing	28 Days After Sowing	35 Days After Sowing
S0B100	56.5a	93.7a	1.5c	2.4d	2.7c	3.3c
S25B75	64.0a	91.6a	1.7b	2.8bc	3.2b	4.0b
S50B50	65.5a	94.3a	1.8ab	2.8bc	3.3b	4.4b
S75B25	66.7a	93.2a	1.8ab	3.1a	3.7a	4.9a
S100B0	73.3a	81.6b	1.9a	3.0ab	3.3b	4.3b

Means followed by the same letter in the same column show no significant difference, S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar

Effects of Substrates on Biomass Weight of Rice Seedling

There was no significant difference between the tested substrates on biomass weight of rice seedling. Notwithstanding, 75% soil and 25% biochar (S75B25) performed better recording 3.72 g while the lowest was 3.05 recorded at 0% soil and 100% biochar (S0B1000) Figure 1.

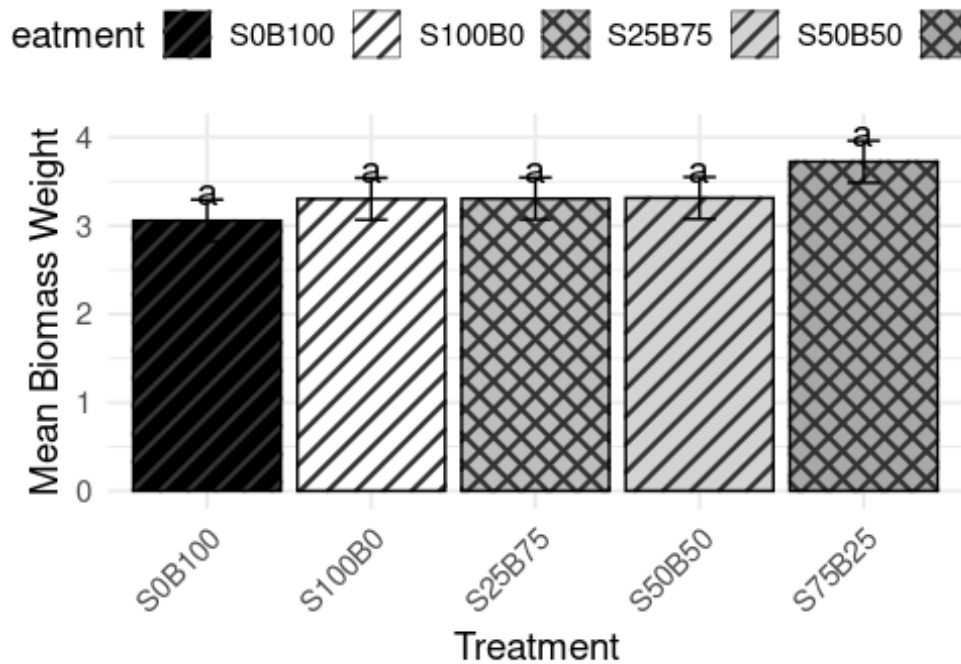


Figure 1: Effects of Substrates on Biomass Weight of Seedling

S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar

Effects of Substrates on Total Nitrogen in Tissue of Rice Seedlings

Tested substrates are significantly different in terms of total nitrogen content in seedling tissue.

The highest total nitrogen is 5.2% recorded in substrate 100% soil and 0% biochar(S100B0) then 25% soil and 75% biochar (S25B75) that produced 5.1%. The lowest total nitrogen was recorded from the combination of 50% soil and 50% biochar (S50B50%) Figure 2.

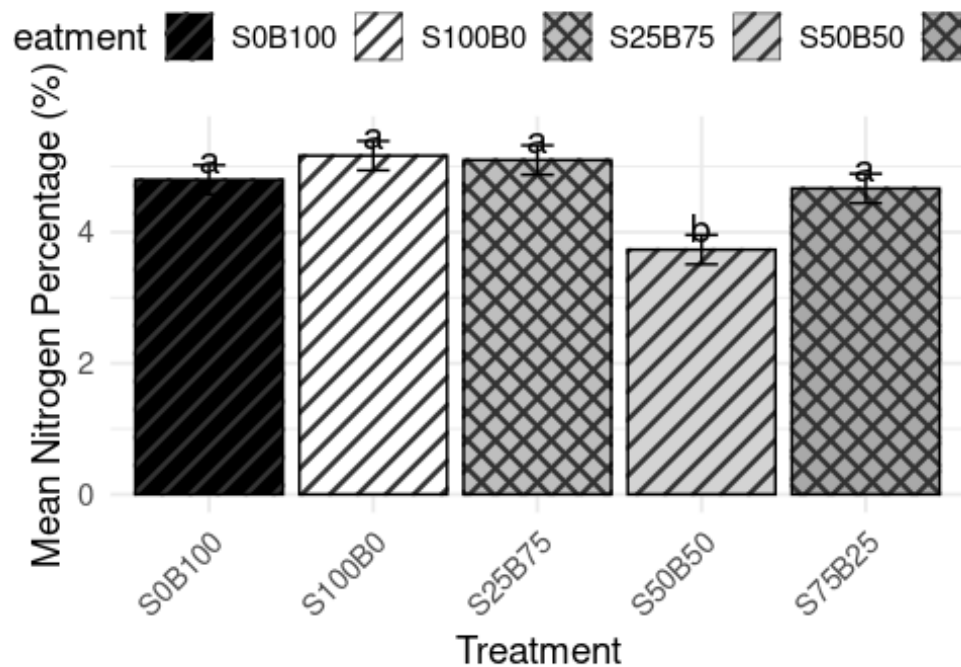


Figure 2: Effects of Substrates on Total Nitrogen in Seedling Tissue

S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar

Effects of Substrates on Total Phosphorus in Tissue of Rice Seedling

The substrates significantly affected total phosphorus available in the seedling tissues. The highest phosphorus content 0.48% was recorded from substrate composed of 0% soil and 100% biochar (S0B100) followed by 25% soil and 75% biochar (S25B75). The lowest was 0.32% recorded from 75% soil and 25% biochar (S75B25) and 50% of soil and 50% biochar (S50B50) Figure 3.

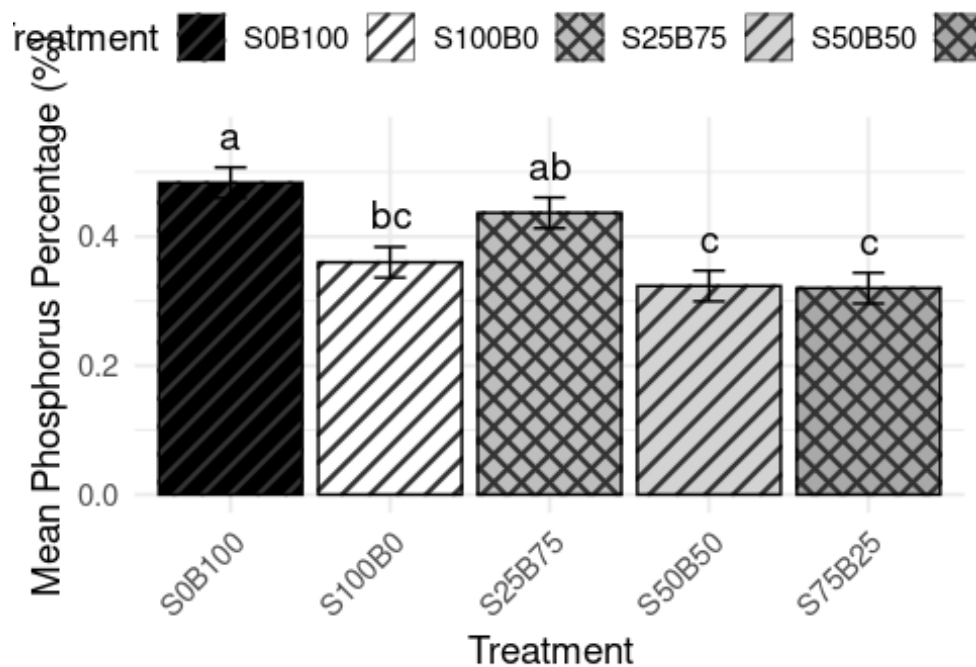


Figure 3: Effects of Substrates on Total Phosphorus in Seedling Tissue

S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar

Effects of Substrates on Chlorophyll Content (SPAD) in Rice Seedlings

The substrates showed significant effect on chlorophyll content in rice seedlings. From 14 days after sowing, the highest soil plant analysis development (SPAD) was 25.0 recorded at 75% soil and 25% biochar (S75B25). The lowest SPAD was 19.1 recorded at 0% soil and 100% biochar (S0B100) which showed low SPAD throughout the time of experiment. In general, SPAD tends to decrease at after 28 days after sowing across all treatments Table 3.

Table 3: Effects of Substrates on Chlorophyll Content (SPAD) in Rice Seedlings

Treatments	14 Days After Sowing	21 Days After Sowing	28 Days After Sowing	35 Days After Sowing
S0B100	19.1c	18.6c	18.8d	18.7b
S25B75	19.5bc	24.7b	20.3c	20.3a
S50B50	20.9b	26.5ab	20.9bc	20.0a
S75B25	25.0a	25.3b	21.8ab	19.6a
S100B0	20.1bc	28.4a	22.8a	20.4a

Means followed by the same letter in the same column show no significant difference, S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar.

Effects of Substrates on Number of Leaves in Rice Seedlings

There was significant difference on number of leaves among the substrates throughout the time of experiment. All treatments at 14 days after sowing produced two leaves except from the combination of 0% soil and 100% biochar (S0B100) that produced only one leaf. From 14 to 35 days after sowing, number of leaves increased by time for all substrates including negative control though the substrates showed significant difference compared to the control but among themselves there was no difference as presented in table 4 below.

Table 4: Effects of Substrates on Number of Leaves in Rice Seedlings

Treatments	14 Days After Sowing	21 Days After Sowing	28 Days After Sowing	35 Days After Sowing
S0B100	1b	3a	3b	4b
S25B75	2a	3a	4a	5a
S50B50	2a	3a	4a	4b
S75B25	2a	3a	4a	5a
S100B0	2a	3a	4a	5a

Means followed by the same letter in the same column show no significant difference S0= 0% soil; S25= 25% soil; S50= 50% soil; S75= 75% soil; S100= 100% soil; B0= 0% biochar; B25= 25% biochar; B50= 50% biochar; B75%= 75% biochar and B100= 100% biochar

Correlation of growth parameters and tissue nutrients at 35 days after sowing

Emergence showed weak positive correlation of 0.12 and 0.18 for plant height and phosphorus respectively. Leaf number, nitrogen, spaad and biomass weight were weakly negatively correlated with emergence with coefficient of correlation of -0.521, -0.37, -0.44 and -0.33 respective of the above stated parameters. Plant height was positively correlated with spaad and biomass weight with coefficient of correlation 0.57 and 0.45 respectively, while it was negatively correlated with tissue phosphorus. Leaf number was positively correlated with biomass with 0.48 coefficient of correlation. Tissue nitrogen was positively correlated with SPAAD and biomass with coefficient of correlation 0.52 and 0.13 respectively as shown in table 5.

Table 5: Correlation of growth parameters and tissue nutrients at 35 days after sowing

	Emergence	Plant Height	Leaf no	Nitrogen	Phosphorus	SPAD	Biomass
Emergence	1.0	0.12	-0.51	-0.37	0.18	-0.44	-0.33
Plant Height		1.0	0.02	0.04	-0.64	0.57	0.45
Leaf no			1.0	0.25	-0.11	0.32	0.48
Nitrogen				1.0	0.13	0.52	0.13
Phosphorus					1.0	-0.33	-0.23
SPAD						1.0	0.32
Biomass							1.0

DISCUSSIONS

The substrate combination of paddy soil with biochar and biochar alone showed significant different compared to the substrate composed of only paddy soil. Biochar is known to its capacity to improve soil physical and chemical properties which help in facilitating seed germination due to reduction of bulk density and increase porosity that results in improved emergence and growth in general (ZHOU Jin-song1, 2016). Paddy soil which is clay in texture is prone to compaction which can cause water logging when water is in excess and this can affect seed emergence. (XiaoLi et al., 2020) reported that application of biochar increased the content of seed germination promoting hormone (indole-3-acetic acid) and reduced seed dormant induction hormone (abscisic acid) content. This could explain the results obtained from this experiment.

The substrates affected seedling growth (plant height) significantly with tallest plant produced at the combination of 75% soil and 25% biochar, 100% soil and 0% biochar. Soil has readily available nutrients that a crop can use immediately and promote early growth without biochar combination of any rate. Pure soil or when mixed with biochar in low amount, have good water moisture retention (Hashim et al., 2024). Several studies such as : (Hashim et al., 2024; Otsuka et al., 2023) reported that biochar applied at high proportions can make medium drier as water drains too quickly and may stay locked inside pores and became inaccessible to roots. They also found out that soil pH is closer to preference of seedling which can be disturbed by biochar by raising it beyond optimal levels thus reduce nutrient solubility and limits seedling growth.

Seedlings harvested from substrate with higher proportion of soil have high content of nitrogen compared to the seedlings grown in substrate with high proportion of biochar. Most soil has organic matter as well as native nitrogen in terms of ammonium, nitrate and amino compounds which can be mineralized by soil microbes into plant available nitrogen which seedlings can absorb immediately (Abukari et al., 2018). Several researchers like: (Rasse et al., 2022; Selvarajh et al., 2021) conducted their studies on nutrients availability to plants when apply biochar as soil amendment, they found out that biochar can initially stimulate microbes to immobilize available nitrogen. Fresh biochar can also adsorb ammonium that cause a temporary nitrogen drawdown. This could be the reason why the seedlings grown on substrate of higher percentage of biochar are lower in tissue nitrogen.

Tissue phosphorus was higher in substrate with high proportion of biochar compared to soil. Paddy soil is high in clay content and has iron (Fe) and aluminium (Al) oxide and can bind phosphorus to Fe/ Al oxide compounds and strongly fix it. In this case, available phosphorus to seedlings becomes low even when total phosphorus in soil is high and this reduces its uptake in substrate where soil is dominant (Hou et al., 2022). On the other hand, biochar contains ash which is rich in phosphorus, potassium, calcium and magnesium. Biochar reduce P fixation due to its alkaline property which reduce Fe/Al by neutralizing acidity and make phosphorus available to seedlings (Luo et al., 2024). There was a varying strengths and directions of the relationship among growth parameters and tissue nutrients as it was revealed by correlation analysis. Early seedling emergence has slight influence on subsequent plant growth and nutrient uptake especially phosphorus, this could be the reason of the weak correlation from the study (Drescher et al., 2020). Emergence was negatively correlated with almost other parameters: leaf number, tissue nitrogen, SPAAD and biomass weight. Higher emergence rate can result in competition among seedlings instead of translating into greater vegetative growth and nutrient accumulation, higher densities limit individual plant performance (Otsuka et al., 2023). The positive association of plant height, SPAAD and biomass weight is an indication of vigorous shoot elongation in enhancing chlorophyll content and overall growth of seedlings, this is supported by a study conducted by Gholizadeh et

al.(2017) that revealed that nitrogen application at different growing stage enhanced vegetative growth and increased the chlorophyll content in rice.

CONCLUSIONS

1. The substrate with 100% of biochar improved emergence of rice seedling
2. The substrate with 75% soil and 25% biochar (S75B25) performed well in plant growth and yield (plant height and biomass yield).
3. The substrate with high proportion of soil (S100B0) recorded the highest nitrogen content in tissue of seedlings and the trend was the same for soil plant analysis development (SPAD).
4. S0B100 produced seedlings with high percentage of tissue phosphorus.

RECOMMENDATIONS

1. It is better for farmers to integrate at least 25% biochar in their nursery beds to improve rice seedlings growth and development
2. It is recommended for farmers in a low phosphorus soil to add biochar to the nursery bed to enhance phosphorus availability and uptake
3. Further researches are recommended to study the effects of those substrates on the entire life cycle of rice (seedlings, vegetative growth and yield).
4. Studies on biochar from different feed stocks like bean waste, wheat straw and woody materials can be tested

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