

Soil fertility status as influenced by the carryover effect of biochar and summer legumes

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Abstract

There are numerous benefits of biochar and summer legumes in the soil fertility status enhancement, so, keeping in consideration these benefits, a research study was designed to investigate the soil fertility status influence with the carryover effect of biochar and summer legumes at the UAP Research Farm, during winter 2016-2017. An experiment in the rotation was conducted in summer 2016 having three summer legumes for a specific purpose i.e. mungbean (grain), sesbania (green manuring), and cowpea (fodder), control was also comprised. Biochar synthesized domestically in a furnace from small wood cuttings on a pyrolysis temperature (400–500°C) and applied once to legumes @ 0, 5 and 10 tons ha⁻¹. When the legumes were harvested, the residues of sesbania remained in the soil, while the residues of the other two legumes were taken away. The test for soil fertility status investigation was performed on subsequent wheat in RCBD with three replicates on the previous field layout of legumes. Significantly maximum soil total nitrogen, extractable P, K, Fe, Zn, Mn were obtained in the plots previously incorporated with sesbania. However, Cu was not significantly affected. While, in the case of preceding biochar, maximum soil total nitrogen, extractable P, K, Cu, Fe, Zn, and Mn were obtained on 10 tons ha⁻¹. The biochar-legumes interaction was significant for macronutrients while non-significant for micronutrients. Thus, it is concluded that preceding legumes and previously applied biochar showed a significant carry-over effect on soil fertility status.

Keywords: Biochar, Summer legumes, Soil fertility status

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Introduction

Declining soil fertility due to extensive agricultural practices is one of the most serious problem and obstacle to meet the increasing need for food supply and maximum yield of crops. Land degradation

especially in terms of soil fertility/nutrients losses, severe climate change and food security problems indicating that the conventional farming system cannot be sustainable for the long-term (Gliessman, 2007). Problems related to soil degradation influencing round about 2 billion hectares soils across



the world with severe consequences on food security, ecosystems services, agro-ecosystems resilience and global climate change (Lal, 2009). So, with these problems, the main challenge now a days is the restoration, conservation and improvement of soil quality and fertility. So, now, among the agricultural research community the inclusion of biochar, legumes and other cover crops as a climate smart agricultural practices in the cropping system gaining a great interest as a sustainable strategy to increase the growth and yield of crops by improving soil properties and fertility which resultantly increased the yield of crop and its productivity (Yamato et al., 2006).

In the early past, biochar, a carbon rich solid material which is synthesized by the process of pyrolysis from different types of biomass in the absence of oxygen is gained attention to enhance the quality of soil. The physicochemical properties of the biochar affect the function of biochar after addition to the soil system (Lehmann and Joseph, 2009). The important physical characteristics of biochar are its high porosity, low biodegradability and also having high surface area which can easily affect the nutrient retention in the soil (Spokas et al., 2012), moreover it can increase the fertility of soil because of its low decomposition rate (Steiner et al., 2007).

Similarly, nitrogen fertilizer is also essential and have an important role in soil fertility improvement, growth & yield of crops (Ogola et al., 2002), however, the excessive nitrogenous fertilizers application have several agricultural & environment related problems like deterioration of soil health, yield decline, infiltration of NO_3^- to the ground water causing abnormalities in infants & also nitrous oxides & ammonia volatilization which are huge global warming agents (Katyal et al., 2001). Considering these issues, it is needed to abase dependence on synthetic nitrogenous fertilizers and to integrate the legumes in cropping system to fix the atmospheric nitrogen and make possible its supply easy for successful and fruitful crop production (Arif et al., 2014).

So, for this purpose, the combination of legumes (N source) and biochar (C source) will help in decreasing abundance on chemical nitrogen fertilizers and stimulate the legumes utilization, which is a good alternative for nitrogen supply to crops and hence getting higher production by balancing the C:N ratio. So, in the present research study, three summer legumes crops, sesbania, mungbean and cowpea were sown in summer 2016 for the specific purposes. A

fallow was adjusted in the experiment for the purpose of control. The rate of biochar addition was 0, 5 and 10 tons/ha.

Material and Methods

Experimental setup

An experiment was conducted to examine the soil fertility status under the carry over effect of biochar and summer legumes at the UAP, Research farm in winter 2016-2017. A field trial in rotation was conducted during summer 2016 having three legumes crops & grown for their specific purpose i.e. mungbean (grain), sesbania (green manuring), cowpea (fodder), and a control for comparison. Biochar prepared domestically in a furnaces from small wood cuttings with a pyrolysis temperature (400–500°C) and added once to summer legumes @ 0, 5 and 10 tons/ha. When the legumes was harvested, the residues of sesbania was remained in the soil and residues of the remaining legumes were eliminated. The field trial for soil fertility investigations was conducted on subsequent wheat in RCBD two factor factorial arrangement with three replicates on the previous field lay out of summer legumes. The size of the plot was 13.5m x 4.2m & Pir Sabaq-2013 was grown according to the recommended rate. Prior to start the work, the representative samples of the site have taken and measured for the selected soil fertility parameters as presented in table-1. Similarly, when wheat was harvested, soil samples in proper moisture condition were taken from every test unit and were analyzed for selected soil parameters like soil total nitrogen, extractable phosphorous, potassium, Cu, Fe, Zn, and Mn. All other agronomic practices were done according to the recommended procedures.

Factor A: Legumes grown in summer

Factor B: Biochar

1. Mungbean were added for food grain
 1. 0 tons ha^{-1} (control)
 2. Cowpea for forage
 2. 5 tons ha^{-1}
 3. Sesbania for green manuring
 3. 10 tons ha^{-1}
 4. Fallow (control)

Soil total nitrogen (%)

The measurement of total nitrogen in soil was done with the guidelines given by (Bremner, 1996).



AB-DTPA Extractable phosphorous (P), potassium (K), Zn, Cu, Mn and Fe ((mg/kg)

Extractable Phosphorous, potassium and micronutrients in soil was measured by the technique as illustrated by (Soltanpour and Schwab, 1977).

Statistical analysis

The data was carefully recorded and subjected to statistical analysis. Statistical tools used to analyse the data were described by Jan et al. (2009).

Results

The soil of the experimental site was alkaline in reaction, non-saline and low in soil nutrients content (phosphorous, total nitrogen and micronutrients).

Table 1. Soil nutrients status of the experimental site before sowing of summer Legumes.

Property	Units	Concentration
pH	-	7.67
ECe	dSm ⁻¹	0.14
Soil total nitrogen	%	0.017
Extractable P	mg/kg	4.21
K	--	112
Cu	--	2.27
Fe	--	3.82
Zn	--	0.51
Mn	--	3.33

Soil total nitrogen (%)

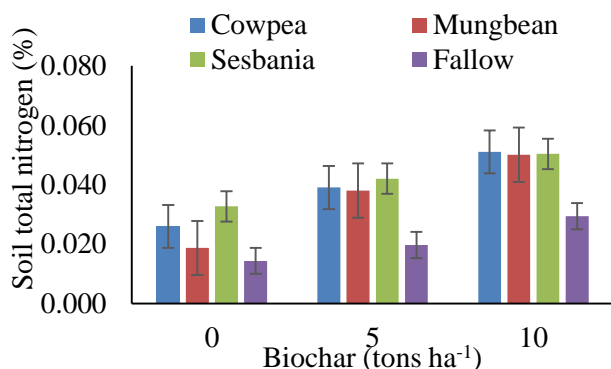


Fig 1. Soil total nitrogen (%) as affected by carry over effect of biochar application and summer legumes

As shown in table-2, figure-1, mean values of the soil total nitrogen (STN) after wheat harvest revealed that

previously grown legumes and biochar have significant effect on STN. The biochar-legumes interaction was also significant. The plots with sesbania incorporation had highest STN (0.042 %), followed by cowpea (0.039 %) and mungbean (0.036 %) which were statistically equal to each other, the lowest STN (0.021 %) was noted in fallow plots. In case of biochar, 10 tons/ha application rate increased STN (0.045 %) succeeded by 5 tons/ha (0.035 %), the lowest STN (0.023 %) was observed in control.

Soil phosphorous (mg/kg)

Statistics of the data concerning phosphorous (P) after wheat harvest presented in table-2, figure-2, revealed that P was significantly affected ($p \leq 0.05$) by both treatments. Moreover, the biochar-legumes interaction was also significant. The highest P (8.0 mg/kg) noted in the sesbania incorporated plots followed by cowpea (6.8 mg/kg) & mungbean (6.3 mg/kg), the lowest P (5.8 mg/kg) was noted in the fallow plots. The maximum P (8.4 mg/kg) obtained with biochar @ 10 tons/ha succeeded by 5 tons/ha (6.7 mg/kg), the lowest P (5.1 mg/kg) was noticed in control.

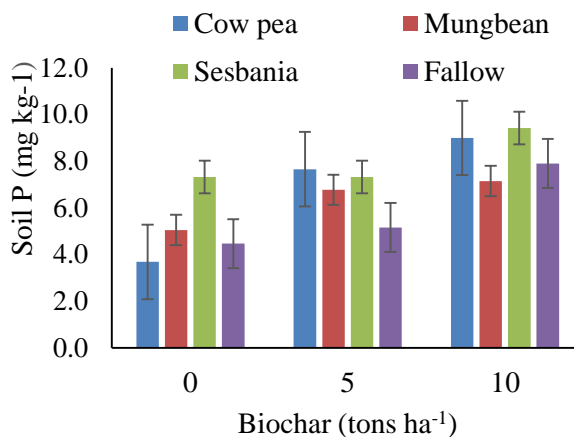


Fig 2. Soil P (mg/kg) content as affected by carry over effect of biochar application and summer legumes.

Soil potassium (mg/kg)

The data about potassium (K) after wheat harvest are given in table-2, figure-3. Mean values presented that the effect of both the treatments on soil K was significant. The interaction of biochar-legumes was also significant, but the K content was considerably affected by preceding legumes. The maximum K (118.5 mg/kg) obtained in the plots mixed with sesbania succeeded by cowpea (116.5 mg/kg) & mungbean (115.6 mg/kg). The lowest K of 107.7



mg/kg was noticed in the fallow. With biochar effect, the highest K of (119.8 mg/kg) was obtained in the 10 tons/ha plots, succeeded by 5 tons/ha (116.3 mg/kg), the lowest K (107.7 mg/kg) was obtained in the control.

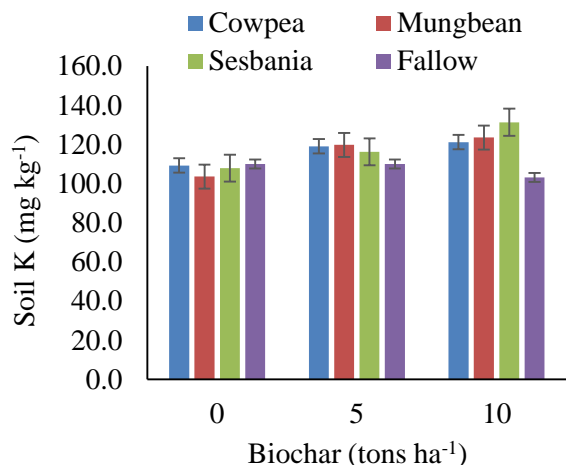


Fig 3. Soil K (mg/kg) content as affected by carry over effect of biochar application and summer legumes.

Table 2. Soil total nitrogen (%), extractible P and K (mg/kg) as affected by residual effect of biochar application and summer legumes

Legumes	Soil total N	Soil P	Soil K
Cowpea	0.039 ab	6.8 ab	116.5 a
Mungbean	0.036 b	6.3 b	115.6 a
Sesbania	0.042 a	8.0 a	118.5 a
Fallow	0.021 c	5.8 b	107.7 b
LSD (0.05)	0.003	1.076	6.497
Biochar (tons ha ⁻¹)			
0	0.023 c	5.1 c	107.7 b
5	0.035 b	6.7 b	116.3 a
10	0.045 a	8.4 a	119.8 a
LSD (0.05)	0.0030	0.932	5.626
Interaction			
L x B	*	*	*

Means followed by different letter(s) are significantly different at $P \leq 0.05$

Soil Zn (mg/kg)

Statistics of the data presented that previous legumes and biochar significantly influenced soil Zn content (table-3). The interaction of biochar-legumes was insignificant. Sesbania mixed plots recorded increased soil Zn (0.60 mg/kg) followed by cowpea (0.58 mg/kg) and mungbean (0.54 mg/kg), while the

minimum Zn (0.52 mg/kg) was noted in fallow, but the soil of experimental site under investigation was deficient in Zn content. The results were, however, inconsistent as no significant differences in soil Zn content were noticed between the legumes and fellow plots. Similarly, in case of biochar, 10 tons/ha application rate enhanced Zn (0.65 mg/kg) after wheat harvest followed by 5 tons/ha (0.56 mg/kg). The minimum Zn (0.47 mg/kg) was obtained in control.

Soil Mn content (mg/kg)

The data representing the means values of soil Mn are shown in table-3. The trends in statistical data showing that both previous biochar application and preceding legumes have significant effect on soil Mn. The biochar-legumes interaction was insignificant. The experimental units incorporated with sesbania noted maximum soil Mn (2.5 mg/kg) followed by cowpea (2.0 mg/kg) and mungbean (1.9 mg/kg), while the minimum Mn (1.7 mg/kg) was obtained in fallow, but all the treatments results were statistically in line with each other. In case of biochar, 10 tons/ha application rate increased soil Mn (2.6 mg/kg) succeeded by 5 tons /ha (2.0 mg/kg). The minimum soil Mn (1.5 mg/kg) was noted with 0 tons/ha biochar.

Soil Fe content (mg/kg)

The carry over influence of biochar and legumes on soil Fe are illustrated in table-3. Mean of the data presented that previous legumes and biochar have significant effect on soil Fe. The biochar-legumes interaction was insignificant. The plots incorporated with sesbania recorded maximum Fe content (9.6 mg/kg) followed by mungbean (mg/kg) and cowpea (8.7 mg/kg), while the minimum Fe (7.1 mg/kg) was obtained in the control. With biochar, 10 tons/ha application rate increased Fe content (10.6 mg/kg) after wheat harvest followed by 5 tons/ha (8.7 mg/kg), the lowest Fe (6.6 mg/kg) was obtained in the control.

Soil Cu content (mg/kg)

Mean values of soil Cu given in table-3 revealed that soil Cu was insignificantly influenced by legumes but biochar application significantly affected Cu. The interaction of both treatments was also non-significant. Although significantly non-different, the plots incorporated with sesbania recorded highest Cu content (2.0 mg/kg) succeeded by mungbean (1.8 mg/kg) & cowpea (1.7 mg/kg), while the minimum Cu content (1.6 mg/kg) was recorded in the plots



previously kept fallow. With biochar, 10 tons/ha application rate increased Cu (2.1 mg/kg) after wheat harvest followed by 5 tons/ha (1.7 mg/kg). The minimum Cu (1.5 mg/kg) was observed in the control.

Table-3: Soil Zn and Mn, Fe and Cu (mg/kg) as influenced by residual effect of biochar

Legumes	Soil Zn	Soil Mn	Soil Fe	Soil Cu
Cowpea	0.58 a	2.0 ab	8.7 b	1.7
Mungbean	0.54 b	1.9 b	9.1 ab	1.8
Sesbania	0.60 a	2.5 a	9.6 a	2.0
Fallow	0.52 b	1.7 b	7.1 c	1.6
LSD (0.05)	0.029	0.472	0.677	ns
Biochar (tons ha ⁻¹)				
0	0.47 c	1.5 c	6.6 c	1.5 b
5	0.56 b	2.0 b	8.7 b	1.7 b
10	0.65 a	2.6 a	10.6 a	2.1 a
LSD (0.05)	0.025	0.409	0.587	0.249
Interaction				
L x B	ns	ns	ns	ns

Means followed by different letter(s) are significantly different at $P \leq 0.05$

Discussion

The experimental results of the current research study indicated that soil fertility was significantly enhanced under the carry over effect of biochar and summer legumes. Biochar at rate of 10 tons/ha, while in case of legumes sesbania biomass showed a maximum significant carry over effect on selected soil fertility parameters. There are many possible reasons and mechanisms for the enhancement of soil fertility. Previously, Saraf and Patil, (1995) reported that incorporation and decomposition of green manuring legumes such as sesbania not only increased the yield of subsequent crop but also have a solubilizing effect on N, P and K. Our results are also in accordance with Jabbar et al. (2010) who reviewed that legumes crop when harvested leave a sufficient amount of nitrogen into the soil as residues. Similarly, Ghosh et al. (2007) reported that legumes play a very important role in solubilizing insoluble P in soil, enhancing the physical environment of soil, improving microbial activity in soil and restoring soil organic matter and also has smothering effect on weeds. Singh and Shivay, (2016) reported that the incorporation of sesbania aculeate residue supplied the maximum quantity of nutrients into the soil, that were comparably maximum than

other green manuring crops.

With respect to biochar investigation Ali et al. (2015) reported that soil total nitrogen, phosphorous and potassium was significantly enhanced by biochar application over two years study. During first and second years of experiment changes was observed in soil total nitrogen with respect to application rates, while, the P and K was increased irrespective of biochar rate. Similarly, Matsubara et al. (2002) reported that biochar has the capability to promote soil P availability by enhancing michorizal association in which phosphorous is made available by fungi. Olmo et al. (2016) stated that patches along with high biochar content revealed low micronutrients availability in soil. Ali et al. (2015) published that biochar significantly increased yield of wheat and soil fertility in two years study under wheat-maize-wheat cropping system. Comparably, Rahim et al. (2019) published that biochar and legumes have pleasant effect on the physical properties of soil.

Conclusion

The results of the current work showed that both previously applied biochar and preceding legumes showed a significant carry over effect on soil fertility status. Especially, biochar @ 10 tons/ha and legume “sesbania” had a strong carryover effect on the soil fertility status. The interaction of biochar and legumes was significant for macro while non-significant for micronutrients. Further detail research is needed on farmers’ fields at different locations and climatic zones in order to get more precise results.

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Contribution of Authors

Rahim HU: Designed and performed experiment and analyzed data and manuscript write up
Mian IA: Designed experiment and analyzed data
Arif M: Designed experiment
Ahmad S: Performed experiment
Khan Z: Performed experiment

