Impact Of Biochar Base Organic Amendment On Morphological Changes And Yield Of Potato (*Solanum Tuberosum* L.)

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ABSTRACT

The present research was undertaken to analyze the impact of biochar-based organic amendment on the growth and yield of the potato crop. Results revealed that all the morphological, growth and yield attributing parameters were significantly affected except the emergence percentage ($p > 0.05$). Among all the thirteen treatment combinations of biochar base organic amendment, treatment T_4 i.e. [25% RDF + 75% (BM+VC+PM) + 40% Biochar)] resulted in maximum emergence percentage, plant height (cm), LAI, days to maturity, no. of haulm plant^{-1}, average weight of tuber plant^{-1}and yield of tuber q ha^{-1} while minimum was recorded under T_1 [Control]. The data related to % increase/decrease concerning control also showed that emergence % was rapid under T_4 (+0.86%). Therefore, treatment combination of biochar base organic amendment consisting of [25% RDF + 75% (BM+VC+PM) + 40% Biochar)] may be recommended to farmers for achieve best results in terms of potato growth and production.

Keywords: Biochar, Bone meal, Poultry manure, RDF and Vermicompost

INTRODUCTION

Potato (*Solanum tuberosum* L) is the most important cash crop in India producing around 48 million tons of potato from 2.07 million hectares while at present 378 million tons from 19 million hectares in the world (FAO, 2019). Now it is a major concern to maintain such yield sustainability because of population pressure which is around 7.3 billionin the world (WHO, 2018; Elferink and Schierhorn, 2016).The nutrient requirement of the potato crop is very high due to which soil fertility followed by productivity is incessantly degrading (Singh, 2018), However, to enhance the agricultural sustainability, environment-friendly organic amendments may be helpful (Chen et al., 2018 and Shahane and Shivay, 2021). Biochar is an organic amendment produced by the pyrolysis of organic wasteswithout oxygen which is used as a soil amendment to increase the efficiency of nutrient recycling by providing a larger contact surface area. It is well established that the amendment of biochar helps to increase the soil organic matter which is a key to increasing nutrient recycling consequently better morphological growth and yieldcan be obtained from crops such as corn andsoybean. Different sources of plant material which is used to produce biochar may produce different quality (Agegnehu et al., 2017). Biochar

made with bamboo, wood, rice husk and kunai grass was assessed forthe growth and yield of potatoes where (Hien et al. 2017 and Walter and Rao 2015) reported a positive impact while (Liu et al. 2017) reported its negative impact on yield. Therefore, our goal was to understand the effectiveness of organic base amendment biochar on the potato crop.

MATERIALS AND METHODS

A field experiment was conducted during the *Rabi* season during 2017-18 and 2018-19 at the farm of Lovely Professional University to assess the impact of biochar-based organic amendment on morphological growth and yield of potatoes. The experiment was comprised of total of thirteen combinations of biochar base organic amendment. The potato variety under investigation was Kufri Pukhraj and experiment was laid in randomized block design along with three replications. The main source of biochar base organic amendment which was used in different combinations consisted of recommended dose of fertilizer (RDF), bone meal, vermi-compost, poultry manure and biochar and standard agronomic practices were adopted during the conduct of research trial. The treatments consisted of T_1= Control (positive amendments – 100% NPK), T_2= 25% RDF + 75% (BM+VC+PM) + 20% Biochar), T_3= 25% RDF + 75% (BM+VC+PM) + 30% Biochar), T_4= 25% RDF + 75% (BM+VC+PM) + 40% Biochar), T_5= 25% RDF + 75% BM + 20% Biochar, T_6= 25% RDF + 75% VC + 20% Biochar, T_7= 25% RDF + 75% PM + 20% Biochar, T_8= 25% RDF + 75% BM + 30% Biochar, T_9= 25% RDF + 75% VC + 30% Biochar, T_{10} = 25% RDF + 75% PM + 30% Biochar, T_{11}= 25% RDF + 75% BM + 40% Biochar, T_{12}= 25% RDF + 75% VC + 40% Biochar, T_{13}= 25% RDF + 75% PM + 40% Biochar. Before the planting of tuber, soil samples were collected thereafter physical and biochemical parameters were analyzed in which soil pH, available N, P and K were estimated according to the (Jackson 1967; Subbiah and Asija, 1956; Olsen et al., 1954; AOAC, 1970).

The standard procedures were followed to observe morphological parameters like emergence %, days to emergence, plant height, dry matter accumulation, and days to maturity while the leaf area index was calculated according to (Watson, 1947).

$$LAI = \frac{\text{Total leaf area plant}^{-1}}{\text{Total ground area plant}^{-1}}$$

The parameters related to yield attribute were recorded on per plant basis i.e no. of haulm and average weight of tuber, however yield of potato was recorded in q ha^{-1}.

All the data collected from the present piece of work was subjected to SPSS analysis where mean data was subjected for analysis of variance Duncan's multiple range tests at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of biochar on plant growth

The growth parameters were significantly affected by all studied treatment combinations except for emergence percentage. Plant height was recorded to be maximum (30 DAS (27.19 cm), 60 DAS (48.88 cm) and at harvest (58.92 cm) under treatment T4 (Table 1). The observations under T3 i.e. (25% RDF + 75% (BM+VC+PM) + 30% Biochar) were at par with T4 while minimum values were recorded under T5 i.e. (25% RDF + 75% BM + 20% Biochar). Similarly, dry matter accumulation was recorded to be higher under T4 while lowest under T5. The results were found in accordance with previous investigations that emphasized the positive role of biochar and organic amendments on plant growth and development (Graber et al. 2010, Schulz and Glaser 2012). Thus, it may be suggested that the combination of biochar with organic amendments prove to be the most promising practice for agronomic performance.

Table-1: Effect of biochar based organic amendments on emergence (%), plant height (cm), dry matter accumulation plant^{-1} in Potato (*Solanum tuberosum* L)

Treatments details	Emergence (%)	Height (cm) (30 DAS)	Height (cm) (60 DAS)	Height (cm) (harvest)	Dry matter accumulation (%)
T_1	96.0±0.58^{a}	23.00±0.50^{a}	40.00±0.52^{a}	49.00±0.16^{a}	15.97±0.18^{a}
T_2	96.13±1.33^{a} [+0.14%]	25.80±0.25^{ef} [+10.86%]	46.42±0.73^{g} [+13.82%]	56.42±0.51^{f} [+13.14%]	18.04±0.29^{de} [+11.49%]
T_3	96.50±0.99^{a} [+0.52%]	26.20±0.16^{fg} [+12.21%]	47.70±0.55^{gh} [+16.14%]	57.53±0.61^{fg} [+14.82%]	18.07±0.09^{de} [+11.96%]
T_4	96.83±0.32^{a} [+0.86%]	27.19±0.06^{g} [+15.42%]	48.88±0.12^{h} [+18.17%]	58.92±0.61^{g} [+16.83%]	18.20±0.42^{e} [+12.27%]
T_5	94.93±1.23^{a} [-1.12%]	24.00±0.58^{abc} [+4.17%]	41.96±0.36^{bcd} [+4.67%]	52.00±0.58^{bcd} [+5.76%]	17.25±0.12^{bcd} [+7.58%]
T_6	95.20±1.18^{a} [-0.84%]	23.20±0.47^{a} [+0.86%]	41.00±1.0^{ab} [+2.45%]	51.07±0.83^{b} [+4.04%]	17.00±0.08^{b} [+6.08%]
T_7	96.0±0.95^{a} [0.0]	23.42±0.57^{ab} [+1.78%]	41.60±0.89^{abc} [+3.85%]	51.50±0.87^{bc} [+4.85%]	17.14±0.16^{bc} [+6.83%]
T_8	95.0±0.87^{a} [-1.05%]	24.44±0.40^{abcde} [+5.89%]	43.00±0.57^{cdef} [+6.98%]	53.00±0.58^{cde} [+7.54%]	17.67±0.43^{bcde} [+9.66%]
T_9	95.13±0.90^{a} [-0.91%]	24.14±0.49^{abcd} [+4.72%]	42.08±0.58^{bcd} [+4.95%]	52.10±0.68^{bcd} [+5.94%]	17.27±0.37^{bcd} [+7.53%]
T_{10}	95.73±0.86^{a} [-0.28%]	24.44±0.52^{abcde} [+5.89%]	42.47±0.73^{bcde} [+5.81%]	52.56±0.35^{bcd} [+6.77%]	17.50±0.26^{bcde} [+8.76%]
T_{11}	95.0±0.95^{a} [-1.05%]	25.47±0.32^{def} [+9.69%]	44.50±0.26^{f} [+10.11%]	54.60±0.20^{e} [+10.25%]	18.07±0.34^{de} [+11.64%]
T_{12}	95.60±0.83^{a} [-0.42%]	24.75±0.44^{bcde} [+7.06%]	43.60±0.23^{def} [+8.26%]	53.51±0.36^{de} [+8.43%]	17.86±0.17^{bcde} [+10.61%]

T_{13}	96.03±0.74[a] [+0.03%]	25.00±0.58[cdef] [+8.0%]	44.30±0.48[ef] [+9.71%]	54.42±0.42[e] [+9.95%]	17.95±.13[cde] [+11.05%]

Effect on Leaf Area Index

Leaf area index was dramatically affected with various treatment combinations. It was found that the leaf area index increased by one to two-fold under T4 (30 DAS) and at harvest. The observations of LAI under T3 and T2 were at par with T4 while the minimum LAI was observed under T1 i.e. control (Fig. 1). Leaf surfaces are the primary borders of important processes related to energy and mass exchange such as canopy interception, evapo-transpiration and gross photosynthesis and these were directly proportional to LAI. The difference in LAI among the treatments might be due to the biochar based organic amendments (De et al. 2011, Camargo et al 2016).

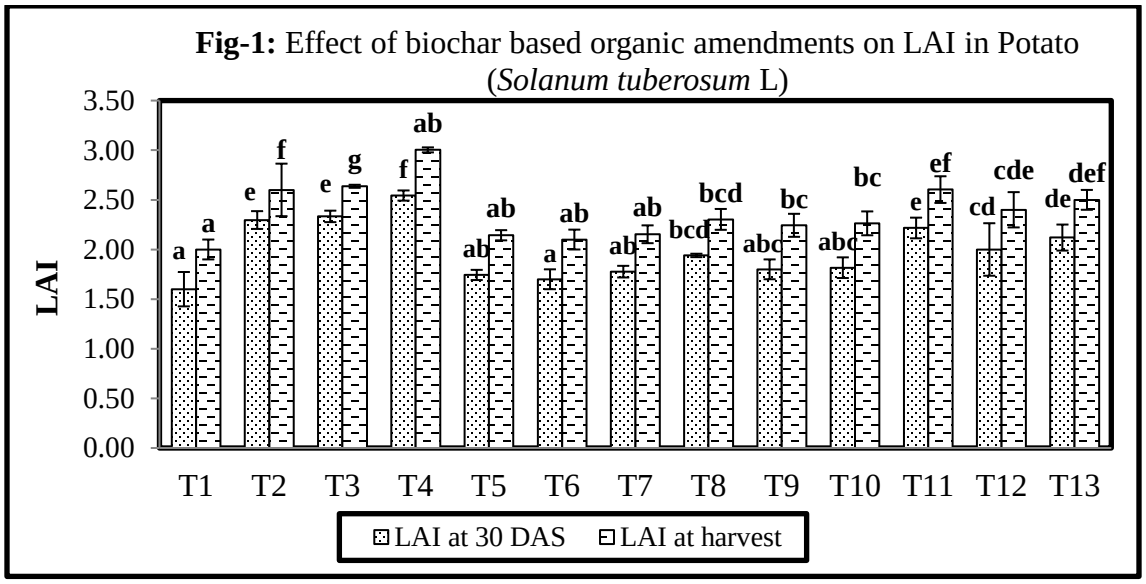

Fig-1: Effect of biochar based organic amendments on LAI in Potato (*Solanum tuberosum* L)

Effect of biochar on yield attributes of potato

All treatment combinations posed a positive impact on the yield parameters of potato (Table. 2). The days to emergence were found to be lowest under T4 while days to emergence were recorded to be highest under control conditions, clearly depicting the positive response of potato seeds towards treatment. On the contrary, plants took more days to mature i.e. (115) under T4. The treatment T4 resulted in maximum no. of haulms per plant (4.43) that eventually led to increased average weight of tubers per plant and ultimately resulted in increased yield. Numerous studies have indicated the strong potential of biochar application in improving crop production (Van Zwieten et al., 2010; Zhang et al., 2012; Nair et al., 2014). Increased crop yield

is a mostly recognized benefit of biochar application. However, crop responses are highly variable and reliant on biochar type and application rates.

Table-2: Effect of biochar based organic amendments on days to emergence, days to maturity, number of haulm, average weight of tuber plant^{-1} (g) and yield q ha^{-1}in Potato (*Solanum tuberosum* L)

Treatments details	Days to emergence	Days to maturity	Number of haulm plant^{-1}	Average wt. of tuber plant^{-1} (g)	Yield qha^{-1}
T_1	20.00±1.0±^{d}	111.33±0.67^{a}	4.00±^{a}	315.9±1.44^{a}	266.00±2.27^{a}
T_2	17.63±0.32^{ab} [-13.42%]	112.33±1.20^{abc} [+0.89%]	4.37±0.06^{bcd} [+8.54%]	388.7±1.62^{h} [+18.71%]	363.67±1.80^{f} [+26.86%]
T_3	18.33±0.88^{abc} [-9.09%]	114.67±0.67^{bc} [+2.91%]	4.40±0.05^{cd} [+9.16%]	392.6±3.22^{hg} [+19.52%]	365.10±2.08^{f} [+27.14%]
T_4	17.59±0.26^{a} [-13.70%]	115.00±0.58^{c} [+3.19%]	4.43±0.06^{d} [+9.64%]	399.1±0.40^{g} [+20.84%]	366.17±2.16^{f} [+27.36%]
T_5	19.20±0.42^{bcd} [-4.17%]	112.00±0.58^{abc} [+0.60%]	4.33±0.07^{bcd} [+7.69%]	349.5±5.83^{c} [+9.60%]	303.33±1.37^{b} [+12.31%]
T_6	19.59±0.38^{cd} [-2.09%]	112.00±1.52^{abc} [+0.60%]	4.28±0.04^{bcd} [+6.61%]	337.9±5.13^{b} [+6.49%]	298.67±1.53^{b} [+10.94%]
T_7	18.20±0.15^{abc} [-9.89%]	111.67±0.33^{ab} [+0.30%]	4.29±0.05^{bcd} [+6.83%]	342.7±2.08^{bc} [+7.80%]	300.30±1.55^{b} [+11.42%]
T_8	19.20±0.20^{bcd} [-4.17%]	113.00±1.15^{abc} [+1.47%]	4.34±0.05^{bcd} [+7.83%]	367.2±3.44^{def} [+13.97%]	343.40±1.34^{cde} [+22.54%]
T_9	19.00±0.0^{abcd} [-5.26%]	114.33±0.88^{abc} [+2.62%]	4.31±0.03^{bcd} [+7.26%]	358.9±1.41^{d} [+11.98%]	338.12±1.58^{c} [+21.33%]
T_{10}	18.20±0.42^{abc} [-9.89%]	113.33±0.88^{abc} [+1.76%]	4.35±0.06^{bcd} [+7.98%]	362.6±2.0^{de} [+12.87%]	341.70±1.04^{cd} [+22.15%]
T_{11}	18.50±0.29^{abcd} [-8.11%]	113.33±1.20^{abc} [+1.76%]	4.38±0.03^{bcd} [+8.61%]	376.7±1.53^{g} [+16.13%]	347.33±1.80^{e} [+23.42%]
T_{12}	18.50±0.29^{abcd} [-8.11%]	113.33±0.67^{abc} [+1.76%]	4.17±0.04^{ab} [+4.00%]	369.5±1.04^{efg} [+14.50%]	344.70±1.67^{de} [+22.83%]
T_{13}	19.20±0.42^{bcd} [-4.17%]	115.00±0.58^{c} [+3.19%]	4.20±0.12^{bc} [+4.76%]	373.1±1.54^{fg} [+15.31%]	346.66±1.87^{de} [+23.27%]

Note: T_1= Control (positive amendments – 100% NPK), T_2= 25% RDF + 75% (BM+VC+PM) + 20% Biochar), T_3= 25% RDF + 75% (BM+VC+PM) + 30% Biochar), T_4= 25% RDF + 75% (BM+VC+PM) + 40% Biochar), T_5= 25% RDF + 75% BM + 20% Biochar, T_6= 25% RDF + 75% VC + 20% Biochar, T_7= 25% RDF + 75% PM + 20% Biochar, T_8= 25% RDF + 75% BM + 30% Biochar, T_9= 25% RDF + 75% VC + 30% Biochar, T_{10} = 25% RDF + 75% PM + 30% Biochar, T_{11}= 25% RDF + 75% BM + 40% Biochar, T_{12}= 25% RDF + 75% VC + 40% Biochar, T_{13}= 25% RDF + 75% PM + 40% Biochar.

CONCLUSION

In nutshell, it is concluded that among different treatment combinations of biochar amendments, the treatment T4 i.e. (25% RDF + 75% (BM+VC+PM) + 40% Biochar) not only resulted in growth promotion in terms of plant height but also accelerated the yield parameters. Thus, this

treatment combination may be recommended to farmers for improved agronomic performance of crop.

REFRENCES

Agegnehu, G., Srivastava, A. K., & Bird, M. I. (2017). The role of biochar and biochar-compost in improving soil quality and crop performance: A review. Applied soil ecology, 119, 156-170.

AOAC. 1970. Methods of analysis. Association of official agricultural chemists, Washington DC

Camargo, D.C., Montoya, F., Moreno, M.A., Ortega, J.F., Córcoles, J.I. Impact of water deficit on light interception, radiation use efficiency and leaf area index in a potato crop (*Solanum tuberosum* L.). J. Agric. Sci. 2016, 154, 662–673

Chen, J., Lü, S., Zhang, Z., Zhao, X., Li, X., Ning, P., & Liu, M. (2018). Environmentally friendly fertilizers: A review of materials used and their effects on the environment. Science of the total environment, 613, 829-839.

de la Casa, A., Ovando, G., Bressanini, L., Martinez, J., Rodriguez, A. Radiation use efficiency in potato crop estimated from the foliage coverage. Agriscientia 2011, 28, 21-30.

Elferink, M., & Schierhorn, F. (2016). Global demand for food is rising. Can we meet it. Harvard Business Review, 7(04), 2016.

FAO (2019) FAO statistical databases FAOSTAT. http://faostat3.fao.org

Graber, E.R., Meller Harel, Y., Kolton, M. (2010). Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. Plant Soil 337, 481-496.

Hien T.T.T., Shinogi Y., Mishra A., Viet D.D. (2017). The effect of bamboo biochar on crop's productivity and quality in the field condition. J FacAgric Kyushu Univ 62:477–482

Jackson ML. 1967. Soil Chemical Analysis. Prentice Hall of India Ltd. New Delhi. p 498

Liu C, Liu F, Ravnskov S, Rubæk G.H., Sun Z., Andersen M.N (2017) Impact of wood biochar and its interactions with mycorrhizal fungi, phosphorus fertilization and irrigation strategies on potato growth. J Agron Crop Sci 203:131–145.

Nair, A., Kruse, R.A., Tillman, J.L., Lawson, V., 2014. Biochar application in potato production. Iowa State Res. Farm Progress Rep., 2027. (http:// lib.dr.iastate.edu/farms reports/2027; Last accessed Dec. 16th 2017).

Olsen SR, Cole CV, Watanbe FS and Dean LA. 1954. In: Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture circulation 939: 1923

Schulz, H. and Glaser, B. (2012), Effects of biochar compared to organic and inorganic fertilizers on soil quality and plant growth in a greenhouse experiment. Z. Pflanzenernähr. Bodenk., 175: 410-422.

Shahane, A. A., & Shivay, Y. S. (2021). Soil Health and Its Improvement through Novel Agronomic and Innovative Approaches. doi.org/10.3389/fagro.2021.680456.

Singh, B. (2018). Are nitrogen fertilizers deleterious to soil health?. Agronomy, 8(4), 48.

Subbiah BV and Asija GL. 1956. A rapid procedure for estimation of available nitrogen in soils. Current Science 25: 259-260

Van Zwieten, L., Kimber, S., Morris, S., Chan, K.Y., Downie, A., Rust, J., Joseph, S., Cowie, A., 2010. Effects of biochar from slow pyrolysis of paper mill waste on agronomic performance and soil fertility. Plant Soil 327, 235-246.

Walter R, Rao BKR (2015) Biochars influence sweet-potato yield and nutrient uptake in tropical Papua New Guinea. J Plant Nutr Soil Sci 178:393–400.

Watson, D. J., 1947. Comparative physiological studies in the growth of field crops. I: Variation in net assimilation rate and leaf area between species and varieties, and within and between years. Ann. Bot., 11: 41-76.

World Health Organization. (2018). The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition. Food & Agriculture Org.

Zhang, A., Bian, R., Pan, G., Cui, L., Hussain, Q., Li, L., Zheng, J., Zhang, X., Han, X., Yu, X., 2012. Effects of biochar amendment on soil quality, crop yield and greenhouse gas emission in a Chinese rice paddy: a field study of 2 consecutive rice growing cycles. Field Crops Research 127, 153-160.

Guha, Subhanil, and Anindita Dey. "Coastal Morphological Dynamics Of Nayachara Island Using Geoinformatics." International Journal of Environment, Ecology, Family and Urban Studies (IJEEFUS) 5.6 (2015):21-28

Panja, Sudeshna, et al. "Performance of true potato seed (TPS) hybrids in gangetic alluvial zone of West Bengal." *IASET: International Journal of Agricultural & Bio-Chemical Science (IASET: IJABS) 1.2* (2016): 1-8.

Yadav, Deependra, Sarvesh Singh, and Priyanka Singh. "Influence of Levels and Application Techniques of K on Performence of Graded Tubers and Yield in Potato." International Journal of Agricultural Science and Research (IJASR) 6.2 (2016):5-8