Original Research Article

Effect of chemical fertilizer and tobacco stalks-derived biochar on FCV tobacco yield, nutrient use efficiency and carbon management index in a light textured Alfisol

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ABSTRACT

Aims: To investigate the effect of tobacco stalk biochar (TS Biochar) and synthetic zeolite (SZ) on light textured sandy loam soil in terms of improving the nutrient use efficiency and productivity of FCV tobacco. of esophageal varices in advanced liver disease to validate other screening parameters.

Study design: Randomized block designe (RBD)

Place and Duration of Study: ICAR-CTRI RS, Jeelugumilli, Andhra Pradesh, India.

Methodology: Field experiment was conducted with eight treatments and three replications. The treatments included T1: 100 % NPK; T2: 100% NPK + 1 t ha^{-1} TS Biochar; T3: 100% NPK + 250 kg ha^{-1} Synthetic Zeolite (SZ) ; T4: 100 % NPK + 1 t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ; T5: 100% NPK + 0.5 t ha^{-1} TS Biomass; T6: Adjusted N & K + 1 t ha^{-1} TS Biochar; T7: 1 t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ; T8: Control.TS Biochar was characterized for different functional groups using FTIR analysis

Results: Results revealed that the application of 1 t ha^{-1} TS Biochar + 100% NPK and 1 t ha^{-1} TS Biochar +250 kg ha^{-1} SZ + 100% NPK resulted in a significant increase in tobacco leaf yield compared to the 100% RDF alone . The highest uptake of nitrogen (84.56 kg ha^{-1}) and potassium (122.73 kg ha^{-1}) by tobacco was observed in T_2 (100% NPK +1 t ha^{-1} TS Biochar). Recovery efficiency of N and K applied was greater in tobacco stalk biochar soil amendment with 50.78 and 77.83 per cent as against 100 % NPK alone with 32.83 and 49.64 per cent, respectively. FTIR analysis indicated that TS Biochar is having negative hydroxyl, carbonate and carboxyl functional groups on the surface.

Conclusion: Tobacco stalk biochar (TS Biochar) can serve as soil amendment for enhancing nutrient use efficiency in light textured Alfisols.

Keywords: Tobacco stalks Biochar, Tobacco yield, leaf quality, CMI and Nutrient Use efficiency

1. INTRODUCTION

Tobacco, the golden leaf is one among the leading commercial crops in India with a cultivated area of 0.45 million ha, producing 760 million kg annually. Tobacco made a significant contribution in terms of excise revenue (Rs. 22,737 crore) and export earnings (Rs. 5969 crore), and provides livelihood security to 45.7 million people during the year 2021 [1]. The water soluble fraction of nitrogen and potassium are readily available to plants and are also prone to leaching losses especially in sandy soils due to low cation exchange capacity (CEC). High N and K losses through leaching adversely affect the groundwater quality. To minimize the nutrient leaching losses and to protect environment soil amendments like biochar and zeolite are the best options available. To curtail the leaching losses and improving the soil fertility and nutrient use efficiency, application of soil amendments is in need of use. Soil amendments like Biochar and Zeolite are generally designed to gradually release nutrients at rates that can closely match nutrient demand by plants, while potentially reducing nutrient losses to the environment through leaching, volatilization, and/or runoff. The present study area belongs sandy loam soil and comes under light textured tobacco growing northern light soils (NLS) of Andhra Pradesh are prone to leaching of nutrients, especially nitrogen (N) and potassium (K). These soils are prone to leaching of nutrients, especially nitrogen movement to a depth of 180 cm was observed in these soils [2]. Efforts should be taken to increase nutrient use efficiency and minimize N and K losses from terrestrial to water ecosystems.

On a global scale, crop residue biomass is a problem as well as scope for new challenges and opportunities. The field burning is causing severe air pollution. Therefore, recently thermo chemical conversion has been foreseen as an interesting tool for potential crop residue management strategy under changing climate scenario [3]. Biochar, a byproduct of thermo chemical processes, has been evaluated as a potential soil ameliorant and C sequestration agent. As soil ameliorant, it improves soil basic properties directly and improves essential nutrient dynamics [3]. Use of oat hulls biochar and pine bark biochar in volcanic soil is an effective strategy to increase wheat biomass, increase grain yield production, stimulate the indigenous Arbuscular Mycorrhiza fungi activity, enhance soil quality properties, and increase the sustainability levels of agricultural systems [4]. The grain yield of rice was increased by 37.90% in fertiliser based on soil test value (STV) + biochar + FYM + $ZnSO_4$ and by 22.87% in STV + lime + FYM + $ZnSO_4$ plots than RDF + FYM + $ZnSO_4$ plot. Seed and haulm yield of cowpea increased by 33.57% and 18.53% in STV + biochar + FYM + ZnSO4 treatments as compared with RDF + FYM + ZnSO4 treatment [5]. The combination of Sewage Sludge Biochar (SSB) with mineral NPK fertilizer provided all the macronutrients required for corn and increased the leaf contents, especially for P, leading to an average 16% increase in grain yield in soils that received the treatment SSB300 + NPK [6]. In terms of crop biomass yields, significant biochar × fertilization interactions were observed in barley (in 2013) and peas (in 2016), three and six years after the application of biochar in Stagnosol, respectively. In both cases, the biochar combined with the normal fertilization rate (100% of the recommended value) significantly increased crop biomass yield compared to corresponding fertilization treatment without biochar [7]. The enhanced peanut yield with biochar-based fertilizer could be attributed to increases in main stem height, leaf area, chlorophyll content, photosynthetic rate, and total N and K uptake [8]. The control of soil nutrient loss to lighten non-point source pollution to water body and improving soil fertility is a global problem. Biochar application to soil is widely considered as an effective method to improve soil fertility and reduce nutrient loss [9]. Biochar application to soil can improve soil fertility and increase crop productivity [10]. The application of biochar to soil can significantly improve soil physical and chemical properties to prevent from soil degradation [11]. Biochar-based fertilizer altered soil microbial community and enhanced some plant growth-promoting microbes, which were associated with the improvements of yield and quality of tea plants. Thus, the combination of biochar and chemical fertilizer is feasible for the improvements of tea growth and low nutrients acidic tea orchard soil [12]. Over six years the maize-derived organic materials use have led to significant improvement in soil quality and maize yield, where straw derived biochar was more effective for soil carbon sequestration in Mollisol of Northeast China [13]. Biochar significantly increased the biomass yield by 61 (2% Biochar) and 82 % (3% Biochar), compared to no Biochar. Soil pH, cation exchange capacity, and the concentration of Mehlich-1 P and exchangeable bases (K, Na, and Ca) were significantly enhanced, while exchangeable acidity and the concentration of exchangeable H+, Al, and Fe were significantly decreased following biochar addition. The soil quality index was significantly better in the biochar-added soil than the non-biochar soil [14]. Rice husk biochr (RHB) application improved the short-term soil organic carbon (SOC) gain and rice grain and straw yield. The brown rice yield increased with higher N application rates. RHB supplied significant amounts of C to the paddy soil which was recalcitrant and this increased the soil carbon content after rice cultivation [15]. Application of corn straw biochar has improved the total nitrogen, total organic carbon and available phosphorus in the 0–10 cm soil layer increased by 41%, 55% and 45%, respectively [16]. Biochar produced from a 1:1 mixture of sewage sludge and sugarcane bagasse (MB) treatments increased soil total C (by 27.8%) and pH (by 0.6), reduced the concentrations of nutrients, except for potassium (K), and chromium (Cr), and did not significantly alter lead (Pb) and cadmium (Cd) concentrations [17]. Zeolites are natural minerals and also can synthesize artificially. Zeolites were first discovered in 1756 by a Swedish mineralogist, who named the porous minerals from the Greek word meaning ‘boiling stone’ [18]. They are hydrated alumina silicates, characterized by three dimensional networks of SiO4 and AlO4 tetrahedra, linked by sharing of all oxygen atoms. Partial substitution of Si4+ by Al3+ leads to an excess of negative charge, which is compensated by cations. Within the structure of natural zeolite, water and cations can be reversibly removed or replaced by other cations [19].

Keeping in view of the importance of Biochar and zeolite in improving the crop yield, nutrient uptake, nutrient use efficiency and soil properties, tobacco stalks are the crop residues which are left in the field unutilized were utilized for producing biochar. Hence, the present study has been carried out to evaluate tobacco stalk biochar and synthetic zeolite as well as TS Biomass as such as an amendments for light textured soil with the objective to evaluate the effects of organic and inorganic amendments on FCV tobacco yield, nutrient use efficiency and soil carbon management index in a light textured Alfisol.

2. MATERIAL AND METHODS

The soil amendments used in this study were tobacco stalk biochar (TS Biochar) and synthetic zeolite (SZ). TS Biochar was produced from TS Biomass and SZ was procured from M/S. Zeolites and Allied products, Mumbai, India. TS Biomass is the crop residue which is left unutilized in the field, have been used for preparing the TS Biochar. Synthetic Zeolite is a porous mineral (part of a group of hydrated alumino silicates). It carries a negative charge balanced by freely moving cations with positive charges providing an ideal trap for cations like ammonium and potassium which are then released when demanded by plants.

2.1. Collection of feedstock and its characterization

Freshly harvested stalks of tobacco were used to produce biochar. TS Biomass was manually cut to appropriate size. Fresh samples were stored and left to sundry naturally to moisture content below 10%. Dry bioresidues are prerequisite to hasten satisfactory and quicker conversion. Representative biomass samples were taken for nutrient content analysis. Nutrient composition of biochar depends on the nutrient composition of original TS Biomass, hence chemical analysis of N, P, K, secondary and micronutrients were done as per standard procedures used for plant chemical analysis. Total major nutrient content in tobacco stalks (*Nicotiana tabaccum*) is 0.9 per cent of nitrogen, 0.25 per cent of phosphorus, 1.9 per cent of potassium, 1.02 per cent of calcium and 0.43 per cent of magnesium. [20].

2.2. Biochar preparation

Fresh tobacco (*Nicotiana tabaccum*) stalk biomass was collected for biochar production. It was air dried first and then in an oven at 105 ^{0}C. Biochar was prepared in a low cost, Annual core biochar reactor developed by ICAR-Central Institute of Agricultural Engineering, Bhopal, under limited supply of air. Optimized production parameters earlier for producing tobacco stalks biochar were 500 ^{0}C temperatures over a time period of 90 minutes [20].On cooling, the prepared biochar was stored in a sealed container until further use and subsequent analyses.

2.3. Biochar characterization

2.3.1. Nutrient composition

The TS biochar yield at optimized pyrolysis conditions was around 40% and had 74.9 % fixed carbon, 17.5% ash and remaining 7.6% as volatile matter. The tobacco stalk biochar contained 79% total organic carbon, 1.23% N, 0.51% P, 3.81% K, 2.1% Ca and 0.9% Mg. TS Biochar was alkaline in reaction, with pH of 9.42. and CEC of 30 C mol (p+) / kg [20].

2.3.2. Characterization of TS Biomass and TS Biochar for functional group analysis (FTIR)[23-25]

Prior to FTIR analysis, tobacco stalk biomass was cleaned, dried, powdered, sieved (<0.5mm) and stored in sealed jars. Around 1 g for powdered sample was weighed and dried at 105 ^{o}C for 2 h and then kept in a desiccator for 24 h. Infrared spectroscopy of the powdered samples was carried out using Bruker ALPHA, FTIR/ATR system (Typically 24 scans, Resolution- 4cm^{-1}). Samples analysis was done at ICAR-NINFET, Kolkata.

2.4. field experiment

A field experiment was conducted during winter (*rabi*) season of 2015-16 and 2016-17 at the research farm of ICAR-Central Tobacco Research Institute Research Station, Jeelugumilli (17° 11’ 30" N and 81° 07’ 50" E at 150 m above mean sea-level), West Godavari district in Andhra Pradesh under semi-arid tropical climate. The soil was sandy loam (0-15 cm) and deeper layers (15-45 cm) were sandy clay classified Typic Haplustalfs, with pH 6.30 (1:2.5) and EC 0.20 dS/m (1:2.5). The 8 treatments in all were tested in a RBD with 3 replications. T1: 100 % NPK; T2: 100% NPK + 1 t ha^{-1} TS Biochar; T3: 100% NPK + 250 kg ha^{-1} Synthetic Zeolite (SZ) ; T4: 100 % NPK + 1 t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ; T5: 100% NPK + 0.5 t ha^{-1} TS Biomass; T6: Adjusted N & K + 1 t ha^{-1} TS Biochar; T7: 1 t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ; T8: Control. The tobacco seedlings of 60 days were transplanted in the first week of October in two years. TS Biochar (1 t ha^{-1}), synthetic zeolite (250 kg ha^{-1}), nitrogen (120 kg ha^{-1}) and potassium (120 kg K_2O ha^{-1}) each were applied in three splits in 1:2:1 proportion at 10, 30 and 45 days after planting. Phosphorus was applied @ 60 kg P_2O_5/ha. First split of N in the form of ammonium sulphate & K in the form of sulphate of potash and full dose of P in the form of single super phosphate were applied 10 days after planting as basal dose. Second split of N (50%) was given through urea along with K (50%) in the form of potassium sulphate at 30 days after planting. Remaining 25% N & K was top dressed at 45 days after planting at a spacing of 10 cm away and at a depth of 10 cm on either side of the plant. The recommended packages of practices were followed to raise FCV tobacco in *rabi*. Tobacco leaves were harvested at maturity by priming 2-3 matured leaves each time at 7-8 days interval and cured in the flue-curing barn and on average 8 primings were done to complete harvesting of tobacco. Plant samples were collected at final harvest. Dry weights of the plant parts were taken and N and K content were estimated in various plant parts, *viz.* root, stem, leaves. Soil and plant samples were processed and analysed for the nutrient status as per the standard procedure.[21,22,27]

Data were subjected to statistical analysis as per the standard methods [26]. The N, P and K contents in leaf and stem of all the treatments were determined. Nutrient uptake in terms of kg ha^{-1} (N, P and K) was estimated by multiplying the nutrient content with respective dry weights and total nutrient uptake was obtained by summing the individual uptakes of leaf and stem. The following measures/indices of N and K use efficiency were defined and estimated as per the standard calculations.

***Partial factor productivity for (kg kg^{-1})*:** The partial factor productivity from applied NPK is the ratio of cured leaf yield in amended plot to amount NPK applied.

$PFP = Y_{/} A_{NPK}$

Agronomic Efficiency of K (AE_K): It is the increase in crop yield per unit of NPK applied (i.e ratio of the increase in yield to the amount of NPK applied) and expressed as kg kg^{-1}.

$AE = (Y - Y_0)/ A_{NPK} = \Delta Y/ A_{NPK}$

Apparent Recovery Efficiency of N (RE_N): It refers to the increase in N uptake by plant per unit of N applied. The recovery efficiency is generally expressed in percentage terms (%).

$RE_{N =} (NU- NU_0)/ A_N) \times 100 = (\Delta NU/ A_N)_{x} 100$

Apparent Recovery Efficiency of P (RE_P): It refers to the increase in P uptake by plant per unit of P applied. The recovery efficiency is generally expressed in percentage terms (%).

$RE_{P =} (PU- PU_0)/ A_P) \times 100 = (\Delta KU/ A_P)_{x} 100$

Apparent Recovery Efficiency of K (RE_K): It refers to the increase in K uptake by plant per unit of K applied. The recovery efficiency is generally expressed in percentage terms (%).

$RE_K = ((KU - KU_0)/ A_K) \times 100 = (\Delta KU/ A_K) \times 100$

2.5. Pre-sowing and post-harvest soil analyses

Initial soil samples were collected at randomly and pooled together then made to half kg which represents the entire tobacco field. Soil samples were collected during fallow period and after crop period. Depth wise post harvest soil samples were also collected at 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depths. The soil samples thus collected were air dried, sieved through 2 mm sieve and stored in polythene bags for analysis of various chemical analyses [21-22].

Carbon Management Index [28]

Treatment and reference soils were analyzed for TOC (C_T) by TOC analyzer, labile OC (C_L = C fraction oxidized by 20 mM $KMnO_4$) and total OC (C_T) and Non-labile OC ($C_{NL} = C_T - C_L$).

The CMI was calculated as: Carbon Pool Index (CPI) x Carbon Lability Index (CLI)

$$\text{Carbon Pool Index (CPI):} = \frac{C_T \text{ in treated plot soil}}{C_T \text{ in reference soil}}$$

$$\text{Carbon Lability Index (CLI):} = \frac{\text{Lability of C in treated plot soil}}{\text{Lability of C in reference soil}}$$

Where lability of C represents the ratio of C_L *to* C_{NL}

Carbon Management Index (CMI): = CPI x CLI

2.6. Statistical analyses:

The data obtained was statistically analyzed and LSD was used to compare the mean differences according to the instructions for randomized block design [26]

3. RESULTS AND DISCUSSION

3.1. Characteristics of TS Biomass and TS Biochar for functional group analysis (FTIR)

3.1.1. FTIR of TS Biomass

The FTIR analysis shows several peaks, indicating presence of various functional groups in TS Biomass. The broad characteristic peak around wave number(WN) 3340 cm^{-1} coupled with a weak peak at WN 604 cm^{-1} typically correspond to the O–H stretching vibration of free hydroxyl groups of cellulose and lignin and the out-of-plane deformation of O–H, respectively. The bands around WN 2918 cm^{-1} are due to the stretching vibration of C–H bond in methylene ($–CH_2$) and methyl ($–CH_3$) groups. The peaks at WN 1375, 1328 and 1238 cm^{-1} indicate the in-plane symmetric deformation vibration of $–CH_3$ in lignin, the in-plane bending vibrations of O-H or stretching of C-O in cellulose, and the asymmetric stretching of =C–O–C attached with aryl groups in lignin. The peak at WN 1616 cm^{-1} corresponds to vibration of C=O and C=C. A very weak peak observed at WN 895 cm^{-1} could be associated with the in-plane bending vibrations of C–H or out-of-plane deformation mode of C–H and O–H in pyranoid rings involved in cellulose. A strong band at around WN 1025 cm^{-1} corresponding to C–O–C stretching vibration confirms the cellulose and lignin structures of TSB. (Figure 1)

3.1.2. FTIR of TS Biochar

Production of biochar as a high temperature treatment of tobacco stem biomass resulted in diappeaence of various functional groups. The disappearance of WN 2918 cm^{-1} doublet bands in biochar spectra correlates to a loss of cellulosic content in comparison with the biomass. This also indicated removal loss of volatile hemicellulosic materials from the biomass. Similarly degradation of broad peak around WN 3340 cm^{-1} and resulting degraded broad peak around WN 3030 cm^{-1} indicated dehydration of biomass structure and cleaved of phenolic groups at high temperature (500^{0}C). Vibration in the frequency range of WN 1100 cm^{-1} to 1500 cm^{-1} reflect peaks for carbonate and carbonate-carboxyl and WN 1660 cm^{-1} to 1670 cm^{-1} represents the peaks for carboxylic acid. Peaks at WN 1555 & 1613 cm^{-1} represent basic groups such as quinones. Disapearence of WN 1025 cm^{-1} corresponding to C–O–C stretching vibration confirms degradation of the cellulose and lignin structures of the raw biomass. (Figure 2)

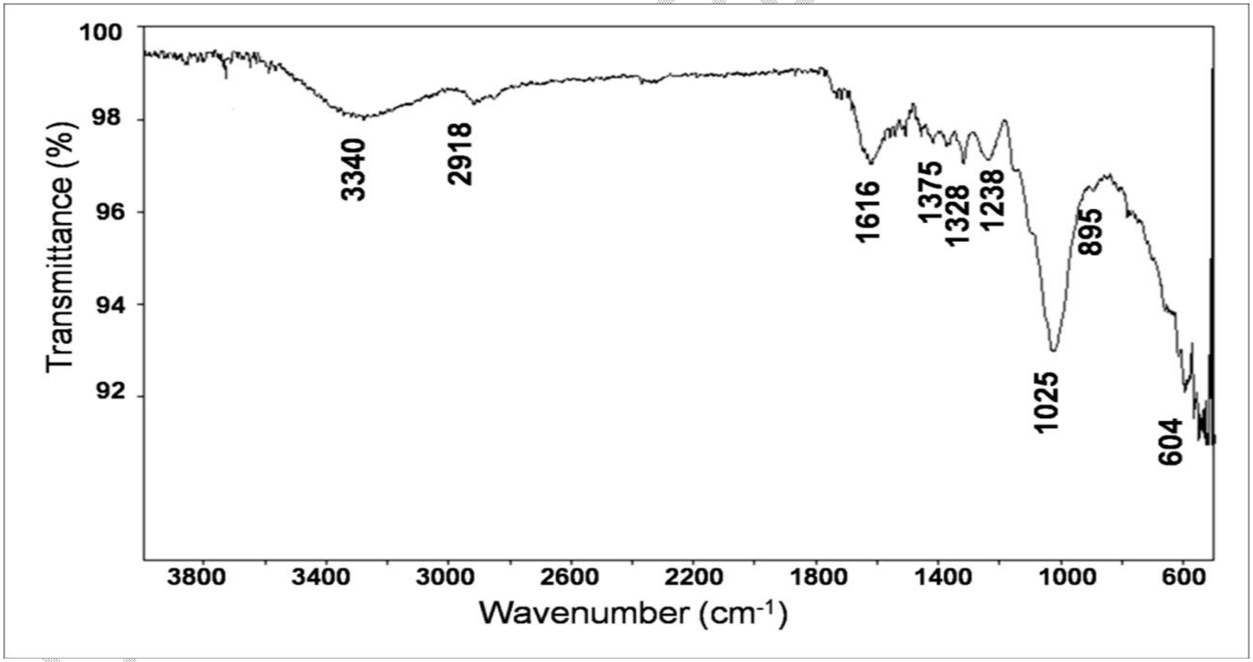

Figure 1: FTIR Spectrum of TS Biomass

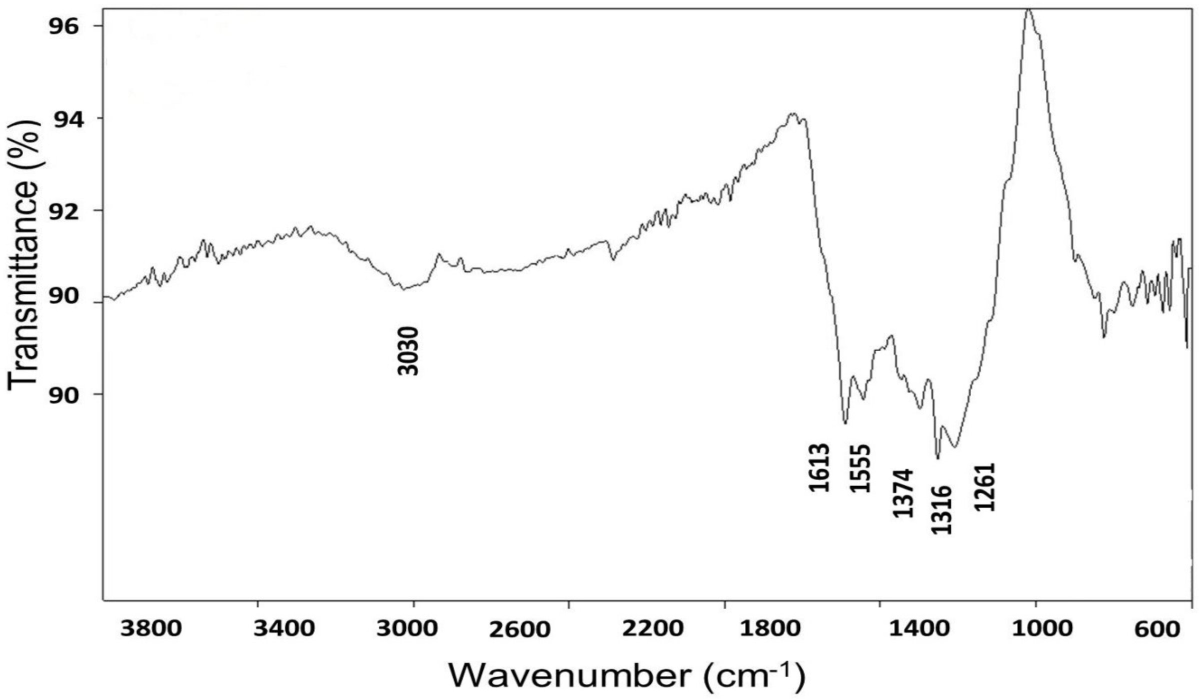

Figure 2: FTIR Spectrum of TS Biochar

The FTIR analysis shows several peaks, indicating presence of various functional groups in TS Biomass. The broad characteristic peak around wave number(WN) 3340 cm^{-1} coupled with a weak peak at WN 604 cm^{-1} typically correspond to the O–H stretching vibration of free hydroxyl groups of cellulose and lignin and the out-of-plane deformation of O–H, respectively. The bands around WN 2918 cm^{-1} are due to the stretching vibration of C–H bond in methylene (–CH_2) and methyl (–CH_3) groups. The peaks at WN 1375, 1328 and 1238 cm^{-1} indicate the in-plane symmetric deformation vibration of –CH_3 in lignin, the in-plane bending vibrations of O-H or stretching of C-O in cellulose, and the asymmetric stretching of =C–O–C attached with aryl groups in lignin. The peak at WN 1616 cm^{-1} corresponds to vibration of C=O and C=C. A very weak peak observed at WN 895 cm^{-1} could be associated with the in-plane bending vibrations of C–H or out-of-plane deformation mode of C–H and O–H in pyranoid rings involved in cellulose, results are in aggrement with [29]. A strong band at around WN 1025 cm^{-1} corresponding to C–O–C stretching vibration confirms the cellulose and lignin structures of TS Biomass, similar results were reported by

[24, 25, 30] for tobacco biomass and tobacco biomass ash and rice husk ash, respectively. The FTIR spectrum indicates the lignocellulosic nature of TS Biomass coupled with various polar functional groups which may develop negative charges and participate in the adsorption of cationic molecules.

Production of biochar as a high temperature treatment of tobacco stalk biomass resulted in diappeaence of various functional groups. The disappearance of WN 2918 cm^{-1} doublet bands in biochar spectra correlates to a loss of cellulosic content in comparison with the biomass. This also indicated removal loss of volatile hemicellulosic materials from the biomass. Similarly degradation of broad peak around WN 3340 cm^{-1} and resulting degraded broad peak around WN 3030 cm^{-1} indicated dehydration of biomass structure and cleaved of phenolic groups at high temperature (500^0C). Results are in aggrement with the [31] reported that charring temperature modifies the functional groups aliphatic C groups to decrease and thery by increases the aromatic C content. Vibration in the frequency range of WN 1100 cm^{-1} to 1500 cm^{-1} reflect peaks for carbonate and carbonate-carboxyl and WN 1660 cm^{-1} to 1670 cm^{-1} represents the peaks for carboxylic acid. Peaks at WN 1555 & 1613 cm^{-1} represent basic groups such as quinones. Disapearence of WN 1025 cm^{-1} corresponding to C–O–C stretching vibration confirms degradation of the cellulose and lignin structures of the raw biomass. Similar results were reported by [32, 33] that peaks representing O- containing functionality, mostly carboxylic groups which were generated in 350-500 ^0C temperature range. The presence of functional groups such as the carboxyl and hydroxyl groups suggest that tobacco stalk biochar could have possibility to be used as a soil amendment for improving the cation exchange capacity and as a potential absorbent. Oxygen containing functional groups present in biochar are responsible for overal sorption of nutrients [34].

3.2. Effect TS Biomass, TS Biochar and Synthetic Zeolite on yield

Application of soil amendments had significantly influenced the growth, yield attributes and yield of tobacco. Number of curable leaves and leaf area index assume practical significance as they are directly related to the productivity. The Plant height, of tobacco is an indirect measure of tobacco growth. The highest plant height, no. of curable leaves, and leaf area index were observed higher in T_2 (100% NPK + 1 t ha^{-1} TS Biochar) and T_4 (100% NPK + 1 t ha^{-1} TS Biochar+ 250 kg ha^{-1} SZ) and were minimum in T_7 (1 t ha^{-1} TS Biochar+250 kg ha^{-1} SZ) (Table 7). The TS Biochar and SZ alone treatment showed significantly lower agronomic performance as compared to NPK and TS Biochar + NPK (Table 1). The increase in yield attributes may be due to the enhanced supply of macro and micro elements as the fact that the incorporation of biochar into crop growing soils might have changed pore size distribution [35] which in turn helps in pores to serve as a shield by protecting biochar decomposing microbes from desiccation, the organic matter adsorbed to biochar provides energy and mineral nutrition requirements for crop growth [36-37]. Biochar amended plots had significant higher maize height, LAI and grain yield than control[38] especially as soil conditioner and organic fertilizer, thus increasing carbon sequestration, soil fertility, microbial activities, value of pH, recycling of plant nutrients, water holding capacity, soil contamination etc. [39].

Table 1. Effect of soil amendments on growth parameters at 60 Days after planting (before topping) of FCV tobacco grown in an Alfisol

Treatment	**Leaf Area Index (LAI)**	**Plant height (cm)**	**No. of Leaves**
100% NPK	1.62	76	22
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	1.89	84	24
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	1.48	78	23
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	1.76	84	24
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	1.58	83	23
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	1.47	76	22
1t ha^{-1}TS Biochar + 250 kg ha^{-1}SZ	0.82	33	15
Un amended and unfertilized cropped control	0.85	40	17
SEm±	0.09	4.68	1.46
CD (p=0.05)	0.18	9.61	3.0

The agronomic performance of the FC Virginia tobacco was studied in field trials under the effect of TS biochar, Synthetic Zeolite and fertilizer treatments during 2015-17 (Table 2). Two years pooled analysis results indicated that the green leaf yield (GLY) and cured leaf yield (CLY) was maximum in TS Biochar along with fertilizer applied treatments. Green leaf yield of tobacco ranged from 6354 to 18205 kg ha^{-1} among different treatments. Green leaf yield in T_2 (100 % NPK+1 t ha^{-1} TS Biochar) registered the highest among different soil amendment treatments with 18205 kg ha^{-1}. Among different soil amendments minimum green leaf yield was recorded in T_7 (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 7538 kg ha^{-1}. Results showed that cured leaf yield was influenced by the different soil amendments (Table 2). Cured leaf yield of FCV tobacco ranged from 856 kg ha^{-1} to 2451 kg ha^{-1} among soil amendments. Among different soil amendments, cured leaf yield was registered the highest in T_2 (100% NPK+1 t ha^{-1} TS Biochar) and was followed by T_4 (100 % NPK +1t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 2451kg ha^{-1} and 2387 kg ha^{-1} respectively. (Table 2).

Table 2. Effect of soil amendments on leaf yield (kg ha^{-1}) of FCV tobacco grown in an Alfisol (Pooled)

Treatment	Green Leaf Yield (GLY)	Cured Leaf Yield (CLY)
100% NPK	16068	2158
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	18205	2451
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	16365	2180
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	17630	2387
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	16169	2170
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	15517	2069
1t ha^{-1}TS Biochar + 250 kg ha^{-1}SZ	7538	1001
Un amended and unfertilized cropped control	6354	856
SEm±	317	52

CD (p=0.05)	917	149
Seasons		
1st Year	10080	2014
2nd Year	8894	1804
SEm±	158	26
CD (p=0.05)	458	75

Our study shows a crop productivity enhancement through TS Biochar application along with recommended NPK. Application of biochar along with recommended dose of NPK will help in increasing in crop yield. Low biochar application rate (~1 t/ha) by banding may provide significant positive effects on yield and fertiliser requirement[40]. Biochar and N fertilizer can synergistically interact to improve soil C storage in paddy fields also mitigating the climate change [41]. Crop yield is mainly a function of nutrients supply from the soil in adequate quantities and their utilization in metabolic process resulting in building up of dry matter and quality of tobacco. Increased yield over 100 % RDF was maximum in T_2 (100% NPK+1 t ha^{-1}) by 13 %. Results are in aggrement with dual application of biochar and KCl fertilizer application, which increased maize production by 29 % [42]. A possible mechanism for yield improvement may be due to increase of soil water holding capacity [43]. The significant additional yield of tobacco stalk biochar applied plots over recommended NPK alone, could be due to additional benefit of biochar. Results are in aggrement with [44], that additional yield increase was observed with the biochar along with fertilizers. TS Biochar increased the crop yield might be due to its added benefit to the soil which has minimized the leaching of nitrogen and potassium which is evidenced from the results of column experiment, which indicates that per cent inhibition of leaching of ammonium and potassium were maximum in tobacco stalk biochar [45]. The reason for this might be due to the high carbon content of TS Biochar which would have improved the structure of sandy soil which helped in improving the yield of crop. The increase in tobacco yield may be due to tobacco stalk biochar which contain hydroxyl functional groups (figure 2) that helped in promoting growth, enhanced the number of curable leaves, plant height and leaf area index. Similar results were observed by [46] that biochar amendment significantly increased rice yield by

10%. [47] reported that maize yields were significantly improved in sandy acid soil by application. of cow manure biochar in a green house experiment. [48] reported that maize yields were significantly improved in sandy acid soils by application of 20 t ha^{-1} cow manure biochar in green house experiment. [49] reported that liming effect of these soil amendments has improved soil pH and available nutrients might have improved plant growth in pot experiment with maize. Among soil amendments, the green leaf and cured leaf yield decreased in T_7 (1 t ha^{-1} TS Biochar +250 kg ha^{-1} SZ) due to the low indigenous supply of nutrients especially nitrogen which is essential for tobacco crop. This is due to the absence of recommended NPK that causes decreased plant height, Leaf area index and less number of curable leaves. Biochar has shown to increase crop production and fertility in acidic, and highly weathered crop soils[50-52]. The improved biomass yield could be involved in a few mechanisms, including liming effect, co-addition of nutrients with the added biochar, and nutrient use efficiency. In brief, biochar is a potential amendment in mitigating the constraints of acidic soils, leading to the enhanced biomass yield of elephant grass in the soils [53]. This suggests that TS biochar application is a viable strategy in light textured Alfisols of Andhra Pradesh, India. Also it can be a effective crop residue management strategy by cutting down the environmental pollution by open burning of crop residues.

3.3. Effect TS Biomass, TS Biochar and Synthetic Zeolite on nutrient uptake and use efficiency

Results showed that the total uptake of nitrogen by FCV tobacco was significantly influenced with soil amendments. Application of soil amendments along with recommended dose of NPK has improved the nitrogen uptake over T_1 (100% NPK) (Table 3). Among different soil amendments, total nitrogen uptake by tobacco varied from 28.87 to 84.56 kg ha^{-1}. Maximum total nitrogen uptake by tobacco was observed in T_2 (100% NPK+1 t ha^{-1} TS Biochar) which was statically on par with T_4 (100% NPK+1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) by **(**84.56 and 80.14 kg ha^{-1}, respectively). The least total nitrogen uptake by tobacco was noticed in T $_7$ (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 28.87 kg ha^{-1}. Among different soil amendment treatments, total phosphorus uptake by tobacoo varied from 5.86 to 19.54 kg ha^{-1}. Maximum total phosphorus uptake by tobacco was observed in T$_2$ (100% NPK+1 t ha^{-1} TS Biochar) (19.54 kg ha^{-1}). The least total phosphorus uptake by tobacco was noticed in T$_7$ (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 5.86 kg ha^{-1}. Among different soil amendments, total potassium uptake by tobacco varied from 47.16 to 120.87 kg ha^{-1}. Maximum potassium total uptake by tobacco was observed in T$_2$ (100% NPK+1 t ha^{-1} TS Biochar) which was statically on par with T$_4$ (100% NPK+1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) (122.73 and 116.97 kg ha^{-1}, respectively). Minimum total potassium uptake by tobacco was noticed in T$_7$ (1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 47.16 kg ha^{-1}.

Table 3. Effect of soil amendments on total nutrient uptake (kg ha^{-1}) of FCV tobacco grown in an Alfisol

Treatment	N	P	K
100% NPK	63.02	11.35	89.94
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	84.56	19.54	122.73
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	71.79	14.19	89.96
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	80.14	16.72	116.79
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	72.29	14.12	104.74
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	65.91	12.93	93.06
1t ha^{-1}TS Biochar + 250 kg ha^{-1}SZ	28.87	5.86	47.16
Un amended and unfertilized cropped control	23.62	4.60	30.37
SEm±	2.86	0.46	3.71
CD (p=0.05)	5.87	0.94	7.61

Agronomic use efficiency of different soil amendments along with NPK varied from 3.94 to 5.29 kg kg^{-1}. Application of tobacco stalk biochar along with recommended dose of fertilizer (T_2) had the highest agronomic use efficiency of FCV tobacco (5.29 kg cured leaf yield per kg of nutrient applied). Partial factor productivity of different soil amendments along with NPK was varied from 7.14 to 8.49 kg^{-1}. Application of TS Biochar along with recommended NPK (T_2) had the highest partial factor productivity of FCV tobacco (8.49 kg cured leaf yield per kg of nutrient applied) (Table 4). Apparent recovery efficiency of nitrogen of different soil amendments along with NPK ranged from 32.83 to 50.78 per cent. Application of soil amendments along with recommended dose of fertilizer (T_2) had the highest apparent recovery efficiency of nitrogen (ARE_N). Apparent recovery efficiency of phosphorus of different soil amendments along with NPK ranged from 11.25 to 24.91 per cent. Application of soil amendments along with recommended dose of fertilizer (T_2) had the highest apparent recovery efficiency of phosphorus (ARE_P) (24.91 %). Apparent recovery efficiency of potassium of different soil amendments along with NPK was ranged from 49.64 to 77.83 per cent. Application of soil amendments along with recommended NPK (T_2) had the highest apparent recovery efficiency of potassium ARE_K (77.83%) (Table 5).

Table 4. Effect of soil amendments on nutrient use efficiency indices of FCV tobacco grown in an Alfisol

Treatment	AE	PFP
100% NPK	4.28	7.48
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	5.29	8.49
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	4.37	7.57
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	5.01	8.21
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	4.55	7.75
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	3.94	7.14

Table 5. Effect of soil amendments on apparent recovery efficiency of FCV tobacco grown in an Alfisol

Treatment	ARE_N	ARE_P	ARE_K
100% NPK	32.83	11.25	49.64

100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	50.78	24.91	77.83
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	40.14	15.09	49.66
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	47.10	20.21	72.67
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	40.56	15.86	59.59
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	35.24	13.89	52.24

Uptake of nutrients like N, P and K are enhanced significantly in TS biochar treated soil (Table 3). These results were in harmony with Similar effect of biochar on N uptake in which it was observed that application of biochar significantly increased uptake of plant N[54] . High N uptake of radish plants grown in biochar amended soils[44]. Increased nutrient uptake due to addition of K rich ash content of biochar[55, 56]. Nutrient uptake of *lactuca sativa* increased due to application of biochar[57]. Recommended the use of biochar with inorganic or organic fertilizer for crop production. Plant uptake was increased due to higher available nutrients present in soil [58]. The minimum nutrient uptake by tobacco was observed in T_7 (100 % NPK+ 1 t ha^{-1} TS Biochar+ 250 kg ha^{-1} SZ). The decrease in nutrient uptake may be due to minimum availability of nutrients in the soil and reduced root development by the plant since it was applied with nutrients from biochar alone. With appropriate recommended doses with extra nutrient application will increase robustly the growth and development of plant. The similar finding where 100% recommended dose of fertilizer significantly enhanced N (157.0 kg ha^{-1}), P (47 kg ha^{-1}) and K (247 kg ha^{-1}) uptake by sorghum but nutrient uptake was decreased at 50% recommended dose of fertilizer [59]. Reductions in foliar N concentrations in a pot trial with a relatively nutrient-rich peanut hull biochar, but in this case the reduction likely resulted from increased N use efficiency since the authors reported biomass increases of up to 60%[60]. Whereas in the present study biochar application has increased the tobacco yield by 13 per cent, which might have increased the concentration in the plant and thereby uptake and use efficiency (Table4). As per [61], biochar can reduce soil N losses such as N_2O emissions, NH_3 voltalization and N leaching [62] and increase N input through N fixation rates [63] so that net outcome of its addition is assumed to be a higher N availability for the crop and higher N use efficiency. The liming effect of biochar reduces concentration of iron and aluminium in the soil solution, so the previously bound P then become better available to plants [64] Indirectly biochar can have positive effects on abundance of mycorrhizal fungi which increases N and P plant nutrition [65]. Biochar can increase soil cation exchange capacity allowing further retention of nutrients such as K while reducing losses of P through leaching due its capacity to adsorb thin nutrients on surface[66]. Plant productivity is directly influenced by nutrient availability, which is a product of nutrient transformations in the soil environment [67]. Application of biochar has increased the nutrient use efficiency of different crops [68, 69]. The higher recovery efficiency of nutrients in TS Biochar (Table 5) could be due to the presence of carbonate and hydroxyl functional groups thus reducing the leaching losses. Biochar has a highly porous structure, large surface area, and high cation exchange capacity all of which bestows on it a high sorptive capacity that can be exploited during nutrient recovery [83-84].

3.4. Effect TS Biochar on Soil Properties and Carbon Management Index (CMI)

Soil quality was evaluated in terms of soil pH, available K and total organic carbon, $KMnO_4$ oxidizable carbon and carbon management index of an Alfisol amended with different organic and inorganic soil amendments after field experiment. Depth wise soil samples results were presented below. Irrespective of the treatments, the soil pH decreased with increase in depth of soil. Application of soil amendments had increased the pH of the soil.

3.4.1. Soil pH

Application of NPK alone has resulted in decrease in pH of soil at all depths over control. NPK along with soil amendments had markedly increased the soil pH over NPK alone. Among different soil amendments with NPK higher change in pH was observed in T_3 (100 % NPK +250 kg ha^{-1} SZ) with 5.46, 5.22, 4.81 and 4.63 at 00-15cm, 15-30cm, 30-45cm and 45-60cm, respectively. The minimum pH was observed in T_5 (100 % RDF +0.5 t ha^{-1} TSP) with 5.11, 4.69, 4.38 and 4.32 at 00-15cm, 15-30cm, 30-45cm and 45-60cm, respectively.Irrespective of all the treatments maximum pH was observed in T_7 (1 t ha^{-1} TS Biochar+250 kg ha^{-1} SZ) followed by T_8 (un fertilized un amended cropped control). Minimum pH was recorded in T_1 (100% NPK) (Table 6)

Available potassium

Soil available potassium was monitored at different depths after harvesting of FCV tobacco. Application of soil amendments has improved the available potassium content of soil. Application of soil amendments improved available potassium status in surface soil layer, whereas at lower depth lower available potassium was observed. (Table 7)

3.4.2. Total organic carbon

Total organic carbon content decreased with increase in soil depth. Total organic carbon content was highly influenced by application of different soil amendments (Figure 3). Among different soil amendments, total organic carbon varied from 0.69 -1.02 per cent. Higher total organic carbon content was observed in T_2 (100% NPK+1 t ha^{-1} TS Biochar) which was on par with T_4 (100% NPK+1 t ha^{-1} TS Biochar +250 kg ha^{-1} SZ) by 1.02 and 0.96 per cent respectively at 00-15 cm depth of soil. The minimum total organic carbon content was measured in T_3 (100% NPK + 250 kg ha^{-1} SZ) with 0.69 per cent. Tobacco stalk biochar containing treatments had significantly improved the total organic carbon content of the soil. In comparison of all treatments, T_2 (100% NPK +1 t ha^{-1} TS Biochar) showed maximum total organic carbon per cent in soil. The minimum total organic carbon per cent in soil was recorded in T_3 (100% NPK + 250 kg ha^{-1} SZ).

Table 6. Effect of soil amendments on soil pH at different depths

Treatments	Soil pH (1:2)

	Soil depth (cm)			
	0-15	15-30	30-45	45-60
100% NPK	4.63	4.93	4.56	4.32
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	5.41	4.23	4.11	4.05
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	5.46	5.22	4.81	4.63
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	4.92	4.57	4.32	4.23
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	5.11	4.69	4.38	4.32
Adjusted RD of N and K + 1t ha^{-1} TS Biochar	5.10	4.49	4.15	4.01
1t ha^{-1}TS Biochar + 250 kg ha^{-1}SZ	6.65	5.75	5.02	5.34
Un amended and unfertilized cropped control	5.85	5.71	5.63	5.43
SEm±	0.15	0.07	0.07	0.09
CD (p=0.05)	0.23	0.15	0.16	0.20

Table 7. Effect of soil amendments on soil available potassium

Treatments	Available Potassium (mg kg^{-1})			
	Soil depth (cm)			
	0-15	15-30	30-45	45-60
100% NPK	34.6	70.0	124.2	172.6
100% NPK + 1t ha^{-1} tobacco stalk biochar (TS Biochar)	43.8	90.3	125.0	132.9
100% NPK + 250 kg ha^{-1}synthetic zeolite (SZ)	65.5	115.7	169.9	136.8
100% NPK + 1t ha^{-1} TS Biochar + 250 kg ha^{-1}SZ	47.2	68.6	123.6	142.5
100% NPK + 0.5 t ha^{-1}Tobacco stalk biomass (TS Biomass)	39.9	72.0	104.4	141.3

Adjusted RD of N and K + 1t ha^{-1} TS Biochar	35.8	83.6	88.1	123.9
1t ha^{-1}TS Biochar + 250 kg ha^{-1}SZ	54.6	75.4	110.7	128.6
Un amended and unfertilized cropped control	30.8	35.9	93.3	110.2
SEm±	0.71	1.64	2.06	2.81
CD (p=0.05)	1.46	3.37	2.94	5.77

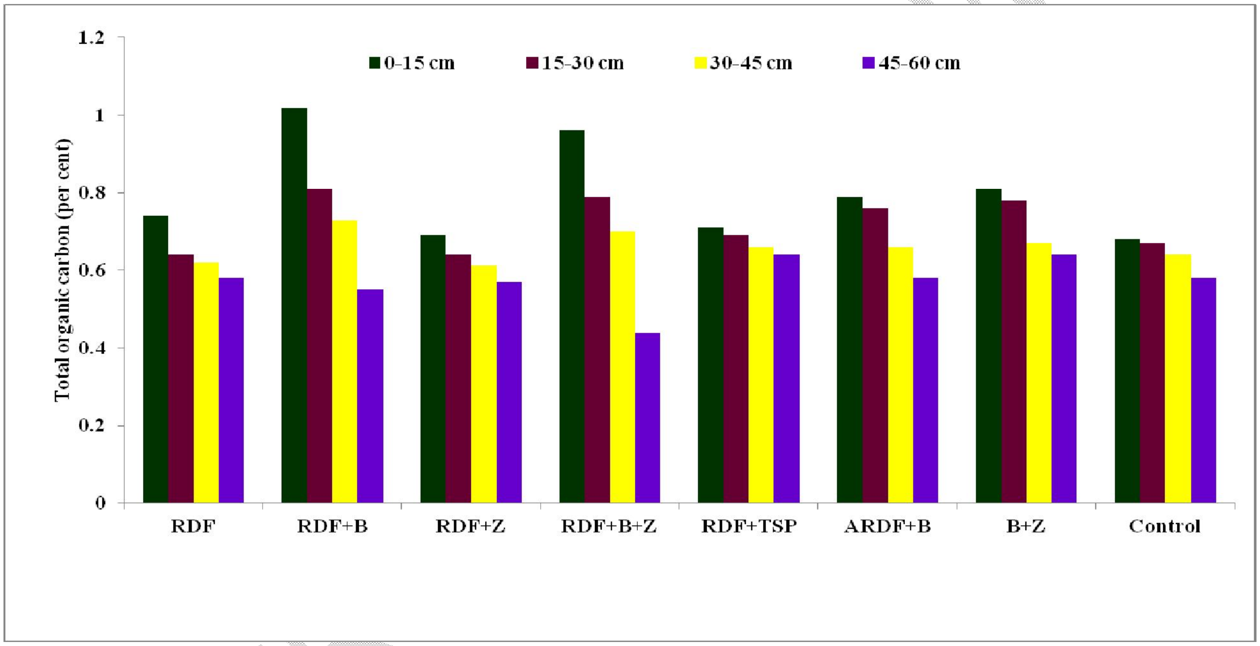

Figure 3. Depth wise distribution of total organic carbon content of soil

3.4.3. KMnO$_4$ oxidizable carbon

To estimate the labile carbon content of the soil potassium permanganate oxidizable carbon content was measured. Application of organic soil amendments has improved the KMnO$_4$ oxidizable carbon content. Irrespective of all the treatments KMnO$_4$ oxidizable carbon content decreased with increase in soil depth. Among different soil amendments, maximum KMnO$_4$ oxidizable carbon content was recorded in T_2 (100% NPK+1 t ha^{-1} TS Biochar) with 998 mg kg^{-1} followed by T_4 (100% NPK+1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 982 mg kg^{-1} in surface soil layers. The minimum $KMnO_4$ oxidizable carbon content was observed in T_3 (100% NPK + 250 kg ha^{-1} SZ) (758 mg kg^{-1}). Irrespective of all the treatments maximum $KMnO_4$ oxidizable carbon content was recorded in T_2 (100% NPK +1 t ha^{-1} TS Biochar) followed by T_4 (100% NPK +1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ). The minimum $KMnO_4$ oxidizable carbon content was observed in T_3 (100% NPK + 250 kg ha^{-1} SZ). (Figure 4).

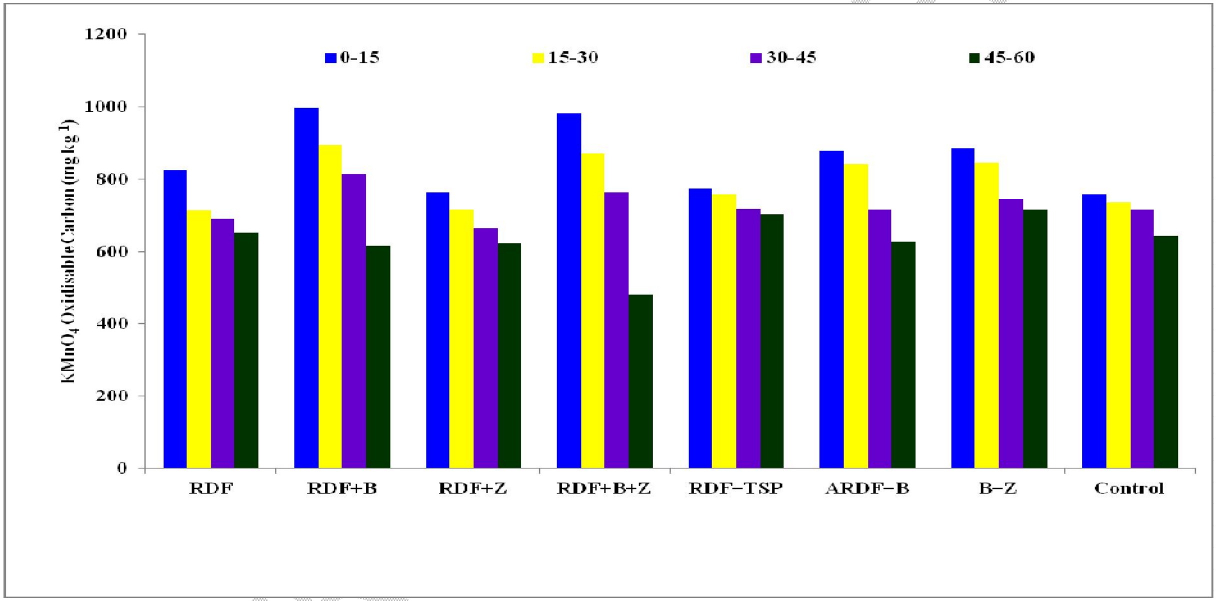

Figure 4. Depth wise distribution of permanganate oxidizable carbon content of soil

3.4.4. Carbon Management Index

All the soil amendments showed significant differences in CMI values as compared to the control (100). Among different soil amendments, maximum CMI was recorded in T_2 (100% NPK +1 t ha-1 TS Biochar) with 129.6 followed by T_4 (100% NPK+1 t ha^{-1} TS Biochar + 250 kg ha^{-1} SZ) with 116.7 at 0-15 cm depth. The minimum CMI was observed in T_3 (100% NPK+ 250 kg ha^{-1} SZ) (100.4).Irrespective of all the treatments, maximum CMI was recorded in T_2 (100% NPK +1 t ha^{-1} TS Biochar). The minimum CMI was observed in T_3 (100% NPK + 250 kg ha^{-1} SZ) (Figure 5).

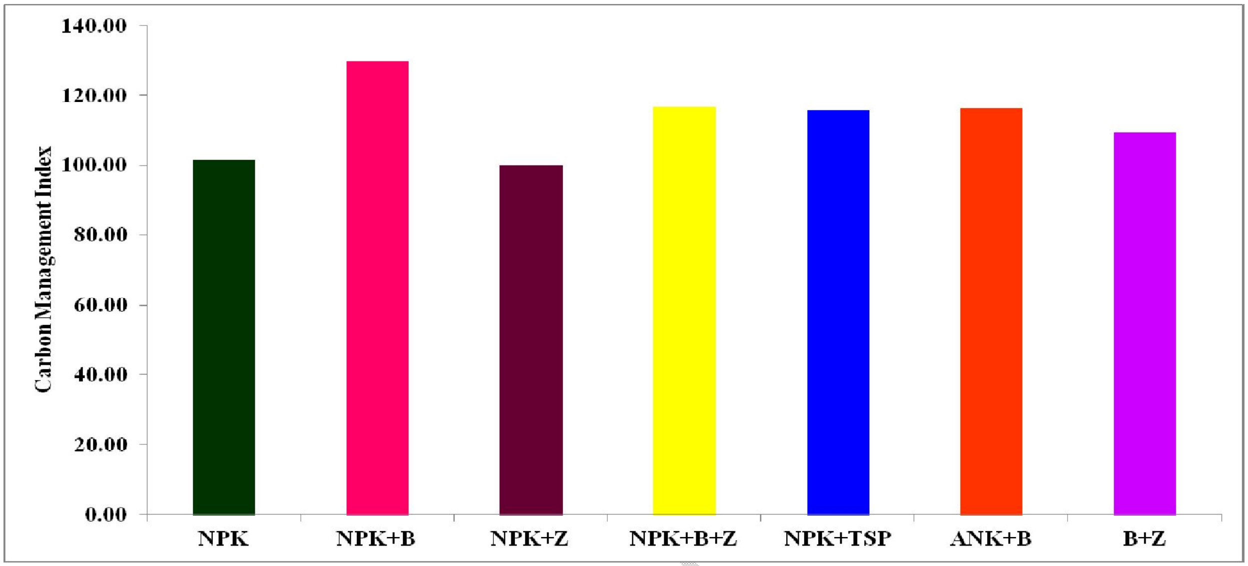

Figure 5. Effect of soil amendments on carbon mangaemet index (CMI) in surface layer (0-15 cm) of FCV tobacco grown Alfisol

Application of TS Biochar has improved the soil properties significantly. Light textured northern light soils (NLS) of Andhra Pradesh are prone to leaching of nutrients, especially nitrogen movement to a depth of 180 cm was observed in these soils [2]. Results indicated that improvement in N and K level in surface layers especially in TS Biochar and NPK shows the significance of biochar application with recommended fertilizer.These results are in accordance with [70] who reported that addition of biochar to the Norfolk soil increased soil pH, soil organic carbon, calcium, potassium, manganese and phosphorus. Generally nutrients are retained in soil and remain available to crops mainly by adsorption to clay minerals and soil organic matter. The addition of organic matter such as compost and manure into soil can help retain nutrients. Biochar is considered much more effective than other organic matter in retaining and making nutrients available to plants [71]. Its surface area and complex pore structure are hospitable to bacteria and fungi that help plants to absorb nutrients from the soil. TS Biochar results are consistent with findings of [51] that biochar application reduced leaching of applied mineral N fertilizer and promoted better use of applied nutrients. This is why the agronomic performance of FCV tobacco was improved over time and the availability of fertilizer improved in the presence of biochar. Soil pH has increased in most studies reporting effects of biochar additions on soil pH [72, 73]. Soil pH is an important indicator of biochar. A number of studies had reported that the addition of biochar increases soil pH [74] who reported that application of oak wood biochar with initial pH 9.4 and carbon content 90% signicantly improved pH by 0.4 units and increased soil carbon by 26% but did not changed soil nitrogen relative to control. Similar results were observed in the present study that application of tobacco stalk biochar has slightly increased the pH of soil (Table 6). Soil organic carbon (SOC) is the most critical determinant of soil quality for sustainable crop production. SOC affects crop productivity through its effects on physical, chemical and biological aspects of soil fertility and productivity. The SOC storage and its pools may be altered variably by soil management practices including fertilizer use, organic amendments, tillage, irrigation *etc.* [81,82] Understanding SOC changes in response to varied fertilizer regimes is important to make informed decisions on appropriate management interventions. [76] reported that biochar application significantly increased the soil carbon content, the soil cation exchange capacity and the availability of NH_4^+, P and K. Biochar addition to soil have significant effects on soil biogeochemical processes and in minimum nutrient losses to influence the yield and quality of crops. In the present investigation, the availability of macro nutrients in soil were increased with the application of 100% NPK+1 t ha^{-1} TS Biochar (T_2) and 100% NPK + 1 t ha^{-1} TS Biochar+ 250 kg ha^{-1}SZ (T_4). Lesser availability of potassium was observed in T_3 (100% NPK+250 kg ha^{-1} SZ). TS Biochar has improved the total organic carbon content of the soil than tobacco stalk powder. SOC is one of several key indicators of soil quality, [76] addition of rice straw and biochar to paddy soils contributed to soil organic carbon. TS Biochar application has significantly improved the soil available nutrients such as potassium which might be due to reduction in leaching losses, which is evidenced from the reduction in leaching losses of nutrients to the lower layers. Biochar amendments had signicantly improved soil nutrient content [77]. This is partly due to direct addition of such as P and K [78] and partly because reduction in runoff and leaching [77]. [79] reported that available P and K contents were signicantly greater in soils amended with biochar especially in rice biochar than in control soils. K content of soil increased from 40-374 mg kg^{-1} [80]. Biochar could store nutrients and be used as a slow release fertilizer due to specific biochar properties eg: pore structure and functional groups. The CMI compares the changes that occur in total and labile C as a result of agricultural practices [28]. The highest CMI value for TS Biochar treated soils indicates that biochar application in the field have resulted in more content of total organic carbon(Figure 3) and labile organic carbon (Figure 4) so there is an advantage of TS Biochar as an carbon sequestration agent. In the present study the TS Biochar applied treatments have showed higher CMI (Figure 5), indicating that it has higher carbon sequestering potential when compared with rest of the amendments.

4. CONCLUSION

Among the three soil amendments i.e. TS Biochar, Synthetic Zeolite and TS Biomass as such tested to enhance the tobacco productivity, nutrient use efficiency in light textured acid soils, it resulted in TS Biochar along with recommended NPK has significantly improved the yield, nutrient uptake, nutrient use efficiency of FCV tobacco due to its carbonate and hydroxyl functional groups as well as acted as liming agent and also as carbon sequestering agent as evindenced from its higher Carbon management index.

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