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INTERACTION EFFECT OF NPK FERTILIZER AND RICE HUSK BIOCHAR ON GROWTH AND YIELD OF PADDY RICE IN AHERO, KENYA

[1,2,]*Anthony AC Mendy, [2]Erick Cheruiyot and [2]Samuel Mwonga

[1]Ministry of Agriculture, Livestock and Food Security, Department of Agriculture, Cape Point, Bakau, The Gambia.

[2]Department of Crops, Horticulture and Soils, Egerton University, P.O. Box 536-20115 Egerton, Kenya.

*Corresponding Author

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ABSTRACT

Rice (*Oryza sativa L.*) is the third most preferred cereal, after maize and wheat in Kenya. Continuous monocropping in Ahero paddy rice fields without fertilizer application and soil amendment reduces yield. This study determined the effects of combining NPK fertilizer and rice husk biochar on the growth and yield of paddy rice. The treatments were rice husk biochar B0, B5, B10, and B15 (t ha^{-1}) and NPK (F0, F100, F200, and F300 (kg ha^{-1}). The study was conducted between May 2024 and January 2025 over two seasons. Three-replications in split-plot Randomized Complete Block Design (RCBD) was used. Tiller number, above-ground biomass, plant height, 1000-grain weight, and yield were measured. ANOVA was performed using R software version 4.4.2, and Fisher's LSD employed to differentiate the mean at $p<0.05$. NPK and biochar combination increased rice tillering by 53%–85%. Above-ground biomass increased by 47.1%–130.6% over control. NPK at 200 kg ha^{-1} and biochar 15 t ha^{-1} increased 1000-grain weight from 11.6% to 12.1% and grain yield 69.2% over the control. However, biochar and NPK fertilizer above 200 kg ha^{-1} tends to lower grain yield and weight. The results imply that Ahero paddy rice production may be managed well with moderate NPK and biochar rates.

Keywords: NPK biochar interaction, NPK Fertilizer, Paddy Rice, Rice Husk Biochar

INTRODUCTION

Rice, (*Oryza sativa L.*) is ranked second as the most consumed food crop after wheat, and is a staple food for over 3.5 billion people globally (Spengler *et al.,* 2021). Rice thrives in various soil types, from loamy sand to heavy clay loams and clays. It can be cultivated in soils with pH ranging

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Volume: 11, Issue: 04 "July-August 2025"

from 5 to 9. Africa is faced with a significant rice production deficit, meeting only 60% of its needs due to limited production systems, abiotic and biotic factors, and low agricultural investment (Zenna et al., 2017). Tsujimoto et al. (2019) assert that rice cultivation in Sub-Saharan Africa has numerous problems, including socio-economic and biophysical constraints, insufficient fertilizer application, and low soil fertility, which are the primary contributors to declining rice yields. Application of fertilizer is a challenge to local farmers in Kenya especially in Ahero due to limited access, high cost and profitability towards rice production (Onyango, 2014).This has made rice production by small-holder farmers in Ahero a big challenge since their production has not hit its full potential. Paddy rice production in Ahero paddy farmers' fields face challenges due to deteriorating soil properties, mono-cropping, high cost of NPK fertilizer, continuous flooding reducing oxygen level and inefficiencies in production technologies (Prasad et al., 2017). NPK and straight fertilizer like urea are nutrient sources in rice production which are used for basal and top dress respectively (Shrestha et al., 2020). High chemical fertilizer (NPK) resulted to grain quality deterioration and leaching thus reduced grain yield and environmental pollution (Zhou et al., 2020). However, its combination with biochar as soil amendments is sustainable and can increase yield compared to chemical fertilizers alone (Moe *et al*., 2019). Biochar is a porous carbonaceous material produced through the pyrolysis of plant biomass known for its ability to enhance soil health. Biochar can be produced from agricultural waste such as, rice husk, maize cobs, peanut shell, forestry wastes and other organic waste materials (Chen *et al.,* 2021). Ahero produce a lot of rice and the main wastes from rice harvest are rice husk and straw. Rice husk in the milling plants are abundant and never utilized, causing a threat to environmental health (Rosado et al., 2021). Therefore, its conversion into biochar can be used by the smallholder farmers who cannot afford NPK fertilizer in their rice fields. Rice husk biochar unlike other organic fertilizer is rich in carbon and is not easily broken down. It has the ability to increase grain yield through its physiochemical properties. It improves soil drainage, aeration, nutrient and water retention, microbial activity, disease control, carbon sink, and pH (Adebajo et al., 2022; Conte et al., 2021; Huang et al., 2019).

It is estimated that 50% to 70% of the total N applied is lost to the environment and account for 39% to 60% of global nitrous oxide (N_2O) emission from the soil (Iboko et al., 2023). Biochar with its porous structure could sustain the nutrient element in the soil besides neutralizing acidity and water retention for plants (Faloye et al., 2017). The objective of the study was to determine the effect of combining rice husk biochar and NPK fertilizer on growth and yield of paddy rice in Ahero, Kenya. Therefore, synergy between biochar and NPK seems to creates a more efficient, sustainable and productive farming system benefiting both the soil and the environment.

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

MATERIAL AND METHODS

Experimental Sites

The study consisted of field experiments and laboratory analysis. The field experiment was conducted at a farmer's field (latitude -0.179518 and longitude 34.974228) in Ahero, Muhoroni Sub-County, Kisumu County. The experimental site is at an altitude of 1,219 meters above sea level and has a mean annual temperature of 19.5ºC. It lies in the lower midland III agro- ecological zones and has an average annual rainfall of 1,550 mm bimodally distributed in two seasons, the long-rain season and the short rain season. Paddy rice production in Ahero corresponds to the two rain seasons of April to July and September to December. The water levels are low in mid-July and late December to February and require supplementary irrigation. The soils at the site are classified as vertisols (Jaetzold, R. (2010).

Research Materials

The rice variety used in the study is IR2793-80-1, a commercial variety preferred by farmers in the region and sourced from Ahero Irrigation Authority. Its main attributes include: high yields (6-7 t ha^{-1}), high tillering (20-25 tillers per plant), tall (80-85 cm high), matures in 120 days, has thin long grain, none aromatic and has high consumer preference. The genotype was tested for response to different rates of inorganic NPK (17:17:17) and rice husk biochar. The NPK fertilizer was commercially obtained from local agro-supplies while rice husk biochar was obtained from Safi Organic Limited, located in the rice growing area of Mwea, in central Kenya.

Experimental Design and Treatments

The experiment was laid out in split-plots in a Randomized Completely Block Design (RCBD) and replicated three times. The main plot factor was NPK (17:17:17) fertilizer while the sub-plot factor was rice husk biochar treatment. The four fertilizer treatments applied were: F0, F100, F200, and F300 (kg ha^{-1}), with each treatment receiving an additional nitrogen top dressing of 0, 40, 80, and 120 kg N ha^{-1}, respectively in split form, 75% at early and 25% at maximum tillering stage using urea (46% N). The biochar was applied at: B0, B5, B10, and B15 (t ha^{-1}). The sub-plot measured 3 m x 2 m with 6 rows and 14 stands of rice per row, giving a total of 84 stands per plot. The experiment was run for 2 seasons, in the April-July 2024 season and repeated in season 2 from September 2024 to January 2025.

Agronomic Practices

The land was ploughed using a mouldboard plough, then puddled manually. The field was divided into 3 main blocks of dimension 10 m x 9.5 m separated by 1 m borders. Each block was sub-divided into 4 main plots and 16 sub-plots each measuring 3 m x 2 m and separated with 0.5 m

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

wide by 0.3 m high dyke to manage water and minimize cross contamination of the treatments. Seedbed preparation and sowing were first done by manual puddling, and seedlings were transplanted 2 seedlings per stand after 21 days. The NPK fertilizer rates were applied as basal, 3 days after transplanting the rice seedlings. The plots were irrigated as required to maintain the water levels of 2 - 3 cm for the entire period between planting and maturity. Hand weeding by uprooting was done twice at 30 and 60 days after transplanting.

Data Collection

The growth and yield parameters measured included: tiller number, plant height, above ground biomass, 1000-grain weight, panicle-harvest index and grain yield. Tiller number was counted randomly from 8 hills at 60 days after transplanting. The above ground biomass was harvested from 3 randomly selected hills per plot at 50% heading. The plants samples were oven dried at 70ºC for 72 hours then dry weight was taken. A thousand grains (1000) were counted manually and weighed using an electronic balance. Panicle Harvest Index (PHI) was obtained from 8 randomly sampled panicles in each plot. Grain yield was taken from a 1 m^2 quadrat of 15 hills in the four middle rows in a plot, threshed and air dried to a constant weight. The panicles were dried and weighed, then threshed and grain weight taken. The PHI was calculated using the formula shown below (Fageria, 2010).

Panicle Harvest Index $= Grains\ Weight \div (Grains\ Weight + whole\ panicle)$… equation 1

Soil and Biochar Analysis

Composite soil samples of depth 0-15 cm were collected randomly from the experimental fields before planting for soil characterization analysis. A sample of the rice husk biochar used for the experiment was taken prior to application for analysis. The soil and biochar samples were analyzed for: pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium. The soil texture was also analyzed and biochar; pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium. The pH was determined using a 1:2.5 soil/biochar: water ratio using a pH meter. Organic carbon was measured using the Walkley-Black wet digestion method while total nitrogen was determined by the Kjedahl digestion method and the digest distilled into boric acid and titrated using HCl. Available Phosphorus was extracted using Mehlich III solution and determined through the molybdenum blue colorimetric procedure and the absorbance measured in a spectrometer set at 880nm. Exchangeable potassium was extracted using ammonium acetate (1N) and determined using a flame photometer. The soil particle size distribution was analyzed using the hydrometer method and the textural class determined using a textural triangle. All the analyses were done using standard methods as described in (Okalebo et al., 2002).

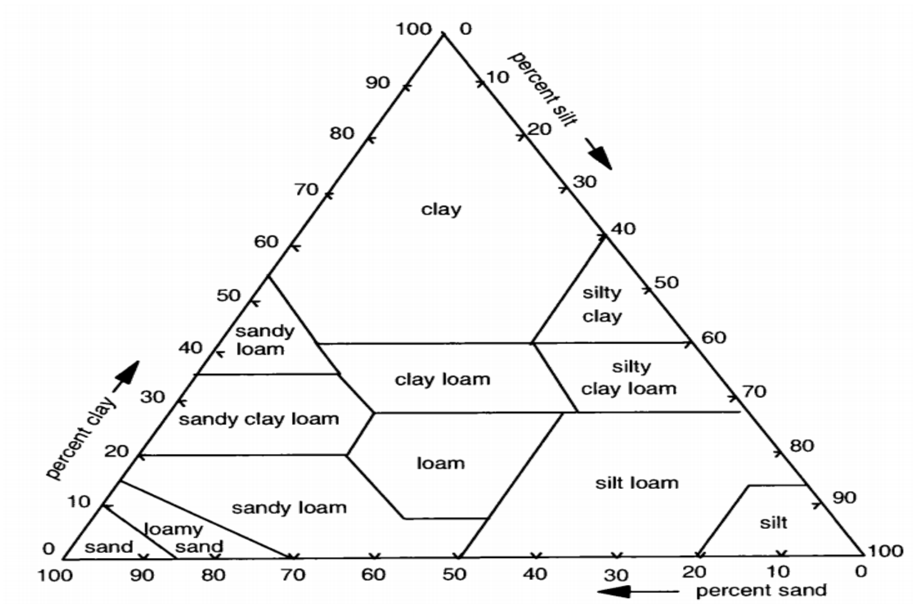

Figure 1: Soil textural triangle (Okalebo et al., 2002).

Statistical Analysis

All the data collected was analyzed using R statistical software 4.4.2 version (R Core Team, 2024). General linear model (GLM) technique was used to conduct analysis of variance (ANOVA). Mean separations were done using Fisher's least significance difference at $p \leq 0.05$.

RESULT

Physical and Chemical Properties of Rice Husk Biochar and Soil

The physical and chemical properties of soil in the experimental field and rice husk biochar (RHB) is presented on Table 1 below. The soil was acidic with a pH of 5.51. It has slightly higher organic carbon content of 1.01%, total nitrogen content of 0.25%, and available phosphorus 61.02 mg kg^{-1}. It has a fairly low available potassium of 7.9 mg kg^{-1}. The clay soil possessed a substantial surface area and a negative charge. Nonetheless, its high total porosity, attributed to the tiny particle size, holds water well, hence restricting air circulation and microbiological activity. The material possesses a cation exchange capacity of 32.6 meq/100g and a particle density of 2.47 g/cm^3.The individual percentage soil particle composition was dominated by clay, silt and sand of 77.8%, 16.4% and 8.4% respectively giving the textural class as clay soil.

Basically, plain rice husk biochar is highly alkaline with an average pH of 9.5 which is 75.3% higher compared to the one used for this experiment. It is rich in organic carbon content of about 50% and potassium of 52.7 mg kg^{-1} but generally low in nitrogen content. On the other hand,

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

available phosphorus depends on pyrolysis temperature and husk composition. The cation exchange capacity (CEC) is 30.7 meq/100g. This CEC level facilitates soil enhancement by improving the retention and exchange of cations such as K^+, Ca^{2+}, NH_4^+, and Mg^{2+}. Rice husk biochar exhibited a density of 0.7 g/cm³ and a porosity of 74.2%. The increased porosity and surface area allow biochar to absorb and retain soil nutrients, rendering them accessible to plants.

Table 1: Physical and Chemical Properties of Rice Husk Biochar and Soil

Property	Soil	Rice Husk Biochar (RHB)
pH	5.51	5.42
Organic Carbon (%)	1.01	31
Total Nitrogen (%)	0.24	0.13
Available Phosphorus (mg kg^{-1})	61.02	551.9.
Exchangeable Potassium (mg kg^{-1})	67.9	52.7
CEC (meq/100g)	32.6	30.7
Total Porosity (%)	40.1	74.2
Density (g/cm^3)	2.47	0.7
Clay (%)	77.8	N/A
Sand (%)	8.4	N/A
Silt (%)	16.4	N/A
Textural Class	Clay	N/A

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

Effects of Combining NPK Fertilizer and Biochar on the Growth of Paddy Rice

The results for the effects of combining NPK fertilizer and biochar on tiller number, above-ground biomass (ABG), and plant height are presented in Table 2. The treatment combinations affected tiller number in both seasons, above-ground biomass in season 2, and plant height in season 1. The highest NPK rate, 300 kg ha^{-1}, and various biochar rates, affected AGB and plant height in the second season. The application of 15 t ha^{-1} biochar and 300 kg NPK ha^{-1} resulted in a 53% increase in tiller count compared to the control, whereas the combination of 15 t ha^{-1} biochar with 100 kg NPK ha^{-1} produced a 10.2% higher tiller number than the application of 5 t ha^{-1} biochar and 100 kg NPK ha^{-1}, as observed in season 1.

Highest treatment combination at 15 t ha^{-1} biochar and 300 kg NPK ha^{-1} yielded 85% more tillers than the control in season 2. Nonetheless, at lower rate of NPK fertilizer, 100 kg ha^{-1} production of tillers increased as its combination with biochar increases as observed in both seasons.

The combination of Biochar with 200 and 300 kg ha^{-1}, except for the two highest levels of biochar in the treatment with 200 kg ha^{-1}, had significantly higher AGB than the control. The highest amounts of AGB were obtained when NPK was added without biochar, that is B0F200 and B0F300. The application of fertilizer with or without biochar increased plant height in season 1. In season 2 plant heights of treatment receiving more than 200 kg ha^{-1} fertilizer were significantly taller than those receiving 100 kg ha^{-1} or less which were the same as the control in both seasons.

Taller plants were observed in higher biochar and NPK treatment interactions B15F300 that were 18.4% and 13.5% taller than the control over both seasons, respectively. Combination of biochar rates and NPK fertilizer at the rate of 200 kg ha^{-1} limits plant growth as it produced shorter plants compared to B0F200. However, taller plants were produced as treatment combination rates increased over both seasons.

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

Table 2: Effect of Combining NPK and Rice Husk Biochar on Tiller Number, Biomass Weight, and Plant Height

Treatments	Season 1			Season 2		
	Tiller Number (60 DAT)	Above Ground Biomass (t ha^{-1})	Plant Height (cm)	Tiller Number (60DAT)	Above Ground Biomass (t ha^{-1})	Plant Height (cm)
B0F0	10.67h	5.20e	55.17h	9.0h	3.61h	56.04g
B5F0	11.33gh	5.94cde	57.25gh	9.03h	3.83h	56.17fg
B10F0	12.33fg	5.74de	56.58gh	10.33gh	3.71h	56.47efg
B15F0	12.67fg	6.78abcde	58.17fgh	11.33fg	4.18gh	56.83defg
B0F100	14.67cd	6.13cde	59.00efg	14.67abcde	5.34fg	56.79defg
B5F100	13.00ef	6.22bcde	59.25efg	13.33ef	5.75ef	57.58cdefg
B10F100	13.33def	6.68abcde	60.83cdef	13.67de	6.27cdef	59.17bcdefg
B15F100	14.33cde	6.88abcde	60.67cdef	14.0cde	6.19def	58.00bcdefg
B0F200	16.67b	8.23ab	63.17abc	14.67abcde	6.53cdef	60.21bc
B5F200	15.67bc	7.93abc	63.17abc	14.33bcde	6.58bcdef	59.29bcde
B10F200	14.33cde	7.06abcde	59.75defg	13.33ef	6.81bcde	58.59bcdefg
B15F200	15.33bc	7.15abcde	62.83abcd	14.0cde	7.34abcd	59.63bcd
B0F300	18.67a	8.40a	62.08bcde	16.33ab	7.97ab	59.50bcde
B5F300	14.33cde	7.70abcd	63.33abc	15.67abcd	7.25abcd	60.92ab
B10F300	14.67cd	7.65abcd	64.17ab	16.00abc	7.65abc	60.96ab
B15F300	16.33b	7.74abcd	65.33a	16.67a	8.30a	63.58a
CV	**5.80**	**17.59**	**3.11**	**9.86**	**13.77**	**3.10**
LSD	**1.40**	**2.03**	**3.18**	**2.25**	**1.41**	**3.07**

Means followed by the same letter in the same column within the NPK treatments and the Biochar treatments are not significantly different as per LSD test ($p<0.05$).

NPK rates: F0 = 0 kg ha^{-1}, F100 = 100 kg ha^{-1} F200 = 200 kg ha^{-1}, F300 = 300 kg ha^{-1}; For Biochar rates: B0 = 0 t ha^{-1}, B5 = 5 t ha^{-1}, B10 = 10 t $ha^{-1}$and B15 = 15 t ha^{-1}.

Effects of NPK Fertilizer and Biochar on Panicle Harvest Index, 1000-Grain Weight and Grain Yield of Paddy Rice

There was a significant interaction effect between the NPK and biochar application on the panicle harvest index (PHI), 1000-grain weight and grain yield (Table 3). In season 1, the application of NPK increased the PHI at the lower application rates of the biochar (0, and 5 t ha^{-1}) while no

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

change in PHI was observed at the higher rates of 10 and 15 t ha^{-1}. PHI tended to decrease or remain the same at the highest rate of NPK application of 300 kg ha^{-1} in both seasons.

The treatment interaction considerably increased grain weight. Higher NPK fertilizer rate at 200 kg ha^{-1} produced 6.56% higher grain weight compared to the combination of 15 t ha^{-1} 100 kg ha^{-1} in season 1 and 4.6% higher compared to the combination of 5 t ha^{-1} of biochar and 100 kg ha^{-1} of NPK in season 2. Combined application of biochar with NPK above 100 kg ha^{-1} resulted in weight loss compared to sole NPK fertilizer in both seasons. The application of biochar and NPK fertilizer at B5F200 produced the highest grain weight, 11.6% more than the control in season 2. Higher rate of rice husk biochar in both seasons at the rate of 15 t ha^{-1} reduces grain weight.

Combination of NPK fertilizer and biochar had a significant impact on grain yield over both seasons. Higher concentrations of NPK fertilizer without biochar increased grain yield by 36.6% and 48.2% in seasons 1 and 2, respectively, compared to where combination of biochar and NPK fertilizer was applied. Treatment combination at B15F200, B10F200 and B5F200 resulted in higher grain yield, surpassing the control by 69.2%, 64.3% and 64.3%, respectively, in season 1. However, B5F200 yielded twice as more grain in season 2 than the control. Application of biochar across all rates, in combination with 300 kg ha^{-1} of NPK fertilizer decreased grain yield compared to when combined with 200 kg ha^{-1} in both seasons. Nevertheless, lower NPK and biochar levels often produce uniform results, leading to a reduction of 0.1% when combined with increased biochar. Treatments with only biochar B5F0, B10F0, and B15F0 show comparable effects on grain yield across both seasons, but differed from the control.

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

Table 3: Effect of Combining NPK and Rice Husk Biochar on Panicle Harvest Index, 1000 Grain Weight and Grain Yield of Paddy Rice

Treatment	Season 1			Season 2		
	Panicle Harvest Index	1000 Grain Weight (g)	Grain Yield (t ha^{-1})	Panicle Harvest Index	1000 Grain Weight (g)	Grain Yield (t ha^{-1})
B0F0	0.32d	24.42f	3.25i	0.32f	23.68h	2.14i
B5F0	0.33d	26.27e	3.57h	0.34f	25.57efg	2.50hi
B10F0	0.43c	26.67cd	3.64h	0.36f	25.46fg	2.60hi
B15F0	0.44c	26.25e	3.69h	0.35f	25.49fg	2.56hi
B0F100	0.46bc	26.24e	4.55g	0.41e	25.40g	3.09gh
B5F100	0.45c	26.69cd	4.60fg	0.42de	25.69defg	3.69fg
B10F100	0.46bc	26.81c	5.19bcd	0.44bcde	25.85cdef	3.92ef
B15F100	0.45c	26.36de	5.18cd	0.43cde	25.65cdef	4.05def
B0F200	0.53a	28.09a	6.16a	0.50a	26.82a	5.47a
B5F200	0.45c	26.66cd	5.34bc	0.48ab	26.43ab	4.93abc
B10F200	0.47bc	26.70cd	5.34bc	0.46bcd	26.39ab	4.67bcd
B15F200	0.51ab	27.37b	5.60b	0.44bcde	26.23bc	4.37cde
B0F300	0.46bc	26.77c	5.16cde	0.47abc	26.26bc	5.17ab
B5F300	0.43c	26.49cde	4.97de	0.44bcde	26.06bcd	4.47cde
B10F300	0.45c	26.78c	4.86ef	0.45bcde	25.87cdef	4.63bcd
B15F300	0.47bc	26.47cde	4.52g	0.44bcde	25.94cde	4.52cde
CV	**6.66**	**0.85**	**3.86**	**6.50**	**1.01**	**9.77**
LSD	**0.05**	**0.38**	**0.31**	**0.05**	**0.44**	**0.65**

Means followed by the same letter in the same column within the NPK treatments and the Biochar treatments are not significantly different as per LSD test ($p<0.05$).
NPK rates: F0 = 0 kg ha^{-1}, F100 = 100 kg ha^{-1} F200 = 200 kg ha^{-1}, F300 = 300 kg ha^{-1}; For Biochar rates: B0 = 0 t ha^{-1}, B5 = 5 t ha^{-1}, B10 = 10 t $ha^{-1}$and B15 = 15 t ha^{-1}.

DISCUSSION

Effect of NPK Fertilizer and Rice Husk Biochar on Growth and Yield of Paddy Rice

The result has shown the significant influence of treatment combinations on tiller number, above-ground biomass, and plant height. This is related to chlorophyll content and net photosynthetic rate that converts carbon dioxide (CO_2) and water (H_2O) into glucose and Oxygen (O_2) and carbon gain, respectively (Baruah et al., 2016). The application of a high rate of rice husk biochar can enhance soil organic matter and water retention capacity, hence indirectly promoting plant growth,

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

including biomass accumulation, and plant height (Ali et al., 2020). Nonetheless, he further explained that its effects are dependent upon the breakdown rate, which is slow owing to its high lignin and silica concentration. The prompt release of nutrients may be inadequate if the breakdown process is slow, resulting in reduced plant development characteristics, such as biomass output, in comparison to NPK fertilizer (Gamage et al., 2022). Conversely, a high rate of NPK fertilizer directly provides key nutrients: nitrogen for vegetative growth, phosphorus for root development, and potassium for stress tolerance, resulting in increased biomass production when nutrient levels are sufficient. Excessive application may result in nutrient imbalance or leaching, adversely affecting biomass and plant height. This outcome was corroborated by additional studies indicating that rice plant growth characteristics are limiting upon nutrient availability, which is influenced by the gradual release from organic amendments such as rice husk biochar, effective over time, while chemical fertilizers supply nutrients with immediate effect (An et al., 2022a; Wu et al., 2021). A study by Akbar et al. (2024) on the effects of incorporating pine-woodchip biochar with reduced NPK fertilizer on calcareous soil characteristics, organic carbon, NPK availability, and maize productivity indicated that biochar amendment incorporated with NPK fertilizer increase plant growth and biomass production.

Panicle harvest index (PHI) responded positively to the combination of higher rates of biochar and NPK in both seasons. NPK fertilizer increases nutrient availability for reproductive growth, which increases the grain to biomass ratio. When combined with biochar improves nutrient uptake for better partitioning of assimilates to panicles, more soil water retention, root and microbial health, and thereby increase PHI. This is in conformity with the result reported by Wang et al. (2021) that PHI increases with targeted nutrient management especially the role of phosphorus in grain development that can have long term benefits like better soil health subsequently increasing PHI.

However, rice husk biochar application may not increase panicle harvest index in the short term due to slow nutrient availability, especially at lower rates, resulting in more allocation to the vegetative part, which causes an increase in biomass yield. This is in line with the study by Huang et al. (2019) who stated that application of biochar decrease PHI for the first three seasons as it may not inadequately maintain and synchronize the essential nutrient supply for optimal PHI due to the limited availability of plant-accessible nutrients and the prolonged period needed for mineralization to make nutrients available for efficient plant uptake.

The combination of rice husk biochar and NPK fertilizer considerably influenced the weight of 1000 grains. The application of rice husk biochar and NPK fertilizer above 100 kg ha^{-1} concurrently results in a decrease in grain weight. Adequate application of NPK fertilizer especially potassium improves grain filling which increases grain weight while excess nitrogen can delay maturity and reduce grain weight. Combination of NPK fertilizer and rice husk biochar can give sustainable optimal rice production. In a study conducted by Falahkar et al. (2023)

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

confirmed that combination of biochar and NPK fertilizer increases grain weight. However, a combination of plain rice husk biochar and NPK fertilizer at reduced rates improves grain filling and rice yield due to better nutrient use efficiency and nutrient synchronization, which depend on several factors, such as biochar properties, soil properties, and experimental conditions (Liu et al., 2022a).

Rice husk biochar and NPK fertilizer combination increased paddy rice grain yield. However, rice husk biochar combination with NPK fertilizer beyond 100 kg ha^{-1} seems to suppress grain yield. This is in agreement with the study done by Win et al. (2019) who reported that Single or combined application of biochar and NPK can adversely affect grain yield depending on the genotype (Win et al., 2019). However, in the short term, rice husk might not provide enough readily available nutrients resulting in low grain yield compared to NPK fertilizer. High NPK fertilizer rate promotes high grain due to better nutrient availability during key growth stages. However, the result shows that application of NPK fertilizer beyond 200 kg ha^{-1} reduced grain yield which is in line with Zhao et al. (2022c) who reported a 2.7-6.3% yield loss due to excess NPK fertilizer application due to prolong ripening, lodging or low grain filling. Balance NPK fertilization significantly increases grain yield while organic residues improve yield sustainability in the long run. This is supported by Rayhanul Hoque et al. (2025) who stated that combining biochar and NPK fertilizer provide optimum environment for crop growth thus increasing yield. Liu et al. (2021) further explained the long-term effect of biochar stating that it influences root development, root structure, soil characteristics, and nitrogen leaching to enhance the nitrogen fertilizer-use efficiency in rice cultivation.

CONCLUSIONS AND RECOMMENDATIONS

A synergistic effect was observed on growth and yield of paddy rice when biochar and NPK fertilizer was combined. Treatment combination at B15F200, B10F200, and B5F200 resulted in higher grain yield, surpassing the control by 69.2%, 64.3% and 64.3%, respectively. Therefore, the optimum application of NPK with biochar is at 200 kg ha^{-1}.

The result indicated that combining rice husk biochar with NPK fertilizer beyond 200 kg ha^{-1} in one planting season does not enhance grain yield or weight of 1000-grains. This suggests that optimal nutrient management is important and excessive fertilization combined with biochar may not improve crop performance. However, it is important to conduct further studies to evaluate the residual effects of biochar over multiple cropping cycles to assess sustainability and soil health benefits over time including cost benefit analysis.

ISSN: 2455-6939

Volume: 11, Issue: 04 "July-August 2025"

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