IJTA © Serials Publications
National Academy of Agricultural Science (NAAS) Rating : 3. 03

Comparative study on tobacco stalks based organic soil amendments and inorganic soil amendment (zeolite) on soil reaction and nutrient (N, K) availability of an Alfisol

J. Poorna Bindu[1], *D. Damodar Reddy*[1], *P. Santhy*[2], *C. Chandrasekhara Rao*[1] *and L.K. Prasad*[1]

Abstract: *A laboratory incubation study was conducted to study the effect of organic soil amendments viz., tobacco stalk biochar and tobacco stalk biomass (TS Biochar and TS Biomass) and inorganic soil amendment synthetic zeolite (SZ) on soil reaction, N and K availability status of FCV tobacco grown in Alfisols of Andhra Pradesh. One of the major characteristics of biochar and zeolite are their buffering capacity and enhancing water and nutrient retention. Results revealed that soil pH tend to decrease with the progress of incubation time. The magnitude of increase in soil pH was higher in soil amendments alone over the combination of soil amendments with fertilizers. The increment in soil pH differed between different soil amendments and followed order: 1 t ha^{-1} TSB+250 kg ha^{-1} SZ > 1 t ha^{-1} TSB > 100 % RDF+1 t ha^{-1} TSB+250 kg ha^{-1} SZ > 100 % RDF+ 250 kg ha^{-1} SZ > 100 % RDF+1 t ha^{-1} TSB > 100 % RDF + 0.5 t ha^{-1} TSP. Among different soil amendments maximum available nitrogen was observed in 100% RDF+1 t ha^{-1}TSB. The relatively greater quantity of available soil potassium was recorded by 100% RDF+1 t ha^{-1}TSB+250 kg ha^{-1} SZ followed by 100% RDF +1 t ha^{-1}TSB. The results suggest that TS Biochar incorporation may have a significant role as liming effect and also in improving the availability of an Alfisol.*

INTRODUCTION

Light textured soils with poor nutrient retention capacity, available nutrients are often subjected to losses through leaching process leading to low fertilizer use efficiency. Some of these environmental issues associated with intensive use of fertilizers have generated a great deal of interest in development and promotion of alternative soil management practices. Soil amendments like Biochar and Zeolite are designed to gradually release nutrients at rates that can closely match nutrient demand by plants, while potentially reducing the nutrient losses to the environment through leaching, volatilization, and/or runoff. In addition to soil carbon storage, soil biochar additions are known to improve N and K retention. Both effects may have environmental benefits and lead to a decrease in use of fertilizers with an enhancement of agriculture sustainability. Biochar is proposed as a soil amendment in environments with low carbon sequestration capacity and previously depleted soils (especially in the Tropics). Charcoal formation and deposition in soils seems to be a promising option to transfer an easily decomposable biomass into refractory soil organic matter (SOM) pools. Agriculture over the past decades has been depending heavily on the chemical fertilizers that are not only very expensive but also have adverse effect on soil quality. Over use of fertilizers also contributes to water and environmental pollution. Adding biochar may increase exchangeable potassium (K) levels in soil through the addition of K which is in the ash fraction of the biochar and by reducing losses of K through leaching [8,12, 3]. Changes in soil microbial composition have been found in biochar-rich soils

1 ICAR-Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh
2 Tamil Nadu Agricultural University, Coimbatore,Tamil Nadu

[13, 6], these changes could alter microbial mediated N dynamics including nitrification [5]. The effect of biochar on soil nutrient retention can also be indirect, through changes in soil chemical and physical properties such as pH and electric conductivity. Biochar CEC is developed when the product is exposed to oxygen and water, creating oxygenated surface functional groups [4]. Similar to soils, biochar CEC represents its ability to electrostatically sorb or attract cations. Although biochars are organically based and therefore should carry pH dependent charge much like soil organic matter, increasing pyrolysis temperature tends to cause a decrease in CEC; this phenomenon was observed by both Rajkovich [16]. Soil biochar applications recycle most of the nutrients that are removed when biomass is harvested. Base cations (primarily Ca, Mg, and K) in biomass are transformed during pyrolysis into oxides, hydroxides, and carbonates (ash) that are mixed with the biochar. Due to the presence of these bases most biochars function as a liming agent when applied to soil. Biochar can also affect key physical and chemical parameters of soil, e.g., soil pH, structure, release of soluble C and micronutrient availability. It is well known that soil pH can strongly influence the availability of both anions and cations such as phosphorus P, Ca, and K [3]. In the present study, an incubation experiment was conducted to study the changes in soil reaction as well as soil available N and K due to application of organic soil amendments(TS Biochar and TS Biomass) and also inorganic soil amendment (synthetic zeolite) in the presence and absence of chemical fertilizers.

MATERIALS AND METHODS

The soil amendments for incubation experiment included organic soil amendments tobacco stalk biochar (TS Biochar), tobacco stalk Biomass (TS Biomass) and inorganic soil amendment *viz.,* synthetic zeolite (SZ). TS Biochar produced from the TS Biomass was alkaline (pH 9.42) with an Ash content 17.47 % [15] has been utilized in the present study. TS Biochar was characterised with various functional groups *viz.,* carbonate and carboxylate groups [15]. Inorganic soil amendment synthetic zeolite (SZ) was characterized by alkaline pH (9.2), high cation exchange capacity (207 C mol p^+ kg^{-1}) and also contains potassium to a limited extent. Bulk soil samples were collected from CTRI-Research station, Jeelugumilli, Andhra Pradesh. The experimental soil collected from FCV tobacco growing soils of CTRI-RS, Jeelugumilli was classified under sandy soil of an Alfisol. The soil was non-saline (EC 0.20 dSm^{-1}), acidic in reaction (pH 5.50) with CEC (2.8 C mol (p+) kg^{-1}). The treatments for incubation experiment included T_1 (100% RDF), T_2 (100 % RDF+1 t ha^{-1} TS Biochar), T_3 (100 % RDF+ 250 kg ha^{-1} SZ), T_4 (100 % RDF+1 t ha^{-1} TS Biochar+250 kg ha^{-1} SZ), T_5 (100 % RDF +0.5 t ha^{-1} TS Biomass), T_6 (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ), T_7 (1 t ha^{-1} TS Biochar) and T_8 (Control). Sub samples of soils were drawn 8 times at pre-decided intervals (1, 7, 15, 30, 45, 60, 75 and 90 days) during the course of incubation and analyzed for soil pH, available N and K by using standard methods [7]. Experiment was conducted in factorial CRD with three replications.

Applied Recovery Efficiency: Applied recovery efficiency of nutrients is the percentage of nutrients recovered after application of soil amendments in comparison with the RDF alone. The applied recovery efficiency of N and K due to application of soil amendments along with RDF was calculated as follows

Applied Recovery Efficiency of Nitrogen (ARE_N):

Availabile nitrogen in treated soil - Available nitrogen in control soil

$$\frac{\text{Availabile nitrogen in treated soil - Available nitrogen in control soil}}{\text{Amount of nitrogen added}} \times 100 \quad (1)$$

Applied Recovery Efficiency of Potassium (ARE_K):

$$\frac{\text{Available potassium in treated soil - Available potassium in control soil}}{\text{Amount of potassium added}} \times 100 \quad (2)$$

RESULTS AND DISCUSSION

Effect of soil amendments on soil reaction

Addition of soil amendments caused a marked increase in soil pH over the fertilizer control T_1 (100 % RDF) and there by indicated the potential of soil amendments as liming material for acid soils. For all the treatments, soil pH tended to decrease with the progress of incubation time. The magnitude of increase in soil pH was higher in soil amendments alone treatments over the combination of soil amendments with fertilizers. Among different soil amendments with RDF treatments higher change in pH was observed in T_4 (100 % RDF+1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 6.04, 5.74, 5.56, 5.44, 5.16, 4.86, 4.76 and 4.74 at 1, 7, 15, 30, 45, 60, 75 and 90 DAI, respectively. The minimum change in pH was observed in T_5 (100 % RDF + 0.5 t ha^{-1} TS Biomass) with 5.47, 5.39, 5.29, 5.13, 4.92, 4.82, 4.71 and 4.60 at 1, 7, 15, 30, 45, 60, 75 and 90 DAI, respectively and which is on par with the T_1 (100% RDF) (Table 1). Irrespective of all the treatments maximum change in pH 5.78 was observed higher in T_6 (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) followed by T_7 (1 t ha^{-1} TS Biochar). The increment in soil pH differed between different soil amendments and followed order: T_6 (1 t ha^{-1} TS Biochar +250 kg ha^{-1} SZ)> T_7 (1 t ha^{-1} TS Biochar)> T_4 (100 % RDF +1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ)> T_3 (100 % RDF + 250 kg ha^{-1} SZ)> T_2 (100 % RDF +1 t ha^{-1} TS Biochar)> T_5 (100 % RDF +0.5 t ha^{-1} TS Biomass).The combination of TS Biochar and SZ has recorded maximum pH, followed by TS Biochar. The reason could be the alkaline pH of both the soil amendments. A number of studies had reported that the addition of biochar increases soil pH, Mukherjee [11], reported that application of oak wood biochar with initial pH 9.4 and carbon conten 90% signicantly improved pH by 0.4 units. Tobacco stalk biochar contains ash portion (17. 5%), might have been also contributed to increase in soil pH. This is in agreement with Sollins, [17], reported that ash content could increase the soil pH. Biochar also can ameliorate soil pH due to its surface ash residue content, alkaline metals especially in acidic soils [2,]. Wang[18]. reported that rice husk biochar increased the tea garden soil (acid soil) pH from 3.33 to 3.63. The agricultural soil pH increased by almost 1 unit for biochar treatment which produced from mixed hard wood [8].

Effect of soil amendments on N and K fertility

Available nitrogen and potassium status of soil was monitored at different days of incubation. A gradual and steady decline in the available nitrogen and potassium status of the soil up to end of incubation period was noticed irrespective of all treatments (Table 2 & 3). A decline in available nitrogen content was observed with respect to increase in the number of days. Among different soil amendments, available nitrogen was recorded higher in T_2 (100 % RDF + 1 t ha^{-1} TS Biochar) for all the days of incubation. Minimum available nitrogen was noticed in T_7 (1 t ha^{-1} TS Biochar). Irrespective of all treatments, maximum available

Table 1
Effect of different soil amendments on soil reaction

Days after incubation (DAI)	*1*	*7*	*15*	*30*	*45*	*60*	*75*	*90*
				Soil pH				
T_1	5.37	5.29	5.28	5.29	4.88	4.83	4.80	4.70
T_2	5.66	5.57	5.50	5.49	5.25	4.73	4.69	4.64
T_3	5.81	5.56	5.57	5.50	5.30	5.01	4.68	4.54
T_4	6.04	5.74	5.56	5.44	5.16	4.86	4.76	4.74
T_5	5.47	5.39	5.29	5.13	4.92	4.82	4.71	4.60
T_6	6.39	6.04	5.82	5.83	5.71	5.51	5.47	5.45
T_7	5.86	5.53	5.47	5.46	5.57	5.48	5.44	5.42
T_8	5.61	5.58	5.45	5.42	5.36	5.23	5.20	5.13
	SEd	CD (0.05)						
T*P	0.12	0.24						

T_1 - 100 % RDF; T_2 - 100 % RDF + Tobacco Stalk Biochar (TS Biochar)1t ha^{-1} ;T_3 - 100 % RDF + Synthetic Zeolite (SZ) 250 kg ha^{-1} ;T_4 - 100 % RDF + 1t ha^{-1} (TS Biochar)+ 250 kg ha^{-1} (SZ); T_5 - 100 % NPK + Tobacco Stalk Biomass (TS Biomass) 0.5 t ha^{-1};T_6 - TS Biochar (1t ha^{-1}) + SZ (250 kg ha^{-1}); T_7 - TS Biochar (1t ha^{-1}); T_8 – Control

Table 2
Effect of different soil amendments on soil available nitrogen (mg kg^{-1}) of soil

DAI	*1*	*7*	*15*	*30*	*45*	*60*	*75*	*90*
				Soil available nitrogen (mg kg^{-1})				
T_1	28.8	27.5	23.8	22.5	15.0	11.3	10.0	10.0
T_2	36.3	30.0	27.5	22.5	22.5	17.5	13.8	12.5
T_3	27.5	26.3	22.5	17.5	17.5	13.8	12.5	8.5
T_4	31.3	25.0	25.0	21.3	16.3	12.5	10.0	8.8
T_5	27.5	26.3	22.5	21.3	15.0	15.0	13.8	8.8
T_6	21.3	16.3	11.3	11.3	10.0	8.8	7.5	7.5
T_7	13.8	13.8	13.8	13.8	11.3	6.3	6.3	6.3
T_8	13.8	13.8	11.3	10.0	7.5	7.5	7.5	7.5
	SEd	CD (0.05)						
T*P	0.33	0.67						

T_1 - 100 % RDF; T_2 - 100 % RDF + Tobacco Stalk Biochar (TS Biochar)1t ha^{-1} ;T_3 - 100 % RDF + Synthetic Zeolite (SZ) 250 kg ha^{-1} ;T_4 - 100 % RDF + 1t ha^{-1} (TS Biochar)+ 250 kg ha^{-1} (SZ); T_5 - 100 % NPK + Tobacco Stalk Biomass (TS Biomass) 0.5 t ha^{-1};T_6 - TS Biochar (1t ha^{-1}) + SZ (250 kg ha^{-1}); T_7 - TS Biochar (1t ha^{-1}); T_8 – Control

Table 3
Effect of different soil amendments on potassium concentration (mg kg^{-1}) of soil

DAI	*1*	*7*	*15*	*30*	*45*	*60*	*75*	*90*
				Soil available potassium (mg kg^{-1})				
T_1	42.23	36.87	34.00	33.53	32.37	32.17	31.90	31.37
T_2	48.30	45.80	41.20	40.63	37.67	36.70	36.10	35.20
T_3	43.50	37.70	37.50	37.47	37.40	36.20	34.13	32.00
T_4	48.53	44.90	42.67	42.23	39.83	36.10	35.53	32.30
T_5	46.73	42.73	37.50	36.87	34.07	32.37	30.47	30.13
T_6	11.83	12.33	11.43	11.00	10.33	10.20	10.00	9.60
T_7	10.63	9.93	9.03	8.87	8.57	8.27	8.17	7.90
T_8	6.73	6.63	6.43	6.27	6.01	5.73	5.37	4.97
	SEd	CD (0.05)						
T*P	0.64	1.29						

T_1 - 100 % RDF; T_2 - 100 % RDF + Tobacco Stalk Biochar (TS Biochar)1t ha^{-1} ;T_3 - 100 % RDF + Synthetic Zeolite (SZ) 250 kg ha^{-1} ;T_4 - 100 % RDF + 1t ha^{-1} (TS Biochar)+ 250 kg ha^{-1} (SZ); T_5 - 100 % NPK + Tobacco Stalk Biomass (TS Biomass) 0.5 t ha^{-1};T_6 - TS Biochar (1t ha^{-1}) + SZ (250 kg ha^{-1}); T_7 - TS Biochar (1t ha^{-1}); T_8 – Control

nitrogen was observed in T_2 (100 % RDF + 1 t ha^{-1} TS Biochar) and minimum available nitrogen was observed in T_8 (control). In soil amendments, available potassium was registered higher value in T_4 (100 % RDF + 1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) for all days of incubation, followed by T_2 (100 % RDF +1 t ha^{-1} TS Biochar) (Table 3). Minimum available potassium was noticed in T_7 (1 t ha^{-1} TS Biochar). Irrespective of all treatments, maximum available potassium was observed in T_4 (100 % RDF + 1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) followed by T_2 (100 % RDF +1 t ha^{-1} TS Biochar).

Applied Recovery Efficiency (ARE): Results indicated that application of TS Biochar along with recommended dose of fertilizer has recorded maximum ARE_N and ARE_K (fig.1 & 2) which could be due to its nutrient retention capacity.

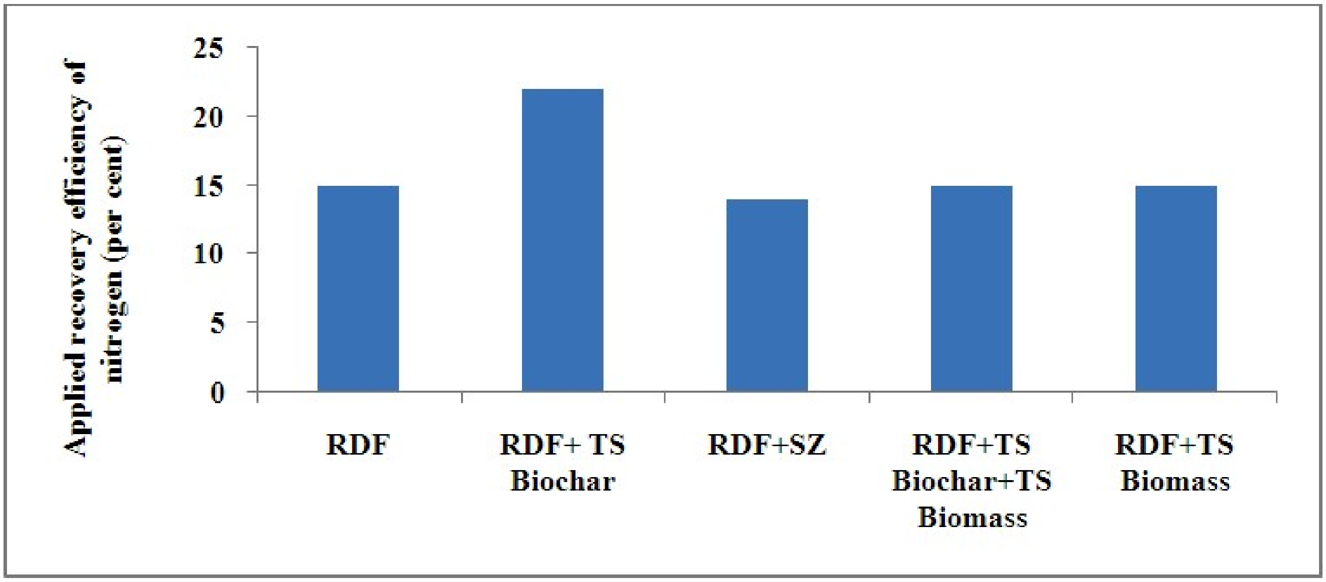

Figure 1: Effect of different soil amendments along with RDF on applied recovery efficiency of nitrogen and potassium

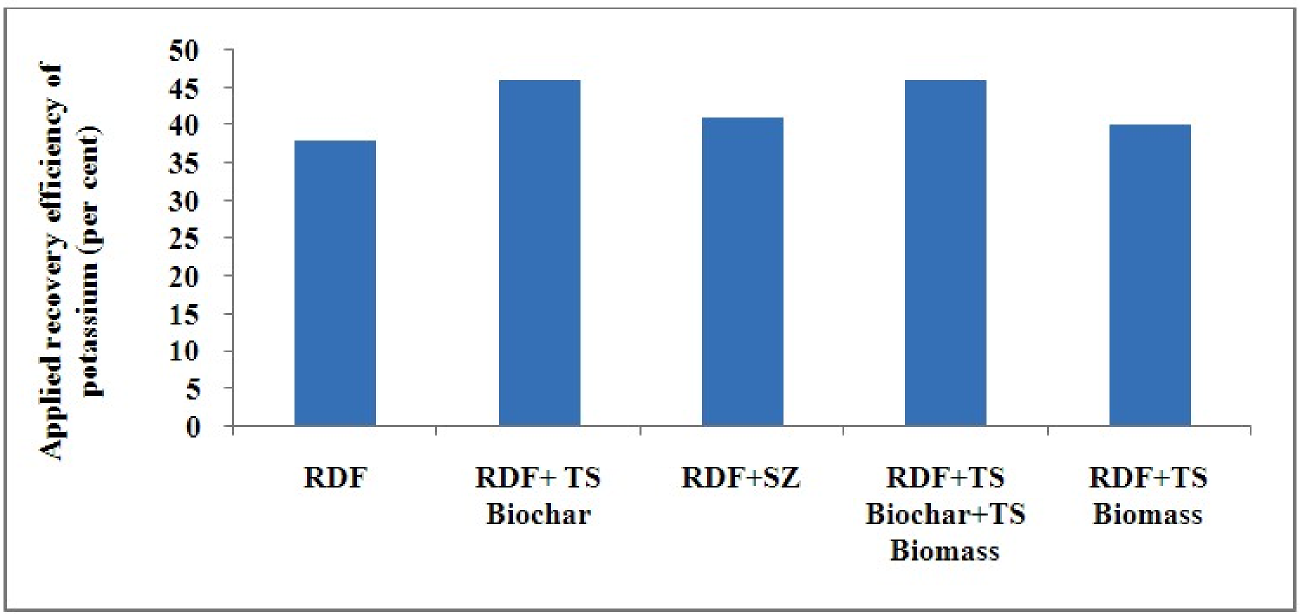

Figure 2: Effect of different soil amendments along with RDF on applied recovery efficiency of potassium

As reported by Rajkovich [16] biochar can reduce soil N losses such as N_2O emissions, NH_3 volatalization, N leaching, and results in net increase in N availability for the crop and higher N use efficiency. Cation exchange capacity is also an important characteristic of biochar. Similar to soils, biochar cation exchange capacity (CEC) represents its ability to electrostatically sorb or attract cations could be responsible for increased availability of N and K. Poorna Bindu [14] suggested that carbonate and carbonate-carboxylate functional groups present in TS biochar are responsible for overall retention of nutrients. Biochar can retain nutrients via several mechanisms including electrostatic adsorption and retention of dissolved nutrients in water i.e entrapment [10]. Biochar amendments had signicantly improved soil nutrient content [8]. This is partly due to direct addition of nutrients such as P and K and partly because reduction in runoff and leaching [9].

CONCLUSION

Application of TS Biochar along with RDF is very essential for improving the N and K in light textured Alfisol. In order to get maximum benefit from organic soil amendments from tobacco, it is necessary to prepare biochar rather than applying biomass. Application of TS Biochar got exclusive advantage of increase in soil pH, when applied alone to acidic soil. Hence, it can be a promising liming material in acid soils.

References

Borchard, N., A. Wolf, V. Laabs, R. Aeckersberg, H. W. Scherer, A. Moeller and W. Amelung. 2012. 'Physical activation of biochar and its meaning for soil fertility and nutrient leaching –a green house experiment', *Soil Use and Management*, 28: 177-184.

Brewer, C. E., Y. Hu, K. Schmidt-Rohr, T. E. Loyanachan, D. A. Laird. and R. C. Nd Brown. 2012. Extent of pyrolysis impacts on fast pyrolysis biochar properties. *Jouranl of Environmental quality,* 41: 1115-1122.

Chan, K. Y, L.Van Zwieten, I. Meszaros, A. Downie and S. Joseph. 2007. Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research*, 45: 629-634

Chan, K. Y. and Z. Xu. 2009. 'Biochar: Nutrient properties and their enhancement' in J. Lehmann and S. Joseph (eds) Biochar for Environmental Management: Science and Technology, *Earthscan,* London, UK, pp68–84.

De Luca, T. H, M. D. Mac Kenxie, M. J. Gundale and W. E. Holben. 2006. Wildfire-produced charcoal directly influences nitrogen cycling in ponderosa pine forests. *Soil Science Society of American Journal*, 70: 448–453.

Grossman, J., B. E. O'Neill, L. McPhillips, S. M. Tsai, B. Liang, E. Neves, J. Lehmann. and J. E. Thies. 2010. Amazonian anthrosols support similar microbial communities that differ distinctly from those extant in adjacent, un modified soils of the same minerology. *Microbial Ecology*, 60:192–205

Jackson, M. L. 1973. Soil Chemical Analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, India, pp. 111-204.

Laird, D. A., P. D. Fleming, B. Wang, R. Horton and D. L. Karlen. 2010 a. Biochar impact on nutrient leaching from a Midwestern agricultural soil. *Geoderma*, 158: 436-442.

Laird, D. A., P. D. Fleming, D. D. Davis, R. Horton, B. Wang. and D. L. Karlen. 2010 b. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma*, 158 : 443-449.

Lehmann, J., P. da Silva, J. Jr, C. Steiner, T. Nehls, W. Zech. and B. Glaser. 2003. Nutrient availability and leaching in an archaeological Antrosol and Ferralsol of the Central Amazon basin : fertilizer, manure and charcoal amendments. Plant and Soil, 249 : 343–357

Mukherjee, A. and A. R. Zimmerman. 2013. Organic carbon and nutrient release from a range of laboratory produced biochars and biochar – soil mixtures. *Geoderma*, 193: 122-130. Doi:10.1016/j.geoderma.2012.10.002

Novak, J. M., W. J. Busscher, D. A. Laird, M. Ahmedna, D. W. Watts. and M. A. S. Niandou. 2009b. Impact of biochar amendment on fertility of a south eastern coastal plain soil. *Soil Science*, 174: 105-112.

O'Neill, B., J. Grossman, M. T. Tsai, J. E. Gomes, J. Lehmann, J. Peterson, E, Neves. and J. E. Thies. 2009. Bacterial community composition in Brazilian Anthrosols and adjacent soils characterized using culturing and molecular identification. *Microbial Ecology,* 58: 23–35

Poorna Bindu, J. Damodar Reddy, D. Santhy P. Ghosh, R. and Ravindra Naik. (2016). Evaluation of tobacco stalk biochar (TS Biochar) for enhancing the nutrient use efficiency of FCV tobacco grown in an Alfisol. *Extended Abstract, Sustainable utilization of tropical plant biomass: bioproducts, biocatalysts and biorefinery (SutB4)* pp: 230-233

Poorna Bindu, J., D. Damodar Reddy, P. Santhy, K.M., Sellamuthu, M. Mohammed Yassin and Ravindra Naik. (2015). Production and characterization of tobacco stalk biochar. *Tobacco Research*. 41(2): 91-96.

Rajkovich, S., A. Enders, K. Hanley, C. Hyland, A. R. Zimmerman. and J. Lehmann. 2012. Corn growth and nitrogen nutrition after additions of biochar with varying properties to a temperate soil. *Biology and Fertility of Soils*, 48: pp271–284

Sollins P, G. P. Robertson. and G. Uehara. 1988. Nutrient mobility in variable and permanent change soils. *Biochemistry*, 6: 181-199. Doi:10.1007/BF02182995

Wang Y, R. Yin. and R. Liu. 2014. Charecterization of biochar from fast pyrolysis and its effect on chemical properties of the tea garden soil. Journal Anals of Applied Pyrolysis, 110: 375-381. Doi:10.1016/j.jaap.2014.10.006