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Research Article

Effect of Biochar and Fertilizer Application on the Growth and Nutrient Accumulation of Rice and Vegetable in Two Contrast Soils

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Abstract

This study investigated the impact of Biochar and fertilizer, applied independently and simultaneously, on plant growth response and nutrient uptake from two contrasting tropical soils. One commonly cultivated winter vegetable (*Amaranthus lividus*) and a high yielding rice variety (BR-48) was grown on both the soils. Eight different treatments namely control, only fertilizer, three different biochars (farmyard manure, water hyacinth and domestic organic waste) with and without recommended fertilizer doses were used in the experiment. Soils with biochar treatments received 10 tons ha^{-1} of biochar. Results revealed that, Biochar treatments alone could enhance the yield of Data Shak 17 - 64% for Sara soil and 17 - 42% for Kalma compared to only fertilizer application. Farmyard manure biochar (FM) was most effective in case of Sara and Domestic organic waste biochar for Kalma. Synergistic effect of biochar and fertilizer was most prominent in terms of vegetable yield. Biochar and fertilizer applications had positive effects on N, P, K and S uptake however that varied with soil type. Farmyard manure Biochar significantly increased P uptake in vegetable and fertilizer application facilitated K intake at 1% significant level. Rice straw yield were significantly affected by fertilizer application. Synergistic effect of Biochar and fertilizer treatments increase the yield by 16 - 23% in Sara and 12 - 49% in Kalma compared to that of only fertilizer application. Only Biochar application sometimes caused reduction in yield, even from the control treatment. Effect of biochar and fertilizer treatments on macronutrient (N, P, S and K) uptake of rice plant was significant at 0.1% level at both the soils. Fertilized domestic organic waste biochar application facilitated highest N uptake in rice plants both in straw and grain. This highly significant uptake of nutrients could be due to the increased crop yield by biochar and fertilizer application together, which might be the best practice for tropical soils.

Keywords: Biochar; Fertilizer; Growth; Nutrient; Rice; Vegetables; Tropical Soils

Introduction

Application of organic matter in the soils has been undoubtedly credited for better soil health and plant growth response all over the world, particularly in the tropical soils having comparatively lower organic matter content. However, the stability of applied organic residues or compost highly varies with the soil it is applied on, molecular structure it has and the environmental and biological condition of the soil [1]. Acidic and highly weathered soils of tropical and sub-tropical regions are the place where favorable temperature and enhanced microbial activity restricts the stability of soil organic matter (SOM) [2]; which implies the need of a stable SOM form that could be sequestered in soil for substantially long period of time.

Biochar, a highly stable and recalcitrant form of organic matter produced by heating biomass in an oxygen limited condition and high temperature (pyrolysis) usually above 250°C [3] has been emerged as an option. Increased yield of crops has been reported by many studies [1-4] since biochar has been introduced as an agronomic tool. Biochars liming effect, high water holding capacity and capability to increase crop nutrient availability might be the main actors behind the positive effects. However, the idea of incorporating biochars in soil has an historical background. Modern day's objective to use biochar in soils are mainly for the carbon sequestration purpose. Biochar can effectively sequestered in soil for hundreds to thousands of years [3]. In addition it can mitigate the agricultural emission of greenhouse gases [5], can be an effective option for waste management and can efficiently amend problem soils [6]. However, the purpose of using biochar varies depending on the effects needed for a particular soil or country. A country's potential to efficiently produce and incorporate biochar in its agriculture system varies with its economy, soil types and other factors. Developing countries like Bangladesh would mainly focus on agronomic and environmental benefits of biochar application rather than its GHG mitigating potential [7].

Experimental results of biochar's effect on plant growth and crop yield are highly variable and depends on the setup of conducted experiment. Soil types, cultivated crops, biochar source and cultivation system are the main causes of this variability of biochar's effect on plant growth [4]. A statistical meta-analysis on the correlation of biochar and crop productivity has shown an average 10% increase [8]. The positive effects of biochar application were seen mainly in soils with acidic (14%) and neutral pH (13%), coarse (10%) and medium texture (13%). Biochar application rates and soil type have also been a significant factor of the variable crop yield. Application of higher rates of (4% w/w) high temperature (800°C) biochar significantly decreased corn biomass production for the first year in a sandy Ultisol, but not in a clayey Oxisol [9]. Lower rates of (1 - 2% w/w) low temperature biochar was appropriate for these soils. Among the biochar feedstocks considered for crop productivity, poultry litter exhibited the strongest positive effect (28%), contrary to biosolids and gasified wood, which had no to significant negative effect [4,10].

Biochar application showed differential results for rice and vegetable yield. Application of only biochar treatments reduced grain yield by 24.7% in spring and 17.9% in summer rice, however increased the vegetable yield [11]. Biochar showed varying positive effect on different water stress conditions as well. Plant height, biomass production and photosynthesis of rice were increased by residual effect of biochar (second year) at water stress conditions [12].

Differential results of fertilizer use efficiency after biochar incorporation were also reported. A pot study conducted to evaluate the effect of biochar and NPK fertilizer on Maize growth in various acidic red soil of china revealed that, biochar treatments increased biomass production, soil pH and availability of P, in contrast didn't affected the available N and CEC of the soils [2]. Contrasting results of Biochar increasing the N use efficiency are also repeatedly reported [13,14]. In some studies, part of the crop response was thoroughly attributed to the nutrient content of biochar itself. For instance, greater crop yield and nutrient uptake was seen in a 4-year field trial (77 - 320% more Ca and Mg) where biochar was applied [15]. Studies also revealed that co-application of biochar with fertilizers reduced the commercial fertilizer demand by 8 - 12% and saved 8 - 10% cost, indicating the potential of biochar compound fertilizers [14].

Furthermore, biochars might have differential effects on vegetative growth and crop yield or fruit quality. According to Vaccari., *et al*. [16] Biochar application had positive effect on soil fertility and stimulated growth of the tomato plant, however, didn't affected the tomato yield or quality. Some researchers have reported low crop yield by the negative effects of biochar on soil biota [17].

Therefore, as the effect of biochar on plant growth and nutrient uptake varies with soil and biochar type, crops to be grown, fertilizer application, cultivation system etc. the objective of the study is to investigate the synergistic effects of biochar and fertilizer on i) crop yield and nutrient uptake from two contrasting soils of Bangladesh and ii) a winter vegetable and a wet season rice and their differential cultivation systems.

Materials and Methods

Soil Sample Collection and Biochar production

The experiment was conducted with two contrasting tropical soils of Bangladesh. The first one was a calcareous fluvisol from Ganges river floodplain (Sara series) collected from Shreenagar Upozilla, under Munshigonj district, Bangladesh. The soil is poorly to moderately well drained, seasonally flooded, silty loam, slightly alkaline, and used as an agricultural land. The other soil (Kalma series) was collected from Shreenpur Upozilla of Gazipur, Bangladesh which belongs to Modhupur tract. This soil is at medium highland and well drained, acidic in nature and silty clay. Vegetables are usually grown; rice is also cultivated in the valleys of highland in wet seasons. Both soil samples were collected from top 15 cm by composite sampling method as described in Soil Survey Staff of USDA [18]. Biochar feedstocks were selected on their availability and keeping municipal organic waste management practice in mind. Farmyard manure, water hyacinth and domestic organic waste were selected for this study. Biochar production process and their agronomic parameters are described in Piash., *et al* [19].

Experimental setup

The pot experiment was consisted of eight different treatments for both the soils with 3 replicates each. The treatments were: 1. control (C), 2. Only fertilizer (F), 3. Farmyard manure Biochar (FM), 4. Water Hyacinth Biochar (WH), 5. Domestic Organic waste Biochar (DW), 6. Farmyard manure Biochar + Fertilizer (FM+F), 7.

Water Hyacinth Biochar + Fertilizer (WH+F), 8. Domestic Organic waste Biochar + Fertilizer (DW+F). Similar fertilizer doses were applied in both the soils as recommended in online fertilizer recommendation system of Soil Resources Development Institute [20].

Cultivated crops

Two plants were grown on each soil to have a holistic view of biochar effect on Bangladeshi cultivation pattern and different moisture conditions. Data shak (*Amaranthus lividus*) was grown to see the effect of biochar on winter season vegetable plants. Rice (BR 48; wet season) was also grown to determine the effect of biochar on rice dominated cultivation system of Bangladesh. Each pot received 4 kg of soil and adequate biochar at a rate of 10 ton ha^{-1} according to the treatment combination. After preparing the pots with necessary biochar and fertilizer treatments, those were left for about 15 days before further activities. Vegetable seeds were sowed on moist soils. Proper irrigation practice was followed throughout the period to maintain adequate moisture level. Rice seedlings of 25 days were collected from the Bangladesh Rice Research Institute (BRRI), those were then transplanted on pots in the net house. Each pot had 2 hills with 5 seedlings and 3 cm standing water was maintained from the beginning of this planting period upto next 60 days. Nitrogen fertilizer dose were applied in the rice pots in three installments as described in standard procedure. Adequate weeding, thinning and irrigation were done during the respective period.

Sampling and measurements

Vegetable plants were harvested at 60 days after sowing, uprooted vegetable plants were taken to the laboratory. Roots of the plants were removed. Plant height (cm), leaf length (cm) and Fresh-weight (g) were measured. After that, those were washed with distilled water and kept in oven at 65°C for 24 hours. Dry weight of the plants was then taken. Therefore, those were grinded with a grinder machine and sieved through a 2-mm sieve and stored in labeled plastic containers for further analysis. Rice plants were harvested at the ripening stage (90-days after planting). Both the rice grains and straws were harvested for further analysis. In the laboratory, fresh and dry weight was taken following the described procedure above. Paddy grains were analyzed for sterility, their weight and number of grains per panicle.

Plant and soil analysis

The above ground parts of vegetable, rice grain and rice straw were analyzed for total nutrient content determination. Total N content of plants and soils was determined by micro Kjeldahl's method following concentrated sulphuric acid (H_2SO_4) digestion [21]. Total P and S content was determined by spectrophotometric method and Total K and Ca was determined by flame photometric method [21]. Soil pH, Textural class, Moisture %, Plant available N, P, K, S etc. were determined by the standard methods as described in Huq and Alam [22]. Organic carbon content in the soils were analyzed by wet oxidation method [23].

Statistical analysis

The effect of biochar and fertilizer treatments was analyzed by one-way ANOVA test with the help of STATA version 14.0. Significant variations were further analyzed by Tukey pair-wise comparison test at 5% significance level.

Results and Discussion

The soils used in this study were analyzed in the laboratory for their physical, chemical and physicochemical properties. The results have been presented in the table 1.

Properties	Sara series	Kalma series
Textural Class	loam	Silty clay loam
Moisture (%)	24.10 ± 1.65	19.25 ± 1.28
pH	6.48 ± 0.1	5.48 ± 0.1
CEC (me/100g soil)	28.71 ± 1.58	30.08 ± 1.23
Total Organic C (%)	1.24 ± 0.15	0.80 ± 0.09
Total N (%)	0.2952 ± 0.02	0.2383 ± 0.02
Total P (%)	0.0378 ± 0.005	0.0191 ± 0.005
Total K (%)	0.2393 ± 0.01	0.0200 ± 0.01
Total S (%)	0.0234 ± 0.004	0.0174 ± 0.003
Total Na (%)	0.0701 ± 0.005	0.0742 ± 0.003
Available N (mg kg^{-1})	25.3 ± 1.2	17.3 ± 1.3
Available P (mg kg^{-1})	2.40 ± 0.1	1.90 ± 0.1
Available K (mg kg^{-1})	0.0527 ± 0.006	0.0202 ± 0.004
Available S (mg kg^{-1})	12.3 ± 1.1	11.2 ± 0.8
Total Ca (%)	0.172 ± 0.01	0.0216 ± 0.001
Total Mg (%)	0.8519 ± 0.02	0.1249 ± 0.02

Table 1: Physicochemical properties of soils.

The pH of kalma soil was considerably lower than Sara. It had lower organic carbon content compared to Sara and lower essential nutrient content as well. Sara soil had the loamy texture whereas Kalma was from the Silty clay loam class.

Effect of biochar and fertilizer on vegetable growth and nutrient uptake

The overall results show that the growth response of vegetable (Data Shak) was significantly better in Sara soil as expected considering the inherent nutrient content of it.

Application of different treatments in Sara and Kalma soil significantly ($p < 0.001$) improved the plant height (Figure 1 and 2). The average plant height grown in the untreated Sara soil (C) is the lowest with 17 cm whereas fertilized farmyard manure biochar treatment (FM+F) almost doubled the plant height (30 cm). Fertilizer application along with biochar improved plant height in most of the cases though it was not significantly ($P = 0.0596$) proven. In contrast, heights of plant are reasonably low in Kalma soil. Shortest plants (12 cm) were grown in Control soil while plant heights doubled after application of domestic organic waste biochar with adequate fertilizer dose. Biochar application (FM, DW) without fertilizer sometimes caused reduction in plant height than the only fertilized treatment. Effect of fertilizer on plant height was statistically ($p < 0.001$) proven in Kalma soil. Schulz and Glaser also found increased oat heights when biochar was applied with fertilizer in tropical condition [24].

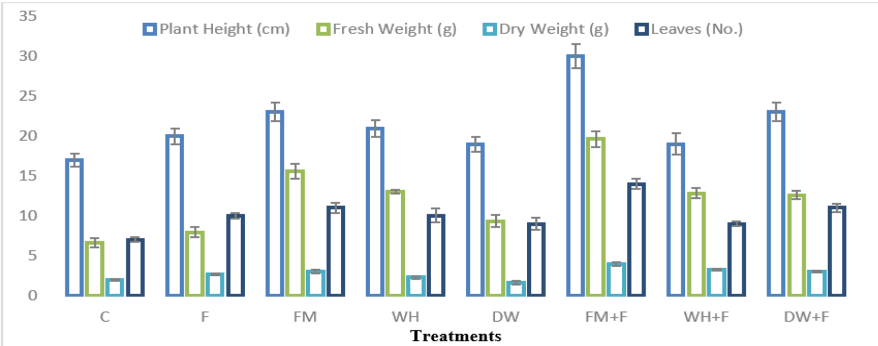

Figure 1: Growth response of Data Shak to biochar and fertilizer treatments in Sara soils.

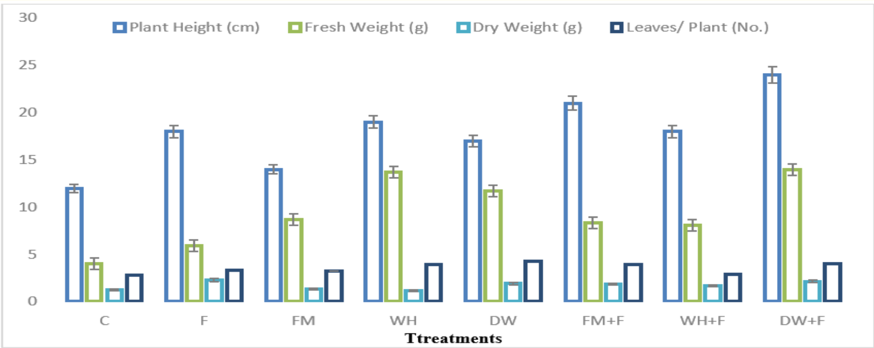

Figure 2: Growth response of Data Shak to biochar and fertilizer treatments in Kalma soils.

Average number of leaves per plant was also significantly ($p < 0.001$) affected by the biochar treatments in both the soils (Figure 1 and 2). However, Fertilizer application didn't prove to have significant effect on it. The maximum leaves were the product of FM+F and DW+F treatment in Sara and Kalma soil respectively. The fresh weight of three plants grown in each pot was measured and the results demonstrated significant effects of treatments applied in both the soils. The fertilized biochar treatments of Sara soil improved the fresh weight of Data Shak. Kalma soil didn't respond in similar manner to biochar and fertilizer treatments. The dry weight of the produced fresh biomass followed the same trend for both the soils as the weight loss from all the treatments followed a rational trend.

The yield of biomass (fresh weight) grown in the Sara soil was considerably higher than the other one. FM+F treatment in Sara soil produced 10.07 t ha^{-1} of Data Shak which is the highest in this soil whereas with 8.31 t ha^{-1}, fertilized domestic waste biochar yielded the maximum in Kalma soil (Figure 1 and 2). Similar trend of producing high yields by fertilized biochar application also supports the findings of Schulz and Glaser [24]. However, fertilizer application in combination with biochar didn't showed any significant effect in any of the soils. Farmyard manure biochar alone produced the second highest biomass in Sara soil, which implies the fact that high P content of this Biochar might have the growth promoting effect on Data Shak. In contrast, N and P enriched domestic waste derived biochar could have influenced the higher biomass production in Kalma soil. Results showed that biochar treatments increased Biomass yield at 0.01% significance level both in Sara and Kalma, A metadata analysis done by Biederman and Harpole [25] also confirmed biochars capability in increasing the above ground biomass in most of the experiments. Fertilizer didn't have any considerable effect Kalma soil as well; rather fertilized FM and WH treatment caused slightly reduced yields than their non-fertilized counter parts. Carter., *et al.* [26] also found a similar trend where they observed the growth of Lettuce and Cabbage and found increased growth of vegetables at non-fertilized biochar treatments rather than fertilized ones.

All the fertilized biochar treatments caused for lower N concentration in plants than their non-fertilized correspondents. A similar phenomenon was reported by O'Toole., *et al.* [27] while the applied wheat straw biochar with 4 rates of fertilizers. In contrast, total N uptake was significantly higher in fertilized biochar treatments as those increased the crop yield significantly (Table 2). In Sara soil, fertilized farmyard manure biochar treatment (FM+F) caused the maximum N uptake in plants (98.78 mg) whilst fertilized domestic waste biochar in Kalma (58.85 mg). Unlike Sara, FM+F treatment caused significantly lower amount of N uptake in Kalma soil.

The results of Nitrogen uptake by plants (Table 2) clearly disclose the fact that, biochar addition to soils doesn't always improve yield or nitrogen use efficiency, rather it needs a very sophisticated form of study like N- leveled fertilizer or biochar to completely understand the mechanism of N dynamics in biochar incorporated soils. Though we found increased N intake in biochar amended soils, most of the studies didn't experience any significant effect of biochar on plant tissue N content [25].

Results from table 2 show that, application of fertilizer with water hyacinth biochar increased P uptake in Data Shak at Sara soil than non-fertilized ones, however, not in Kalma soil. Farmyard manure biochar application with fertilizer proved to be the best treatment in Sara soil for P uptake (Table 2). The average P uptake in plants was significantly better in DW, FM+F and DW+F treatments of Kalma. This might be due to increase in soil pH after biochar application. Biederman and Harpole [25] found increase in soil P concentrations but not plant p uptake which they attributed to limited N availability that restricts the overall growth of plants.

Soils	Treatments	N	P	S	K
Sara series	C	43.96^{b}	1.07^{c}	1.52^{bc}	60.39^{a}
	F	65.91^{a}	3.36^{b}	2.51^{a}	112.98^{b}
	FM	83.08^{c}	4.31^{b}	1.25^{b}	159.53^{c}
	WH	62.88^{a}	2.55^{a}	0.73	116.91^{b}
	DW	38.48^{b}	2.04^{a}	1.62^{c}	70.76^{a}
	FM+F	98.78^{d}	6.08^{e}	2.53^{a}	248.92^{d}
	WH+F	79.14^{c}	4.91^{d}	2.79^{a}	206.72^{d}
	DW+F	65.93^{a}	3.99^{b}	3.11^{d}	178.20^{c}
Kalma series	C	16.97	0.63	0.65^{c}	54.12^{c}
	F	34.30^{bc}	1.99^{a}	0.85^{ad}	63.36^{ac}
	FM	30.59^{ab}	2.98	0.97^{ab}	69.83^{a}
	WH	28.20^{ad}	2.33^{a}	0.77^{cd}	70.81^{a}
	DW	36.48^{c}	3.51^{b}	1.22	108.87^{b}
	FM+F	24.79^{d}	3.44^{b}	0.96^{ab}	112.85^{b}
	WH+F	32.09^{abc}	1.99^{a}	1.01^{b}	111.72^{b}
	DW+F	58.85^{e}	3.59^{b}	1.41	141.24^{d}

Table 2: Effect of biochar and fertilizer on nutrient uptake (mg pot^{-1}) in Data Shak.

Fertilized DW+F treatment accounted for the best S uptake by Data Shak in both the soils. Rest of the treatments didn't show any significant trend in any of the soils. Fertilizer application increased K uptake in plants at 1% significance level for both the soils. Different biochar treatments demonstrated strong improvement ($p < 0.001$) in plant total K intake applied in Sara and Kalma soils. This might be due to biochars inherent high K content. Fertilized farmyard manure biochar proved to be the best treatment for Sara soils and fertilized domestic waste biochar for Kalma. The total K content in plants grown in Sara soil was considerably higher than Kalma soil. All the biochar treatments significantly improved K intake in plants (Table 2). Results also indicate that, biochar application can replace the need of K fertilizer application. The metadata analysis of Biederman and Harpole [25] revealed a similar fact that, Biochar can effectively increase K concentrations in plant tissue.

Results of this experiment overall supports the fact that, biochar application was effective to increase plant height, biomass production and uptake of macro nutrients in most of the cases. Carter., *et al.* [26] found increased final biomass, root biomass, plant height and number of leaves of Lettuce and Chinese cabbage after applying rice husk biochar. They also concluded that, this increase might slow down third year after initial application. The best vegetables were found after the application of fertilized biochar. Biochar treatments in combination with fertilizer have proved to reduce fertilizer need in earlier literature as well. Hamdani., *et al.* [28] reported highest (95%) recovery of fertilizers in wheat after application of 1% biochar in addition to 50% of the recommended fertilizer dose. Thus, biochar application with justified fertilizer dose might potentially reduce the cost of agricultural inputs.

Effect of biochar and fertilizer on rice growth and nutrient uptake

Both grain and straw yield was measured with other growth response parameters. Results have been demonstrated in the following figure 3 and 4. The results clearly indicate that, rice grown in Sara soil yielded better than Kalma and application of only biochar sometimes reduced the plant growth.

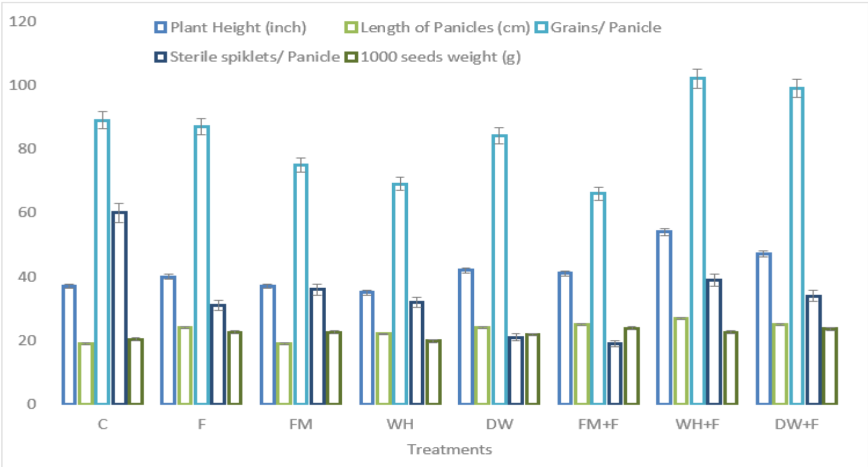

Figure 3: Rice growth response after biochar application in Sara soil.

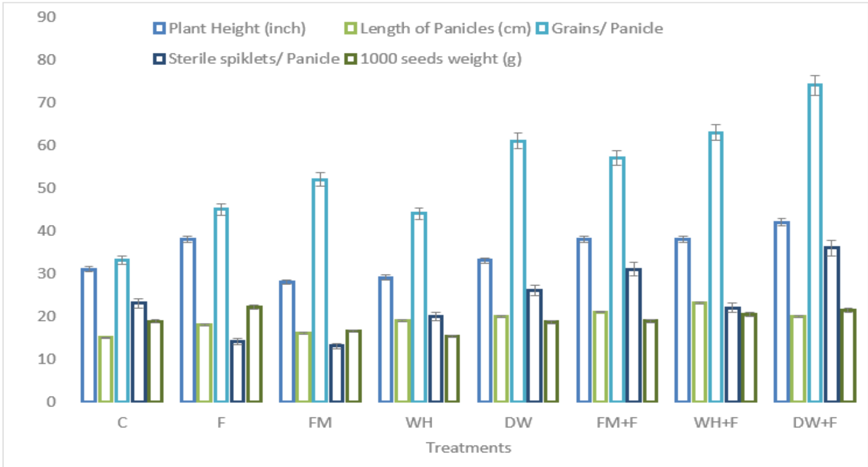

Figure 4: Rice growth response after biochar application in Kalma soil.

Height of the rice plants grown on Sara soil is affected both by the treatment and application of fertilizer at 0.1% significance level. The plant height of 54 inches grown by fertilized water hyacinth biochar (WH+F) treatment is better than any other treatment (Figure 3). In contrast, the lowest height of rice plant was the result of same biochar application without fertilizer. Domestic organic waste biochar treatments performed comparatively better than all others except the WH+F treatment. On Kalma soil, biochar treatments with fertilizer performed significantly ($p < 0.05$) better than all the other treatments except the only-fertilized treatment. The maximum height of 42 inches was the result of DW+F treatment. Only biochar treatments (FM, WH) might have reduced the nutrient availability for plants in soil as these treatments declined plant height even from the control.

Among the treatments applied on Sara soil, WH+F treatment caused the highest increase in panicle length while untreated soil caused the least. Application of fertilizer and domestic organic waste biochar produced the same average panicle length; the rest two non-fertilized biochar treatments (FM, DW) caused reduction in the panicle length. Effect of treatments were substantially ($p < 0.001$) proved in Sara soil. Treatments significantly ($p < 0.001$) increased the panicle lengths in rice grown on Kalma soil as well. Fertilized biochar treatments were significantly ($p < 0.01$) better in panicle enlargement than non-fertilized ones in Kalma soil.

Treatments significantly ($p < 0.001$) affected the grains produced par panicle in both Sara and Kalma soil (Figure 3 and 4). Effect of fertilizer was insignificant in Sara but significant ($p < 0.05$) in Kalma. Number of Sterile spikelets per panicle was found highest in control treatment in Sara but surprisingly it was DW+F for Kalma. In Sara, FM+F and DW treatments significantly reduced the number of sterile spikelets (Figure 3). In Kalma, only fertilizer and the FM treatment proved the best in reducing sterile spikelets (Figure 4). Fertilizer application didn't affect the no. of sterile spikelets among the treatments, however, treatments significantly ($p < 0.001$) did.

The results of 1000 seeds weight shows that, different treatments and the application of fertilizer had significant effect on rice yield on Sara soil at 1% significant level. At Kalma soil fertilizer application significantly ($p < 0.01$) increased yield but effect of treatments was more prominent ($p < 0.001$) on yielding rice. At Sara soil, treatment C and WH produced significantly lower yield than fertilized application of farmyard manure and domestic organic waste biochar. The rest of the treatments didn't significantly vary the rice production (Table 2). In contrast, the application of fertilizer, fertilized WH and DW produced significantly higher yields than rest of the treatments. Water hyacinth and farmyard manure biochar treatments (WH, FM) caused the lowest yield (5% level) rice in Kalma soil. A study conducted by Dong., et al. [29] oppose to the finding of this study, where they found sequential increase of rice yield with rice straw biochar without urea fertilizer.

Production of Straw increased significantly with fertilizer application on both the soils at 0.1% level of significance. In Sara soil, application of water hyacinth biochar caused the lowest yield of straw; however, incorporation of fertilizer with the same biochar produced maximum Straw of rice (Figure 5). Biochar application with fertilizer was significantly (5% level) better in Sara soil than all the treatments except domestic organic waste biochar alone (Figure 5). At Kalma soil, effect of different treatments on straw yield were highly significant ($p < 0.001$). Fertilizer application with domestic waste biochar was found to be the best treatment here (Figure 5).

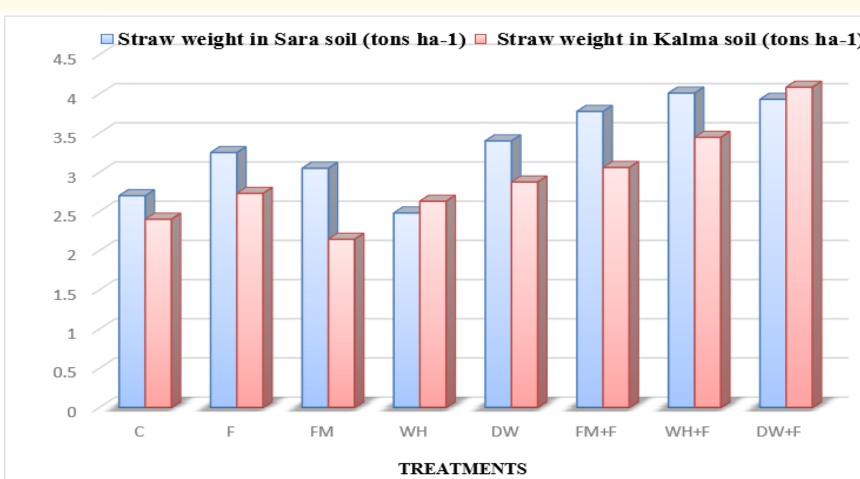

Figure 5: Yield of rice straw affected by different treatments.

Effect of biochar and fertilizer treatments on macronutrient (N, P, S and K) uptake of rice plant was significant at 0.1% level at both the soils (Table 3). The results of total nutrient uptake by rice plants is different compared to the nutrient concentrations in rice straw and grain of various treatments. In both the soils, fertilized domestic organic waste biochar application facilitated highest N uptake in rice plants (both straw and grain). In Sara soil, application of fertilizer alone or incorporation with any biochar resulted significantly ($p < 0.05$) superior N intake. However, in Kalma, fertilized treatments and domestic waste biochar treatment alone resulted substantial N uptake in plants. Dong., *et al*. [29] also reported higher retention of N in the paddy fields through subsequent growing seasons after Biochar application.

Soils	Treatments	N	P	S	K
Sara series	C	250.45^{b}	14.87^{a}	23.46^{b}	105.86^{a}
	F	446.71^{a}	23.54^{b}	28.11^{a}	148.15^{b}
	FM	345.15^{d}	28.71^{b}	25.22^{ab}	126.85^{ab}
	WH	290.30^{bc}	25.65^{b}	28.85^{ab}	115.52^{a}
	DW	306.20^{cd}	36.95^{c}	32.95^{c}	142.84^{b}
	FM+F	464.74^{a}	39.01^{c}	35.47^{cd}	229.97^{d}
	WH+F	423.18^{a}	45.60^{d}	37.93^{de}	202.84^{c}
	DW+F	469.18^{a}	34.11^{c}	41.60^{e}	191.67^{c}
Kalma series	C	185.74^{b}	16.42^{c}	18.46^{a}	85.96
	F	294.46^{a}	43.88^{e}	30.27^{c}	131.35^{bc}
	FM	225.86^{cd}	21.34^{ab}	18.19^{a}	112.24^{a}
	WH	191.88^{bc}	18.29^{ac}	21.75^{a}	119.63^{ac}
	DW	250.13^{de}	21.98^{ab}	26.16^{b}	142.10^{b}
	FM+F	272.06^{ae}	39.90^{e}	29.79^{bc}	107.24^{a}
	WH+F	309.74^{a}	26.79^{d}	35.70^{d}	145.38^{b}
	DW+F	365.67^{f}	24.24^{bd}	36.71^{d}	168.02^{d}

Table 3: Effect of biochar and fertilizer on nutrient uptake (mg pot^{-1}) of rice (straw+grain).

In terms of P uptake in plants, significant variations were seen in the soils. In Sara, fertilized water hyacinth biochar application proved to be the best treatment with 45.60 mg pot^{-1} P intake. Fertilized FM, DW and non-fertilized DW treatments showed comparatively superior effect on P content of rice plants (Table 3). A study of Liu., *et al.* [30] found increased availability of soil-P after rice straw biochar application. In contrast, application of only fertilizer and fertilized farmyard manure biochar resulted the best P uptake by plants in Kalma soil which might be due to the inherent P content of FM biochar. Rest of the treatments of Kalma soil caused comparatively very low P uptake in plants (ranging from 16 to 27 mg P per pot).

Fertilized water hyacinth and domestic organic waste biochar treatment was significantly effective in enhancing rice S content in both the soils. Among all the biochar treatments, farmyard manure biochar caused lowest S uptake in rice, regardless of fertilized or not (Table 3). On the contrary, domestic organic waste biochar application (with and without fertilizer) proved to facilitate highest sulfur uptake in both the soils (41.60 and 36.71 mg pot^{-1} respectively). These treatments are nearly double than the uptake in respective control treatments.

Potassium content in rice was found to be maximum in fertilized farmyard manure biochar treatment at Sara whereas fertilized domestic organic biochar for Kalma soil. Liu., *et al.* [30] also reported increased K in soil after rice straw biochar application The K uptake in rice didn't follow any specific trend though fertilizer application increased K intake significantly (except for FM+F treatment at Kalma soil). In general, both rice straws and grains intake lower amount of K in Kalma soils compared to Sara soils.

The results of rice growth and Nitrogen uptake of this experiment complies with the results found by Dong., *et al*. [29], where they reported enhanced rice productivity and N retention after the application of rice straw biochar in combination with Urea fertilizer. Higher N and K content in rice plants might be due to their retention in soil by biochar surfaces [31]. P, K and S uptake by rice plants varied significantly with the type of biochar application in fertilized conditions. Overall, biochar application in combination with recommended fertilizer dose maximized the biomass production and macro nutrient uptake as well.

Conclusion

The growth response parameters (plant height, no. of leaves, fresh weight, dry weight and biomass production) of Data Shak were found to be significantly affected by the biochar treatments. Application of fertilizer in addition to biochar treatments supported the best plant growth in both the soils. Fertilized farmyard manure biochar application resulted the best biomass production of Sara soil whereas fertilized domestic organic waste biochar for Kalma. Vegetable growth was considerably higher in Sara soil. Application of fertilizer reduced the total N content of the plants mostly than their nonfertilized counterparts. Phosphorus content was found considerably higher in plants grown by biochar treatments than the control. Farmyard manure biochar proved to be best for plant P uptake. Total S and K contents in Data Shak were significantly ($p < 0.001$) affected by the biochar treatments. Fertilizer application increased K uptake in plants at 1% significance level for both the soils.

The results of growth parameters of BR- 48 rice reveal that, biochar treatments significantly improved rice growth. Yield was found maximum in fertilized farmyard manure and domestic organic waste biochar application. In contrast application of water hyacinth biochar alone produced considerable low yield. Production of Straw increased significantly with fertilizer application on both the soils at 0.1% level. Straw N content increased considerably after fertilizer and fertilized domestic organic waste biochar application. In contrast, only biochar treatments (FM and DW) lowered the N uptake. Fertilizer application increased grain N content significantly ($p < 0.05$) but not the straw N content. Phosphorus, Sulfur and Potassium contents in rice straw and grain were affected significantly by the biochar and fertilizer treatments, but different biochar treatments had varying effects on nutrient uptake depending on the soil type.

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