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Impact of eucalyptus biochar application on growth, yield, nutrient uptake and some soil chemical properties of upland rice under pot condition

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ABSTRACT: The soil in Northeastern (NE) Thailand are generally sandy with low fertility, soil facing with nutrient leaching from chemical fertilizers added due to low nutrient holding capacity and the high risk of percolation. It was hypothesized that Eucalyptus biochar may increase soil fertility and plant growth. Thus, the objective of this study was to evaluate the effect isolate or combined application of eucalyptus biochar and NPK fertilizers on growth, yield, nutrient uptake and some soil chemical properties of upland rice grown in poor fertility sandy soil. Pot experiment was conducted under greenhouse condition. The experiment using a completely randomized designs (CRD) with 3 replications. There are 4 treatments i.e. (1) control (no biochar and NPK fertilizer), (2) biochar (0.055 g/ pot, (3) NPK fertilizer (15-15-15) at 1.38 g/ pot and (4) biochar (0.055 g/ pot) + NPK fertilizer (1.38 g/ pot). Urea fertilizer (46-0-0) at 0.277 g/ pot was applied at panicle initiation (PI) stage for all pots. Biochar combination with NPK treatment provided greater upland rice grain yield, harvest index (HI), total P and total K uptake. However, the effect of these combination was not found in root performance, but presented in the sole biochar treatment. In addition, the biochar combination with NPK treatment ameliorate soil organic matter and exchangeable Ca in upper soil depth. Thus, biochar combination with NPK treatment may a promising practice to improve soil fertility and productivity in upland rice.

Keywords: NH_4^+, NO_3^-, root performance, soil organic matter

Introduction

The soil in Northeastern (NE) Thailand are generally sandy with low fertility (Thawaro et al., 2017). In NE region, upland rice growing occur during rainy season (Butphu et al., 2020). In these conditions, soil facing with nutrient leaching from chemical fertilizers added due to low nutrient holding capacity and the high risk of percolation (Laird et al., 2010). Therefore, it was hypothesized that increasing soil organic matter contents through the incorporate with organic matters generally improves soil physical, and chemical properties and nutrient cycling in poor soil (Boer et al., 2007; Carpim et al., 2008).

Biochar has been used as a soil conditioner for enhancing soil physico-chemical properties and crop productivity in arid soil (Liu et al., 2013). Biochar is a carbon-rich solid product obtained by thermal decomposition of biomass (i.e., wood, leaves, manures) under partially or totally lack of oxygen (Beesley et al., 2011). Biochar incorporation to the soil, thereby enhanced carbon (C) sequestration (Luo and Gu, 2016), nutrient adsorption capacities and reduced soil nutrient losses (Knowles et al., 2011). Moreover, biochar application enhances soil pH, nutrient and water retention and reduces in greenhouse gas emission (Spokas et al., 2009; Nelissen et al., 2014). Eucalyptus biochar application in upland rice-sugarcane cropping system was announced approach which improve

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soil fertility and nutrient use efficiency (Butphu et al., 2020). However, the effect of eucalyptus biochar application on root part which the way to uptake nutrient still be a research gap.

Roots are concerned as major nutrients and water supplier from soil as well transporter of photosynthetically fixed C to soil (Peng et al., 2017). For example, the efficiency of plant nutrient accumulation and uptake are totally depended on root length, while the yield of biomass are relied on root volume and diameter (Eissenstat and Yanai, 1997). In biochar amendments soil, thereby root is a medium between biochar fragments and plants which may be related in total biomass and crop yields. Thus, root biomass of rice increased (Varela Milla et al., 2013) and reduced (Van De Voorde et al., 2014) in plant grown soil conjunction with biochar. Besides, there is root growth increased in soil combined application of biochar (Albuquerque et al., 2015).

The effect of biochar and combined with organic or inorganic fertilizers on soil biogeochemistry, crop yields and root traits have been reported in many studies (Prendergast-Miller et al., 2011; Brennan et al., 2014; Pandian et al., 2016). The responses of root traits may vary on types of biochar, pyrolysis temperatures, geographical features and agricultural management practices as fertilization application rates and combined amendments organic and inorganic materials. Eucalyptus biochar application is recommended for upland rice in NE (Butphu et al., 2020), however, the effect on upland rice root characters still be a gap. Therefore, the objective of this study was to evaluate the effect isolate or combined application of eucalyptus biochar and NPK fertilizers on growth, yield, nutrient uptake and some soil chemical properties of upland rice grown in poor fertility sandy soil. This knowledge may improve soil and upland productivity in NE area.

Materials and methods

1. Greenhouse experiment, Eucalyptus biochar and fertilizer application

Pot experiment was conducted in September to December, 2019 under the greenhouse condition, Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Thailand.

The biochar derived from Eucalyptus tree (*Eucalyptus camaldulensis*, Dehnh) under slow pyrolysis at 350°C with low oxygen for 3 days, cold down, and washed with water and air-dried for 4 days. This biochar contained total N (3.3 %), C/N ratio (217), P (987 mg/ kg), K (3538 mg/ kg) Ca (5 mg/ kg), pH 6.7, EC 0.3, CEC (26.4 cmol/ kg), volatile matter (32 %) and ash 3.3 followed by Butphu et al. (2020). The biochar was crushed and sieved by 2 mm sieve plate. The prepared eucalyptus biochar (sieved 2 mm) was used in this study.

The experiment was used completely randomized designs (CRD) with 3 replications, consisted of 4 treatments i.e. (1) control (no biochar and NPK fertilizer), (2) biochar (0.055 g/ pot), (3) NPK (15-15-15) fertilizer at recommend rate of Department of Agriculture, Thailand (1.38 g/ pot) and (4) biochar + NPK fertilizers. Twenty kg soil were filled in each bucket with 1.5 g/ cm^3 bulk density. The buckets having 23 cm height, 31 cm diameter at the top, 11.5 cm at the bottom and 13258 cm^3 volume, respectively. A freeboard space with 2 cm depth for water providing was left at the upper soil surface. All the containers consisted of four holes with 0.5 mm at the bottom. Fertilizer application rates were calculated based on dry weight of soil content.

2. Upland rice cultivation

Upland rice (*Oryza sativa* L., Siew Mae Jan variety) was planted at center of the bucket with 10 seeds per hill and thinned to 5 seedlings after 15 days planting date. The NPK fertilizer (15:15:15) 1.38 g/ pot based on Eucalyptus biochar (0.025 g/ pot) were incorporated at top layer (0-10 cm) of sandy soil before rice sowing in each pot. The urea fertilizer (46-0-0) 0.28 g/ pot was applied at panicle initiation (PI) stage all pots. Irrigation by observe first water drop from bucket holes to kept at field capacity one time per day.

3. Soil chemical analysis

3.1 Soil before experiment

Soil samples were collected for some chemical analysis i.e. pH, electrical conductivity (EC, cation exchange capacity (CEC), organic matter (OM), exchangeable K, exchangeable Ca, available were studied. Soil pH (1:1 H_2O) was analyzed by pH meter, while EC (1:2 H_2O)

determined by EC meter. The content of CEC in soil samples were observed using 1 M ammonium acetate extraction, while OM by following Walkley and Black (wet oxidation). The soil available P was analyzed by Bay II extraction and exchangeable K and Ca were determined after 1 M ammonium acetate extraction at pH 7 using flame photometer.

3.2 Soil during upland rice growth and at upland rice final harvest

Soil samples at soil depth 0-15 cm were collected to detect mineral N content (NH_4^+ and NO_3^-) between upland rice growth (30, 60, 90, 120 days after sowing). Fresh soil samples (20 kg) were extracted with 100 ml 0f 1 M KCl after sampling then mineral N content was analyzed by Flow Injection Analysis (FIA).

Soil samples were collected at soil depth (0-15 and 15-30 cm) for chemical analysis i.e. pH, EC, CEC, mineral N, total N, available P, exchangeable K, exchangeable calcium (Ca) and organic matter (OM) at upland rice final harvest (120 days after sowing).

4. Nutrient analysis in upland rice

At upland rice harvest, plant samples (straw and grain) were dried at 70°C for 40 hours then samples were crushed to analyze total nutrients content (N, P, K and Ca). The nutrient contents were determined by FIA (N), spectrophotometer (P), flame photometer (K and Ca) after Kjeldahl digestion (N) or wet oxidation (P, K and Ca).

5. Plant growth and yield parameters

Plant growth attributes such as plant high and root growth characters as root length, root area, root diameter were measured four times during upland rice growth at 30, 60, 90 and 120 days. Also LAI and SPAD were observed three times at 30, 60 and 90 days after upland rice planting. Yield attributes such as straw fresh and dry weigh, harvest index (HI) and 100 seed weight were measured at upland rice harvest (120 days). The data of LAI and SPAD of rice leaves were not obtained at upland rice harvest (120 days) due to the condition of ready to harvest. Altogether 12 buckets were used in each times of data collected days, one bucket contained five plants.

The plant samples were separated three parts as leaf, stalk, grain and root. Plant height measurement was done from soil profile level to the end of the top leaf. Upland rice leaves were cut out from the leaf collar to detect leaf area index (LAI), analyzed by LI-3100C AREA METER (LI-COR. Biosciences). Five expended rice leaves per hill were chose to measure leaf chlorophyll concentration using SPAD chlorophyll meter (SPAD- value; SPAD 502, KONICAMINOLTA. Inc., Tokyo) and mean values were recorded. Root samples were carefully washed with water on the sieve mesh (2mm) then clean root samples were transferred in transparent tray based distilled water then scanned by Photo Scanner (Epson PerfectionV700). The characteristics of root length, surface area and volume were analyzed using WinRHIZO Basic. Addition, rice leaves, stalk and roots were oven-dried at 70°C for 72 hours.

Panicles were collected from the five plants in each pot, placed in paper bags then labelled, left in oven to get constant weight at 70°C for 48 hours. Later, grains were separated from panicles then calculated for grain yield and 100-grain weight per pot. The harvest index (HI) of grain yield was calculated from grain yield of upland rice and straw yield (HI = grain yield / grain + straw yield) (Fageria et al., 2009).

Results and discussions

1. Soil before experiment

The soil texture and chemical properties before experiment show in **Table 1**. The soil texture was loamy sand and consisted of pH (6.47), EC (0.02 dS/ m), CEC (1.98 cmol/ kg), OM (0.38 %), exchangeable K (30.34 mg/ kg, exchangeable Ca (521 mg/ kg) and available P (2.5 mg/ kg), respectively. The soil was classified in poor fertility (Land Development Department, 2004).

Table 1 Some soil chemical and physical properties

Properties	
Soil texture: Loamy sand	
Soil pH	6.47
EC (dS/ m)	0.02
CEC (cmol/ kg)	1.98
OM (%)	0.38
Exchangeable K (mg/ kg)	30.34
Exchangeable Ca (mg/ kg)	521
Available P (mg/ kg)	2.5

2. Mineral N and upland rice root growth

Application of biochar, NPK fertilizer and biochar in conjunction with NPK fertilizer effect on soil mineral N (NH_4^+- N, NO_3^-- N) accumulation, total mineral N content and root parameters namely root length (RL), root surface area (RSA), and root volume (RV) and root dry weight (RDW) in 30, 60, 90 and 120 days after planting at 0-15 and 15-30 cm soil depth were presented in (**Table 2 and 3**). At 30 days after planting in 0-15 cm soil depth, biochar + NPK fertilizer treatment provided the highest total mineral N (15.92 mg/ kg) contents and NO_3^- (8.75 mg/ kg). in addition, biochar + NPK, biochar and NPK treatments significantly increased soil NH_4^+ content when compare with control.

At 60 days after planting, the high value of NH_4^+, NO_3^- and total mineral N contents at the rate of 5.25 mg/ kg, 5.25 mg/ kg and 10.50 mg/ kg were recorded in biochar + NPK treatment. At 90 days after planting, NH_4^+, NO_3^- and total mineral N content in soil were increased by biochar + NPK and NPK treatments. At 120 days after planting, at soil depth 0-15 cm, there was amount of $NH_4^+$and NO_3^- increased by biochar + NPK and NPK treatments, while total mineral N increased by biochar + NPK treatment. At soil depth 15-30 cm, biochar + NPK treatment induced nutrient availability of NH_4^+ and total mineral N.

The biochar + NPK treatment increased nutrient availability of NH_4^+, NO_3^- and total mineral N at 30, 60, 90 and 120 days and also NPK treatment enhanced the amount of NH_4^+, NO_3^- and total mineral N in plant grown soil (0-15 cm depth) at 90 days. This results may be related in nutrient absorption capacity of biochar particles from soils solution, which lead to reduce positive and negative ions species leaching through the increasing of soil pH and the negative charges of biochar porosity (Steiner et al., 2010). Zheng et al. (2013) found that biochar application increased NH_4^+ absorption and N immobilization.

The sole and combined biochar treatments were stimulated to increase RL, RS and RV (**Table 3**) between 60, 90 and 120 days after planting. This result may due to physical characters of biochar, which contain space for air and water circulation along with the surface areas, thus provide moisture and reduce bulk density, which in turn to activate roots distribution, and to find nutrients source in soil layers. Pratiwi and Shinogi (2016) found that soil amendment rice husk biochar 4% enhanced root area and root biomass than 2% addition. It had been noted that high rates of biochar application could be increased root length and biomass (Pandian et al., 2016).

Table 2 Mineral N and total mineral N of upland rice at 30, 60, 90 and 120 days after planting

Treatment	Mineral N (mg/ kg)		
(30 days) 0-15 cm	NH_4^+	NO_3^-	Total mineral N
Control	3.06b	2.45c	5.51c
Biochar	5.77a	5.77b	11.55b
NPK	5.95a	4.58b	10.53b
Biochar+NPK	7.17a	8.75a	15.92a
F-test	**	**	**
CV (%)	14.45	8.71	6.80
(60 days) 0-15 cm			
Control	4.37ab	4.72b	9.09b
Biochar	4.72ab	2.62b	7.35c
NPK	3.85c	2.62b	6.47c
Biochar+NPK	5.25a	4.72a	10.50a
F-test	**	**	**
CV (%)	9.81	8.90	6.11
(90 days) 0-15cm			
Control	1.22c	3.67b	4.89b
Biochar	3.50b	3.15b	6.65b
NPK	7.78a	6.12a	13.9a
Biochar+NPK	8.05a	5.07a	13.12a
F-test	**	**	**
CV (%)	13.10	9.31	7.82
(120 days) 0-15 cm			
Control	7.70b	1.57d	9.27c
Biochar	9.27ab	3.15b	14.17ab
NPK	10.15a	6.12a	12.95b
Biochar+NPK	10.96a	5.07a	15.22a
F-test	*	**	**
CV (%)	10.65	9.7	7.55
(120 days) 15-30 cm			
Control	3.50bc	0.71b	4.21bc
Biochar	3.21c	0.72b	3.93c
NPK	4.38ab	0.72b	5.10ab
Biochar+NPK	4.55a	0.77a	5.32a
F-test	*	**	*
CV (%)	14.03	1.63	11.89

NH_4^+: ammonium, NO_3^-: nitrate. Treatments: no biochar and no NPK fertilizer (control), biochar (0.055 g/ pot), NPK fertilizer (15:15:15) (1.38 g/ pot) and biochar (0.055 g/ pot) combine with NPK fertilizer (15:15:15) (1.38 g/ pot) (biochar + NPK fertilizer)

Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with $\alpha = 0.05$, ** = significantly different at $P \leq 0.01$ and * = significantly different at $P \leq 0.05$

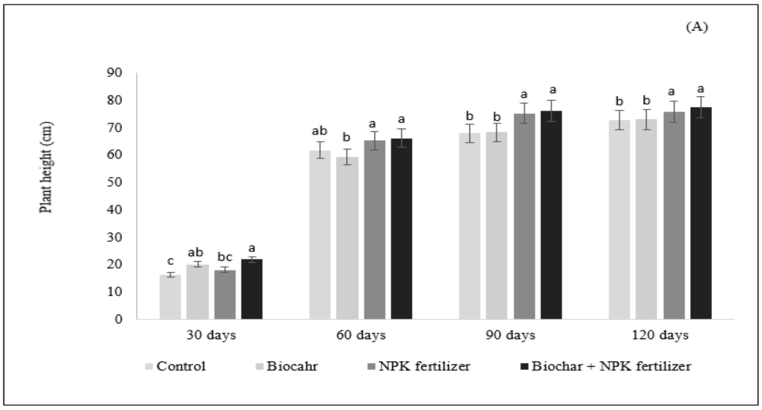
Table 3 Root characteristics of upland rice at 0-15 cm soil depth during 30, 60, 90 and 120 days after planting

Treatment (30 days)	Root length (cm)	Root surface area (cm^2)	Root volume (cm^3)	Root dry weight (g/ plant)
Control	734.02b	183.03b	2.65b	2.65ab
Biochar	997.69ab	205.64ab	3.23ab	2.17b
NPK	1184.00a	220.39a	3.98a	3.05a
Biochar+NPK	1127.5a	210.16ab	3.86a	2.19b
F-test	*	**	*	**
CV (%)	16.95	4.86	14.98	10.16
(60 days)				
Control	822.18b	174.98b	2.02d	1.45c
Biochar	1441.1a	306.54a	4.74a	1.89a
NPK	669.65b	146.29b	2.75b	1.05d
Biochar+NPK	659.84b	130.22b	2.16c	1.71b
F-test	**	**	**	**
CV (%)	19.56	21.10	0.58	4.69
(90 days)				
Control	1076.9b	233.32ab	2.89b	1.80
Biochar	1295.5a	259.98a	3.59ab	2.47
NPK	1197.3ab	237.90ab	3.72a	2.00
Biochar+NPK	471.46c	113.85b	2.91b	2.10
F-test	**	**	*	ns
CV (%)	7.02	21.99	11.73	13.56
(120 days)				
Control	1150.8b	207.64c	3.37c	2.71b
Biochar	1403.7a	273.50a	4.26a	3.67a
NPK	1079.6b	202.97c	3.08d	2.87b
Biochar+NPK	1158.3b	246.18b	3.88b	3.14ab
F-test	*	**	**	**
CV (%)	9.75	2.33	3.42	9.43

Treatments: no biochar and no NPK fertilizer (control), biochar (0.055 g/ pot), NPK fertilizer (15:15:15) (1.38 g/ pot) and biochar (0.055 g/ pot) combine with NPK fertilizer (15:15:15) (1.38 g/ pot) (biochar + NPK fertilizer)
Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with $\alpha = 0.05$, ** = significantly different at $P \leq 0.01$ and * = significantly different at $P \leq 0.05$, ns = not significant difference

3. Plant growth parameters

A variation of growth attributes i.e. plant height and LAI were examined between all treatments and along the upland rice growth duration (30, 60, 90 and 120 days) in **Figure 1**. The data of LAI was recorded for 30, 60 and 90 days. The tallest plants were obtained from the biochar + NPK treatment between 30, 60, 90 and 120 days as well biochar treatment increased plant height at 60, 90 and 120 days after planting. Plant height is drastically affected by nutrients. Despite added biochar, it did not provide more the height than NPK treatment. Ndaeyo et al. (2008) showed that application of 600 kg/ ha NPK (15:15:15) fertilizer enhanced some growth parameters of upland rice i.e., plant height, number of leaves and tiller per plant. Khan et al. (2013) recommended that the soil addition of biochar thus increased plant height. At 30 and 60 days after planting, the greatest value of LAI were recorded by biochar + NPK treatment but not significantly difference with NPK and biochar treatments. At 90 days after planting, the highest value of LAI (394.51 cm^3) was examined by biochar + NPK treatment but not significantly difference with NPK treatment. This was mainly due to positive effect of biochar as it could be induced enough amount of stored nutrients in soil through their physiology properties (Lehmann et al., 2009), which strongly attributes to plant nutrients content and also induce in photosynthesizing area via maximum absorption of soil mineral nutrients.



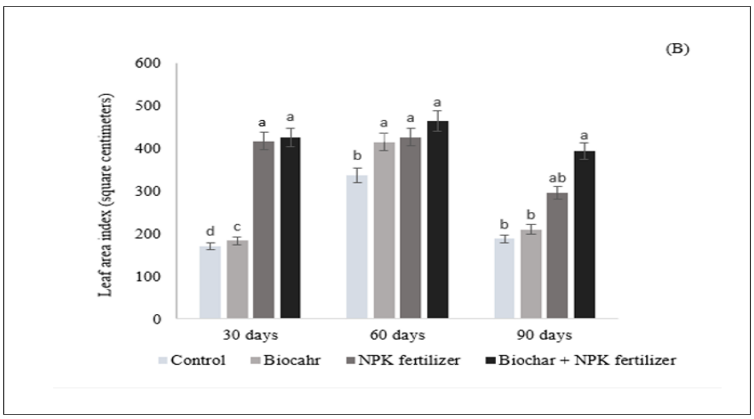


Figure 1 Plant height and leaf area index (LAI) at the final harvest of upland rice
Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with α = 0.05

4. Upland rice yield and nutrient uptake

At the upland rice harvest, the biochar + NPK fertilizer treatment provided the highest grain, straw yields and harvest index (HI) (**Table 4**). Moreover, such treatment gave the greater 100-grain weight but not significantly difference with sole biochar and NPK fertilizer treatments. These results major caused by nutrient holding capacity of biochar, which may result to increase nutrients assimilation in the producing organs via xylem pathway. Asai et al. (2008) examined that biochar 4 and 8 t/ ha with N fertilizer application induced grain yields caused by effect of the improved soil properties and N availability. Also overdoses of biochar (16 t/ ha) with N fertilizer application could be reduced grain yields due to N limitation. The combine application of eucalyptus biochar 6.2 Mg/ ha and mineral fertilizer that increased total dry matters of upland rice (Butphu et al., 2020).

Application of biochar in conjunction with NPK fertilizer was significantly induced grain yield than other treatments. Total P and K uptake were increased by biochar + NPK fertilizer, followed by NPK fertilizer treatment (**Table 5**). However, the NPK and biochar + NPK treatments were not significant in term of total N uptake. This results could be synergistic effect of biochar and available nutrients (NPK) fertilizer by combined application in acidic low fertile soil. Besides, biochar based soils which reduce nutrient leaching, its contain ions exchangeable sites (Chintala et al., 2014). Therefore, soil consisting of rich nutrients source, which in turn may increase plants' nutrient uptake and plant growth (Rondon et al., 2007). However, biochar combine with nutrient-rich chemical fertilizers thus may benefit in soil chemistry than sole application, especially in high water percolated sandy soil. Partey et al. (2014) approved that either co-application of biochar 5 t/ ha made from brich tree and crack willow tree and inorganic fertilizer (90 kg N/ ha, 60 kg P/ ha, and 60 kg K/ ha) or combined biochar and green manure application increased soil available N, P, and K also, increased maize yields for short term pot experiment in sandy-loam soil. Soil treated with NPK fertilizer (180 kg N/ ha, 105 kg P/ ha, and 120 kg K/ ha) significantly enhanced red rice plant nutrients uptake efficiency and grin yield than low rates application (Mansi and Wasli. 2019). However, the biochar + NPK and NPK treatments provided the highest total P uptake when compared to control and biochar treatments. Moreover, the higher total K uptake than other nutrients as N and P uptake were recorded in an aboveground upland rice biomass. Potassium is an essential cation for the reproductive organs of rice at grain filling stage. Panaullah et al. (2006) have reported that the majority of K uptake was in straw compared to grain.

Table 4 Grain yield, straw yield, total dry biomass, HI and 100-grain weight of upland rice at harvest

Treatment	Grain yield (g/ pot)	Straw yield (g/ pot)	Total dry biomass (g)	HI	100-grain weight (g/ pot)
Control	7.00c	7.43b	14.44b	0.48b	2.86b
Biochar	6.65c	6.77b	13.42b	0.49b	2.92ab
NPK	8.64b	7.65b	18.30a	0.47b	2.99a
Biochar+NPK	11.54 a	9.65a	19.19a	0.60a	2.99a
F-test	**	**	**	**	*
CV (%)	4.26	8.18	5.29	3.95	1.76

HI, harvest index

Treatments: no biochar and no NPK fertilizer (control), biochar (0.055 g/ pot), NPK fertilizer (15:15:15) (1.38 g/ pot) and biochar (0.055 g/ pot) combine with NPK fertilizer (15:15:15) (1.38 g/ pot) (biochar + NPK fertilizer). Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with $\alpha = 0.05$, ** = significantly different at $P \leq 0.01$ and * = significantly different at $P \leq 0.05$.

Table 5 Total N, P and K (g/ hill) in upland rice at the final harvest of upland rice

Treatment	Total N	Total P	Total K
		(g/ hill)	
Control	0.066	0.016b	0.340ab
Biochar	0.064	0.018b	0.300b
NPK	0.073	0.024a	0.399a
Biochar+NPK	0.073	0.027a	0.432a
F-test	ns	**	*
CV (%)	9.33	6.11	13.57

Treatments: no biochar and no NPK fertilizer (control), biochar (0.055 g/ pot), NPK fertilizer (15:15:15) (1.38 g/ pot) and biochar (0.055 g/ pot) combine with NPK fertilizer (15:15:15) (1.38 g/ pot) (biochar + NPK fertilizer)
Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with $\alpha = 0.05$, ** = significantly different at $P \leq 0.01$ and * = significantly different at $P \leq 0.05$

5. Some soil chemical properties at final harvest

At the upper soil depth (0-15 cm), the highest pH (7.68) was recorded in rice grown with biochar treatment, while the lowest value of pH 7.24 in NPK treatment (**Table 6**). Soil incorporated with biochar increased pH at the top soil layer (0-15 cm) in sandy soil due to the more surface of biochar which has negative charge of phenolic, carboxyl and hydroxyl groups that assist to reduce H^+ ion and turned to increase pH in soil solution (Lehmann et al., 2003). The soil pH significantly increased following biochar application in different soil types (Stewart et al., 2013; Farrell et al., 2013). There is soil pH increased at 3.9 to 5.1 in low fertile soil by input biochar (5%) produced from white lead trees (Jien and Wangl. 2013).

Moreover, the biochar + NPK treatment increase soil organic matter and exchangeable Ca when compared with the NPK treatment. However, the effect of treatment on soil organic matter and exchangeable Ca was not found at lower soil depth (15-30 cm). The biochar has the ability to increase pH-dependent charge that contribute to improve EC and CEC in soil (Liang et al., 2006; Van Zwieten et al., 2010), and nutrients maintaining capacity through the reducing of cations leaching via enhancing to bind on negatively exchange sites of OM (Curtin and Trolove, 2013). Application of either sole biochar treatment or in cooperate NPK fertilizer, increased total N in soil solution. The humic substances of biochar probably increased soil WHC (Atkinson et al., 2010), also reduced the immobilization of N in biochar amended soils.

Another possible reason is the porosity of biochar surface influenced soil nutrient retention (Prendergast-Miller et al., 2014). In addition, inorganic chemical fertilizer application may not effect to chemical properties in coarse texture soils due to its contain low nutrient holding capacity, as well high nitrification rates. To overcome this adverse conditions, mixed addition with biochar and chemical fertilizers which may enhance soil nutrients availability. Besides biochar improves soil moisture and nutrient retention, which in turns to retained P, Ca, S, and N (Mann, 2002) and reduced losses by leaching in the soil (Chan et al., 2007). Pine sawdust biochar (22 t/ ha) -mediated in two types of desert sandy soils, followed by application of 45% NPK (1:4:7) fertilizer, showed significantly increase in WHC by 11% and 14%, total C by 11% and 7%, K by 37% and 42%, P by 70% and 68% and Ca by 69% and 75%, respectively (Laghari et al., 2015). Therefore, soil treated with long term existing pyrolysis products as biochar, followed by incorporation with chemical fertilizers that may suitable to drawback nutrients in acidic low fertile soils or sandy soils, continuously thereby improve in crop productivity.

Table 6 pH, EC, CEC, OM, mineral N, total N, exchangeable K and Ca and available P at soil depth 0-15 and 15-30 cm at the final harvest of upland rice

Treatment (0-15 cm)	pH	CEC (cmol/ kg)	OM (%)	Total N (mg/ kg)	Exchangeable K (mg/ kg)	Exchangeable Ca (mg/ kg)	Available P (mg/ kg)
Control	7.50b	2.51ab	1.51b	5.25c	50.06	512.57b	11.69b
Biochar	7.68a	2.76a	1.56b	14.0a	56.93	515.83b	11.65b
NPK	7.24c	2.14b	1.53b	5.95c	53.66	512.57b	18.36a
Biochar+NPK	7.46b	2.74a	1.63a	9.54b	56.93	545.22a	17.88a
F-test	**	*	**	**	ns	**	**
CV (%)	0.98	8.96	1.42	12.62	9.04	1.43	7.51
Treatment (15-30 cm)	pH	CEC (cmol/ kg)	OM (%)	Total N (mg/ kg)	Exchangeable K (mg/ kg)	Exchangeable Ca (mg/ kg)	Available P (mg/ kg)
Control	7.37	2.53a	1.51	2.27c	45.15	512.57	10.45ab
Biochar	7.06	2.35a	1.51	6.65a	45.81	515.83	10.01b
NPK	7.39	1.57b	1.51	3.85b	48.42	499.51	10.62ab
Biochar+NPK	7.28	2.61a	1.52	6.47a	47.11	525.63	11.28a
F-test	ns	**	ns	**	ns	ns	**
CV (%)	3.39	10.91	0.74	12.62	8.06	2.34	3.48

Treatments: no biochar and no NPK fertilizer (control), biochar (0.055 g/ pot), NPK fertilizer (15:15:15) (1.38 g/ pot) and biochar (0.055 g/ pot) combine with NPK fertilizer (15:15:15) (1.38 g/ pot) (biochar + NPK fertilizer) Treatment results in a column followed by a common letter are not significantly different according to Least Significant Difference with $\alpha = 0.05$, ** = significantly different at $P \leq 0.01$ and * = significantly different at $P \leq 0.05$

Conclusion

Biochar combination with NPK treatment provided greater upland rice grain yield, HI, total P and total K uptake. However, the effect of these combination not found in root performance but presented in the sole biochar treatment. In addition, the biochar combination with NPK treatment ameliorate soil organic matter and exchangeable Ca in upper soil depth. Thus, biochar combination with NPK treatment may a promising practice to improve soil fertility and productivity in upland rice cropping system.

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