Original Research Article

Use of Biochar as Soil Amendment for Improvement of Soil Properties and Yield of Spinach (*Spinacia oleracea*) Leafy Vegetable

ABSTRACT

The present study was carried out at BAIF, Central Research Station, Urulikanchan near Pune to find out the Influence of Biochar as soil amendment on Spinach yield and soil properties during 2020-21. Biochar was used for the experiment with of different doses (5, 7.5, 10 and 15 tha^{-1}) along with recommended dose of NPK fertilizers (40:40:40 kg NPK ha^{-1}). Maximum growth parameters (plant height, leaf length, leaf width and petiole length) were recorded in (T4) with Biochar @ 10 tha^{-1} + 75% of RDF followed by in (T7) Biochar @ 7.5 tha^{-1} +50% of RDF. Whereas, the highest Spinach yield (18.58 tha^{-1}) was recorded under (T4) Biochar @ 10 tha^{-1} + 75 % of RDF followed by (T3) Biochar @ 7.5 tha^{-1} + 75 % of RDF recorded (17.93 tha^{-1}). The treatment (T1) @ 100 % RDF has registered the superior from economic point of view. Furthermore, the minimum values of growth and yield were recorded under absolute control.

Key words: *Spinach, Yield, Biochar, Growth*

1. INTRODUCTION

Soil fertility degradation, caused by depletion or imbalance of organic matter/nutrients, is affecting world agricultural productivity (Foley *et.al*, 2005) Inorganic fertilizers have played a significant role in increasing crop production since the “green revolution” (Liu *et. al.,* 2010) however, they are not a sustainable solution for maintenance of crop yields (Vanlauwe *et. al.,* 2010). Long-term overuse of mineral fertilizers may accelerate soil acidification, affecting both the soil biota and biogeochemical processes, thus posing an environmental risk and decreasing crop production (Aciego Pietri *et. al.,* 2008). Organic amendments, such as biochar and compost could therefore be useful tools to sustainably maintain or increase soil organic matter, preserving and improving soil fertility and crop yield.

Biochar is a carbon-rich material obtained from thermochemical conversion (slow, intermediate, and fast pyrolysis or gasification) of biomass in an oxygen-limited environment. It can be produced from a range of feedstock, including fire wood of forest trees and agriculture residues, such as straw, nut shells, rice hulls, cotton talk pellets, tree bark, and switch grass (Sohi *et. al.,* 2009). Biochar has been described as a possible tool for soil fertility improvement, potential toxic element adsorption, and climate change mitigation (Ennis *et. al.*, 2012).

Indeed, several studies have shown that Biochar application to soil can improve soil physical and chemical properties (Mukherjee *et. al.*, 2013), enhance plant nutrient availability and correlated growth and yield (Biederman *et.al.*, 2013) and reduce greenhouse gas emissions through C sequestration (Crombie *et. al.*, 2015). Therefore, experiment was conducted on use of Biochar for amendment of soil and with an aim to study the influence of Biochar on soil properties and yield of Spinach (*Spinacia oleracea*) Leafy Vegetable.

2. MATERIALS AND METHODS

The study was conducted at BAIF, Central Research Station, Urulikanchan, Ta Haveli Dist. Pune Maharashtra, India. The land having clay type of soil with properly managed cultivable land was selected for conducting the field experiment. The analysis of soil carried out to understand the chemical properties of soil before conducting the experiment. Initially, land was prepared with deep plough and laid out the plot adapting the RBD design. The plot size of 4 x 3 m^2 were prepared and spread equally the farmyard manure @ 10 tons per ha. The fourteen treatments were designed for this study are given in table 1 below;

Table 1: Treatment details:

Sr #	Treatments *Details*
T 1	100 % Recommended dose of fertilizer (RDF)
T 2	Biochar @ 5 t ha^{-1} + 75 % RDF
T 3	Biochar @ 7.5 t ha^{-1} + 75 % RDF
T 4	Biochar @ 10 t ha^{-1} + 75 % RDF
T 5	Biochar @ 15 t ha^{-1} + 75 % RDF
T 6	Biochar @ 5 t ha^{-1} + 50 % RDF
T 7	Biochar @ 7.5 t ha^{-1} + 50 % RDF
T 8	Biochar @ 10 t ha^{-1} + 50 % RDF

T 9	Biochar @ 15 t ha^{-1} + 50 % RDF
T 10	Biochar @ 5 t ha^{-1} + 100 % RDF
T 11	Biochar @ 7.5 t ha^{-1} + 100 % RDF
T 12	Biochar @ 10 t ha^{-1} + 100 % RDF
T 13	Biochar @ 15 t ha^{-1} + 100 % RDF
T 14	Control (No fertilization)

Different levels of Biochar application in combination with chemical fertilizers (RDF) were applied in the experimental plot with an objective to understand the change in the chemical properties of soil, growth and yield of spinach. Each treatment was replicated into three times under randomized block design. The Biochar was produced from subabul wood (*Leucaena leucocephala*) using a kiln and the coarse powder prepared using pounding machine.

The powdered Biochar was treated with 20% concentration of pure microbial cultures like *Rhizobium, Phosphate Solubilizing Bacteria (PSB)* and *Tricoderma*. The treated biochar was dried under shade for a day and applied to the field as per the doses 5, 7.5, 10 and 15 tha^{-1} separately. At the same time chemical fertilizers applied before sowing of the crop as per the dose mentioned in the Table-1. Before two days of the harvest of crop, the plant growth observations like Plant height, leaf length, width and petiole length were recorded and then spinach leaves were harvested from each treated plot separately.

The change in the soil chemical properties before and after harvest of the crop was analyzed in the laboratory from the collected soil samples. At the end of the study statistical analysis was carried out for each observed characters under the study using MS-Excel (2010) and OPSTAT software (Sheoran *et al.*, 1998).

3. RESULTS AND DISCUSSION

Influence of Biochar on growth parameters of spinach

The data presented in Table 2. Clearly indicates that, except petiole length, there is a non-significant variation in other growth parameters due to application of different doses of Biochar and fertilizers. However, the study shows that, a higher plant growth was recorded in treatment T_9 (Biochar @ 15 t ha^{-1} + 50 % RDF) in plant height (38.4 cm), Leaf length (16.3 cm), Leaf width (11.8 cm), was recorded in and average number of leaves per plant was same in (12 leaves plant $^{-1}$) in treatment T_8 (Biochar @ 10 t ha^{-1} + 50 % RDF) and T_9 (Biochar @ 15 t ha^{-1} + 50 % RDF). Whereas, minimum plant height (22.8 cm), Leaf length (8.8 cm), Leaf width (7.7 cm), Petiole length (12.7 cm) was recorded in treatment T_{14} Control (No fertilization) over all the treatments. The observation made on leaf: petiole ratio shows that there was non-significant effect due to different level of treatments which might be attributed to slow release of nutrients through Biochar, this might have affected the growth of spinach. The growth parameters recorded were near to the results of Chat *et al.,* (2005) and Roy *et al.,* (2009) in spinach.

Table.2: Effects of different levels of Biochar in combination with NPK on growth of Spinach

Tr #	Treatment Details	Plant Height (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Leaf: petiole (Length basis)	Average no. of leaves/ plant
1	100 % Recommended dose of fertilizer (RDF)	32.7	13.4	10.2	18.5	0.72	11
2	Biochar @ 5 t ha^{-1} + 75 % RDF	36.4	14.7	10.4	21.6	0.68	11
3	Biochar @ 7.5 t ha^{-1} + 75 % RDF	30.0	13.2	9.3	17.3	0.77	11
4	Biochar @ 10 t ha^{-1} + 75 % RDF	34.6	13.7	9.3	20.0	0.69	11
5	Biochar @ 15 t ha^{-1} + 75 % RDF	30.1	13.4	8.6	17.6	0.76	11
6	Biochar @ 5 t ha^{-1} + 50 % RDF	35.7	14.4	9.7	21.1	0.69	10
7	Biochar @ 7.5 t ha^{-1} + 50 % RDF	37.9	15.0	9.7	21.6	0.70	11
8	Biochar @ 10 t ha^{-1} + 50 % RDF	34.2	13.6	8.9	20.3	0.67	12
9	Biochar @ 15 t ha^{-1} + 50 % RDF	38.4	16.3	11.8	24.0	0.68	12
10	Biochar @ 5 t ha^{-1} + 100 % RDF	34.2	14.2	9.3	22.4	0.63	10
11	Biochar @ 7.5 t ha^{-1} + 100 % RDF	33.9	14.0	9.5	20.4	0.69	11
12	Biochar @ 10 t ha^{-1} + 100 % RDF	31.5	12.5	8.8	22.9	0.55	10
13	Biochar @ 15 t ha^{-1} + 100 % RDF	30.1	13.6	9.4	19.6	0.69	10
14	Control (No fertilization)	22.8	8.8	7.7	12.7	0.69	7
	SE(m)$\pm$	3.099	1.037	0.721	0.865	0.048	0.661
	CD at 5 %	N.S.	N.S.	N.S.	2.528	N.S.	N.S.

Effects of different levels of Biochar on Spinach yield

The data pertaining to leaf yield and economics of experiment are presented in Table 3. The effect of Biochar dose on Spinach yield is indicated positively showed that, combined application of different levels of Biochar and chemical fertilizers. However, the application of Biochar @ 10 tha^{-1} + 75 % of RDF (T_4) has given significantly higher yield (18.58 tha^{-1}) and is also at par with T_1 (100 % RDF), in T_2 (Biochar @ 5 tha^{-1} + 75 % of RDF), T_3 (Biochar @ 7.5 tha^{-1} + 75 % of RDF), in T_8 (Biochar @ 10 tha^{-1} + 50 % of RDF) and in T_9 (Biochar @ 15 tha^{-1} + 50 % of RDF), were found superior for improving spinach yield. From this study indicates that, as the Biochar doses increases the Spinach leafy yield was not improved. However, the needs to continue at least for three seasons to come out with confined conclusion. The above findings are in conformity with Ansari (2008), Canali *et al.,* (2008) and Patel *et al.,* (2008) who observed higher yield in spinach by application of Farmyard manure with inorganic fertilizers.

Benefit cost ratio of the study:

The data pertaining to economics of each treatment viz., cost of cultivation, gross income, net income and benefit: cost ratio has shown in Table 3. The maximum yield 18.58 tha^{-1} was recorded in T_4 and also the highest gross monetary return of Rs. 278625/- ha^{-1} was calculated. But cost of cultivation of Rs. 250641/- was higher in treatment T_{13} (Biochar @ 15 tha^{-1} + 100 % RDF) followed by T_5 (Biochar @ 15 tha^{-1} + 75 % RDF) Rs. 240500/- ha^{-1}, in T_9 (Biochar @ 15 tha^{-1} + 50 % RDF) Rs. 234668/- ha^{-1}, whereas, in treatment T_{14} lowest gross income Rs. 52500/- ha^{-1} was recorded. By considering all inputs, the benefit: cost ratio was calculated, higher in T_1 (3.75) followed by T_2 (2.15), T_3 (1.78), T_4 (1.73), T_8 (1.55) under, T_{10} (1.79). The highest benefit cost ratio was recorded in treatment T_1 (100 % RDF) i.e. 3.75, this is due to no cost of application of Biochar which has increased the net income.

Table.3 Effects of different levels of Biochar in combination with NPK Fertilization on yield and economics of Spinach

Tr #	Treatment Details	Yield (tha^{-1})	Gross Monetary Returns (Rsha^{-1})	Cost of cultivation (Rsha^{-1})	Net Monetary Returns (Rsha^{-1})	Benefit : cost ratio
1	100 % Recommended dose of fertilizer (RDF)	16.81	252083	67274	184809	3.75
2	Biochar @ 5 t ha^{-1} + 75 % RDF	17.22	258333	120411	137923	2.15
3	Biochar @ 7.5 t ha^{-1} + 75 % RDF	17.93	268958	150973	117985	1.78
4	Biochar @ 10 t ha^{-1} + 75 % RDF	18.58	278625	181536	97089	1.53
5	Biochar @ 15 t ha^{-1} + 75 % RDF	16.03	240500	242661	-2161	0.99
6	Biochar @ 5 t ha^{-1} + 50 % RDF	15.53	232917	112418	120499	2.07
7	Biochar @ 7.5 t ha^{-1} + 50 % RDF	16.25	243792	142981	100811	1.71
8	Biochar @ 10 t ha^{-1} + 50 % RDF	17.89	268292	173543	94749	1.55
9	Biochar @ 15 t ha^{-1} + 50 % RDF	16.74	251167	234668	16499	1.07
10	Biochar @ 5 t ha^{-1} + 100 % RDF	15.20	228042	127491	100551	1.79
11	Biochar @ 7.5 t ha^{-1} + 100 % RDF	15.46	231833	158954	72880	1.46
12	Biochar @ 10 t ha^{-1} + 100 % RDF	16.10	241458	189516	51942	1.27
13	Biochar @ 15 t ha^{-1} + 100 % RDF	15.27	229083	250641	-21558	0.91
14	Control (No fertilization)	3.50	52500	35320	17180	1.49
	SE(m)$\pm$	0.75	11,379.49		12,383.66	0.09
	CD at 5 %	2.21	33,262.61		36,197.84	0.263

Effects of different levels of Biochar application on soil properties

It has been reported that the application of biochar to soil improves nutrient availability, though the effects vary with biochar types/doses and soil types (Khodadad *et al.* 2011). The effects of biochar on soil nutrients can have high adsorption capacity and can reduce nutrient loss and increase soil fertility (Gul *et al.* 2015). The results in our research showed that soil organic carbon content was increased by 0.15 % after application of Biochar @ 10 tha^{-1} + 50% of RDF. Similar findings reported by (Laird *et al*. 2010) and (Wang *et al.* 2014) also reported that addition of Biochar at the rate of (5 tha^{-1}) significantly increased soil organic carbon content. Primary reason for these observations could be due to presence of stable carbon in the Biochar that is difficult to decompose in soil environments, thus contributing to the soil carbon improvement.

Table 4: Soil chemical analysis

Tr #	Treatment Details	pH	EC	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
	Base line	7.34	0.48	0.61	134	30	215
After harvesting							
T 1	100 % Recommended dose of fertilizer (RDF)	7.52	0.42	0.58	139	36	231
T 2	Biochar @ 5 t ha^{-1} + 75 % RDF	7.26	0.44	0.66	125	31	230
T 3	Biochar @ 7.5 t ha^{-1} + 75 % RDF	7.49	0.39	0.64	130	32	225
T 4	Biochar @ 10 t ha^{-1} + 75 % RDF	7.37	0.48	0.68	125	34	223
T 5	Biochar @ 15 t ha^{-1} + 75 % RDF	7.48	0.47	0.65	138	38	238
T 6	Biochar @ 5 t ha^{-1} + 50 % RDF	7.3	0.47	0.52	140	28	225
T 7	Biochar @ 7.5 t ha^{-1} + 50 % RDF	7.48	0.44	0.57	126	25	215
T 8	Biochar @ 10 t ha^{-1} + 50 % RDF	7.45	0.4	0.76	128	29	235
T 9	Biochar @ 15 t ha^{-1} + 50 % RDF	7.41	0.48	0.6	127	34	230
T 10	Biochar @ 5 t ha^{-1} + 100 % RDF	7.36	0.39	0.52	130	43	240
T 11	Biochar @ 7.5 t ha^{-1} + 100 % RDF	7.48	0.47	0.58	132	31	231
T 12	Biochar @ 10 t ha^{-1} + 100 % RDF	7.42	0.42	0.69	134	33	237
T 13	Biochar @ 15 t ha^{-1} + 100 % RDF	7.44	0.47	0.6	135	29	230
T 14	Control (No fertilization)	7.57	0.35	0.5	136	27	230

4. CONCLUSION

It can be concluded that spinach is highly responsive to combined application of different levels of Biochar and inorganic source of nutrition. Application of Biochar @ 10 tha^{-1} + 75 % of RDF (T_4) gives highest yield (18.58 tha^{-1})

Considering the soil health, the consistent use of chemical fertilizer alone will not be recommended. Using chemical fertilizer along with the Biochar will be the more benefit in terms of moisture holding, increased soil organic carbon. However, the study need to be continued for at least for the three seasons to draw a precise conclusion related to yield and soil properties.

REFERENCES

Aciego, J. C. Pietri and Brookes P. C. “Relationships between soil pH and microbial properties in a UK arable soil,” Soil Biology and Biochemistry. 2008; 40(7): 1856–1861.

Ansari, A.A. Effect of Vermicompost and vermiwash on the productivity of spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*). World Journal of Agricultural Sciences. 2008; 4(5): 554-557.

Biederman, L. A. and Stanley Harpole W. “Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis,” GCB Bioenergy. 2013; 5(2): 202–214.

Canali, S., Montemurro, F., Tittarelli, F. and Masetti, O. Effect of nitrogen fertilization reduction on yield, quality and N utilization of processing spinach. Journal of Food, Agriculture & Environment. 2008; 6(3&4): 242-247.

Chat, T.H., Dung, N.T., Binh, D.V. and Preston, T.R. Effect on yield and composition of water spinach (*Ipomoea aquatica*), and on soil fertility, of fertilization with worm compost or urea. *Livestock Research for Rural Development*, 2005; 17(10): 20-25.

Crombie, K. Masek O, Cross A. and Sohi S. “Biochar— synergies and trade-offs between soil enhancing properties and C sequestration potential,” GCB Bioenergy. 2015; 7(5):1161– 1175.

Ennis C. J., Evans A. G, Islam M, Ralebitso-Senior T. K and Senior E. “Biochar: carbon sequestration, land remediation, and impacts on soil microbiology,” Critical Reviews in Environmental Science and Technology. 2012; 42(22): 2311–2364.

Foley, J. DeFries A. R, Asner G. P. “Global consequences of land use,” Science, 2005; 309(5734): 570–574.

Gul S., Whalen J.K., Thomas B.W., Sachdeva V., Deng H.Y.: Physico-chemical properties and microbial responses in biocharamended soils: mechanisms and future directions. Agriculture, Ecosystems and Environment, 2015; 206: 46–59.

Khodadad C.L.M., Zimmerman A.R., Green S.J., Uthandi S, and Foster J.S.: Taxa-specific changes in soil microbial community composition induced by pyrogenic carbon amendments. Soil Biology and Biochemistry, 2011; 43: 385–392.

Laird DA, Fleming P, Davis DD. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. Geoderma. 2010; 158(3-4):443–449.

Liu, E. Yan C., Mei X. “Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China,” Geoderma, 2010; 158(3-4):173–180.

Mukherjee and Lal R. “Biochar impacts on soil physical properties and greenhouse gas emissions,” Agronomy, 2013; 3: 313–339.

Patel, KC, Patel, KP, Ramani, VP and Patel, JC. Effect of Pb and FYM application on spinach yield, Pb uptake and different fractions of Pb in sewage irrigated Fluventic ustochrepts soils of peri urban area of Vadodara. An Asian Journal of Soil Science, 2008; 3(2): 230-235.

Roy, O.P., Saha, B.K. and Chowdhury, M.A.H. Integrated nutrient management of Spinach. Journal of Agrofoestry and Environment, 2009; 3(1): 57-60.

Sheoran, O.P; Tonk, D.S; Kaushik, L.S; Hasija, R.C and Pannu, RS. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar 1998; 139-143.

Sohi, S. E. Lopez-Capel, Krull E and Bol R. “Biochar, climate change and soil: a review to guide future research,” CSIROLand andWater Science Report 2009; 05/09.

Vanlauwe BA, Bationo J. Chianu. “Integrated soil fertility management: operational definition and consequences for implementation and dissemination, “Outlook on Agriculture. 2010; 39(1) 17–24.

Wang Z, Li Y, Chang S. Contrasting effects of bamboo leaf and its biochar on soil CO2 flux and labile organic carbon in an intensively managed Chinese chestnut plantation. Biology and fertility of soils. 2014; 50(7):1109–1119.