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Effect of integrated use of biochar and organic amendments on soil properties and crop yield

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Abstract

In recent years biochar is found to have positive influence on soil fertility, resulting in an increase in crop yield without affecting soil health and environment. Due to increasing interest towards biochar and organic farming, a field experiment was conducted to evaluate the effect of biochar with different sources of organic amendments on soil properties and yield of knolkhol (*Brassica oleracea* var. *gongyloides* L.). The experimental soil showed increase in organic carbon (3.1%), available nitrogen (12.38%), available phosphorus (24.19%), available potassium (8.54%) in treatment containing combined application of FYM, vermicompost and biochar as compare to control. Yield of knolkhol was also highest with the application of manures with biochar over the sole application of amendments.

Keywords: Recent years biochar is found to have positive influence on soil fertility, Effect of integrated use, soil properties and crop yield

Introduction

Inorganic fertilizer has played a significant role in increasing crop production since “green revolution” however they are not suitable solution for sustaining crop yield. The overuse of mineral fertilizer may accelerate soil acidification, affecting both soil biota and biochemical processes. Thus, the responsiveness towards organic farming is being created including the use of biochar to sustain the soil fertility and plant productivity.

Biochar has arisen as an amendment with mineral fertilizer and organic manures and hold a potential to improve the yield of crops. The biochar is found to have positive influence on soil fertility, resulting in an increase in crop yield without affecting soil health and environment. Biochar a pyrolysis product of plant biomass plays a significant role and opportunity to alter large scale surplus agricultural residues from a financial and environmental liability to valuable assets. Biochar is simply a charcoal that is used for agricultural purpose created by using pyrolysis process, heating biomass in low oxygen environment.

Soil chemical properties are the most important factors that determines the nutrient supplying power of the soil to plants and microbes. Many soil development and soil fertility processes occur in soil in the form of chemical processes. Some minerals retrieved from the soil parent materials with time release chemical elements that undergo various changes and transformations within the soil. The biochar application in soil improves soil fertility via two mechanisms one by adding nutrients to the soil and other by retaining nutrients from other sources including nutrients from the soil itself. It may cause increase in soil organic matter (SOM), water retention, and soil biological activity as well as a decreased fertilizer requirement when placed in soil (Hawkins *et al.*, 2007)^[11]. Glaser *et al.* (2002)^[8] concluded that charcoal may contribute to an increase in ion retention of soil and decrease in leaching of dissolved organic nutrients as they found higher nutrient retention and nutrient availability after charcoal additions to tropical soil. Oguntunde *et al.* (2008)^[25] showed a significant increase in soil pH, electrical conductivity and exchangeable Ca, Mg, K, Na and P in the soil and grain and biomass yield of maize increased by 91% and 44%, respectively at the charcoal site soils, compared to the adjacent soils. Rodriguez *et al.* (2009)^[28] reported that the biochar produced from sugarcane bagasse increased the pH of soil from 4.0–4.5 to 6.0–6.5 in a maize trial in Colombia. Laird *et al.* (2010)^[15] revealed that addition of 20 kg ha⁻¹ biochar increases the soil pH by almost 1 unit by showing the liming effect.

The research study also reveals that the biochar enhances the nutrient availability (significant increases in N (up to 7%), organic C (up to 69%), and P, K, Mg and Ca respectively. Steiner *et al.* (2011) [29] reported that addition of biochar to poultry litter during composting reduce the ammonia emissions by 64% and reduced total N loss by 52%. Liu *et al.* (2012) [22] in their study evaluate the effectiveness of biochar mixed with compost and revealed that this mixture significantly improved the fertility of sandy soil, as compared to the addition of compost only. Busch and Glaser (2015) [4] do the collation between the typical compost and co-composted biochar in a two-year field trial in Germany and revealed that the total N and total organic C increased under all treatments in comparison to the control; however, N contents were examined more stable in biochar-amended treatments. In addition, co-composted biochar also showed a significant contribution to the C sequestration of the topsoil, in comparison with all other treatments. Doan *et al.* (2015) [7] performed a three-year mesocosm experiment and examine that, the application of biochar in combination with vermicompost to soil significantly increased the total N, available P, CEC, and pH, as compared to control soil, thus improving soil fertility and crop productivity. According to Bruun (2011) [3], the ability of biochar to increase water holding capacity of soils also improves nutrient retention time in the topsoil. Liang *et al.* (2009) [21] reported that after soil application, biochar is predominately found in fractions of soil organic matter (SOM) that reside in small clusters of soil particles, or soil aggregates, rather than as free organic matter. Biochar itself generally contains high densities of nutrients, but also may improve the performance of added fertilizers due to its cation exchange capacity.

Material and Methods

The field experiment was conducted at Organic farm research center, SKUAST-J, Chatha J&K during the year 2018-19. The soil of experimental soil was sandy clay loam in texture with pH (7.6), EC (0.24), Organic carbon (6.4 g kg⁻¹), Available nitrogen (196.7 kg ha⁻¹), Available P₂O₅ (19.28 kg ha⁻¹), Available K₂O (175.62 kg ha⁻¹).

Experimental details

The experiment was laid out in Randomized Block Design (RBD) having 8 treatment combinations *viz.*, Control (T₁), 100% N through FYM (T₂), 100% N through vermicompost (T₃), 50% N through FYM + 50% N through vermicompost (T₄), 2 t ha⁻¹ biochar (T₅), 2 t ha⁻¹ biochar + 100% N through FYM (T₆), 2 t ha⁻¹ biochar + 100% N through vermicompost (T₇), 2 t ha⁻¹ biochar + 50% N through FYM + 50% through vermicompost (T₈) replicated 3 times. The soil of experimental site was sandy clay loam in texture with pH (7.79), EC (0.24 dsm⁻¹), organic carbon (6.4 g kg⁻¹). The biochar had a pH of 8.9, EC 0.49 dsm⁻¹, biochar to water ratio of 1:10, total carbon 53.5%, phosphorus 0.15%, potassium 0.5%, nitrogen 0.09% and bulk density of 0.28 g cm⁻³.

Materials and Methods

The biochar used in the present study was produced from rice husk as due to the high availability of rice husk in Jammu region of India. The technique used to produce biochar for the study was drum method produced by Venkatesh *et al.* (2010) [32]. F.Y.M and vermicompost was also produced on Organic farm research center.

The chemical properties like pH, EC, organic carbon, available nitrogen, available phosphorus and available

potassium were analyzed from the soil samples during the experiment as per standard methods.

Soil pH was determined by using a pH meter in a 1:2.5 soil: water ratios (Jackson, 1967) [12]. The electrical conductivity of the soil samples was determined by 1:2.5 soils water suspension with EC meter and expressed in dSm⁻¹ (Jackson, 1967) [12]. Organic carbon content was estimated by wet digestion method (Walkly and Black, 1934) [33] and was expressed in gram per kilogram. Available nitrogen content was determined using alkali potassium permanganate method as described by Subbiah and Asija (1956) [30]. The available phosphorus was determined by Olsen's method (Olsen *et al.*, 1954) [26]. 1NNH₄OAc (Ammonium acetate) was used as extractant and was determining by feeding the extract to flame photometer (Jackson, 1973) [13]. Yield was also observed on the basis of plant total weight, the yield per plot was estimated in kg per plot. Further, the yield per hectare was estimated from yield per plot in quintals per hectare.

Statistical analysis

The data generated from field and laboratory analysis were subjected to statistical analysis using the technique of analysis of variance for randomized block design for the interpretation of results as described by Gomez and Gomez (1984) [9]. The treatment differences were compared at 5 per cent level of significance (P= 0.05).

Result and Discussion

Electrical conductivity (EC)

The soil EC did not significantly vary in all different treatments as indicated in Table. 1 the range of EC in the treatments varied from 0.24 dS m⁻¹ to 0.31 dS m⁻¹. The highest EC (0.31 dS m⁻¹) was recorded in the treatment containing 2 t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) followed by (T₆) 2 t ha⁻¹ biochar + 100% N through FYM (0.30 dS m⁻¹). The lowest EC (0.24 dS m⁻¹) was recorded in control. The results showed the slight increase in the EC of soil with the application of biochar. Similar results of increase in EC were also reported by Raison (1979) [27]. He reported the increase in EC of soil due to application of biochar are generally due to carbonates of alkali, amounts of silica, phosphates, and small amounts of organic and inorganic N. Similar results were also reported by Khanna *et al.* (1994) [14].

Organic carbon

Application of biochar with combination of organic amendments (FYM+VC) showed significant difference with respect to control as presented in Table1. The range of organic carbon in the treatments varied from 6.6 g kg⁻¹ to 6.4 g kg⁻¹. The highest organic carbon (6.6 g kg⁻¹) was recorded in treatment containing 2 t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) followed by T₇ containing 2 t ha⁻¹ biochar + 100% N through vermicompost. The lowest organic carbon (6.4 g kg⁻¹) was recorded in T₁= T₂=T₅. It might be due to the reason that biochar is a mixture of two carbon components one which degrades readily (labile fraction) and second is more recalcitrant fraction and the highest values of organic carbon at biochar treated soils indicate the recalcitrance of organic carbon in biochar. Lehmann (2007b) [18] also reported the high organic carbon in soils treated with biochar. Liang *et al.* (2006) [20] also revealed the higher organic C and total N at the ancient Terra-Petra compared with adjacent soils. The organic carbon was also increased in treatments containing FYM and vermicompost. This may be due to the reason that, these organic amendments

add organic matter in the soil and their subsequent decomposition increase organic carbon status of the soil. Li *et al.* (2015) [19] also observed the increase in organic carbon after the application of biochar.

Available nitrogen

The application of biochar and organic amendments significantly influenced the available N content in the soil as shown in Table 1. The range of available N in the treatments varied from 194.7 kg ha⁻¹ to 218.8 kg ha⁻¹. The highest nitrogen content (218.8 kg ha⁻¹) was recorded in the treatment containing 2 t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) followed by T₇ containing 2 t ha⁻¹ biochar + 100% N through vermicompost (212.8 kg ha⁻¹). The lowest available N (194.7 kg ha⁻¹) was recorded in control. The available N decreased in the order of T₈ > T₇ > T₆ > T₄ > T₃ > T₂ > T₅ > T₁. This might be due to addition of biochar to soil have showed increase in the availability of major cations and phosphorus as well as in total nitrogen concentrations depending on the feedstock used and on the other hand decomposition of organic manures also tends to release nutrients in soil. Biochar has high adsorption capacity. Lehmann (2007a) [17] reported that biochar alters the N dynamics in soil. It is understood that biochar can take up N via ion exchange, remove NH₃ via adsorption, and stimulate immobilization with flow on consequences for NO₃⁻ leaching. Biochar adsorption of ammonia (NH₃) decreases NH₃ and NO₃⁻ losses during composting. With manure application it adsorbs the nutrients and offers a mechanism of slow release fertilizers to the plant. Doan *et al.* (2015) [7] also shows the increase in nitrogen content after the combined application of biochar and vermicompost.

Available phosphorus

The range of available phosphorus in the treatments varied from 18.68 kg ha⁻¹ to 23.20 kg ha⁻¹ as indicated in Table 1. There is increase in available phosphorus content as compare to control with the addition of organic amendments (FYM, vermicompost) and biochar. The highest phosphorus content (23.20 kg ha⁻¹) was recorded in the treatment containing 2t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) followed by T₆ containing 2 t ha⁻¹ biochar + 100% N through FYM (22.71 kg ha⁻¹). The lowest available phosphorus (18.68 kg ha⁻¹) was recorded in control (T₁). The available P decreased in the order of T₈ > T₆ > T₇ > T₄ > T₃ > T₂ > T₅ > T₁. This increase was due to the high concentrations of available P found in the biochar. Chan *et al.* (2007) [5] and Chan *et al.* (2008) [6] also reported the increase in available phosphorus in soil after the application of biochar. Vassilev *et al.* (2013) [31] suggested that nutrient contained in biochar ash enhanced microbial secretions of P-solubilizing acids. The increase in available P of the soil also resulting from the application of organic manures, may be due to the

mineralization of organic P, the production of organic acids which have a solubilizing effect on soil P and the organic amines which retard the fixation of phosphorus in soil (Gupta *et al.*, 1992) [10].

Available potassium

The range of available potassium in the treatments varied from 175.40 kg ha⁻¹ to 190.30 kg ha⁻¹ as indicated in Table 1. The highest potassium (190.30 kg ha⁻¹) was recorded in the treatment containing 2 t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) followed by T₇ containing 2 t ha⁻¹ biochar + 100% N through vermicompost (183.59 kg ha⁻¹) showed in Table.1. The lowest available phosphorus (175.40 kg ha⁻¹) was recorded in control. The available K decreased in the order of T₈ > T₇ > T₄ > T₆ > T₃ > T₂ > T₅ > T₁. This increase was due to the high concentration of K found in the biochar (Chan *et al.*, 2007; Abrol *et al.*, 2016) [5, 1]. The immediate beneficial effects of biochar additions on nutrient availability are largely due to higher potassium content (Lehmann *et al.*, 2003a) [16].

Yield

The results indicated that all the treatments had significant influence on yield of knolkhol over the control as showed in Table 1. It also indicated that combined application of FYM + Biochar (T₆), vermicompost (VC)+ B (T₇) and FYM + VC + B (T₈) increased yield by 21%, 25% and 24% as compare with the application of FYM (T₂), VC (T₃) and FYM + VC (T₄) without biochar, respectively. The range of yield in the treatments varied from 70.40 q ha⁻¹ to 216.44 q ha⁻¹. The highest yield (216.44 q ha⁻¹) was recorded in treatment containing 2 t ha⁻¹ biochar + 50% N through FYM + 50% N through vermicompost (T₈) and is followed by T₇ receiving 2 t ha⁻¹ biochar + 100% N through vermicompost (208.60 q ha⁻¹). The knolkhol yield was statically at par in T₈, T₇, T₆ however, the yield was higher as compare to the other treatments. The lowest yield (70.40 q ha⁻¹) was recorded in control (T₁). The application of biochar alone or with combination of manures (FYM and vermicompost) showed a significant change in yield of knolkhol. The yield decreased in the order of T₈ > T₇ > T₆ > T₄ > T₂ > T₃ > T₅ > T₁. This is due to the reason that biochar and organic amendments alone or in combination increased the nutrient status of the soil which helped in the growth of the plants that led to increase the yield of knolkhol in the present investigation. Arif *et al.* (2012) [2] also reported significant increase in maize yield with biochar application along with NPK in coarse textured soils of Pakistan. Nooker 2014) [24] also observed significant improvement in the spinach yield with biochar application in different soils of United States. Manolikaki and Diamadopoulou (2019) [23] also showed the enhancement in plant growth with the addition of rice husk biochar and manures.

Table 1: Effect of integrated use of biochar and organic amendments on soil yield of knolkhol

Treatments	EC	OC	N	P	K	Yield
T1=Control	0.24	6.4	194.7	18.68	175.40	70.40
T2=100% N through FYM	0.29	6.4	202.3	21.22	181.10	167.62
T3=100% N through vermicompost	0.30	6.5	204.3	21.25	181.56	166.30
T4=50% N through FYM + 50% N through vermicompost	0.28	6.6	210.0	22.21	183.58	173.64
T5=2 t ha ⁻¹ biochar	0.26	6.4	200.7	19.10	179.33	92.65
T6=2 t ha ⁻¹ biochar + 100% N through FYM	0.30	6.5	212.5	22.71	182.34	203.73
T7=2 t ha ⁻¹ biochar + 100% N through vermicompost	0.29	6.5	212.8	22.38	183.59	208.60
T8=2 t ha ⁻¹ biochar + 50% N through FYM + 50% through vermicompost	0.31	6.6	218.8	23.20	190.30	216.44
CD	NS	0.13	7.49	0.89	4.88	16.41
SE(m±)	0.01	0.04	2.45	0.29	1.59	5.36
CV	2.36	1.07	2.05	2.35	1.51	5.71

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