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Effect of levels of mulberry shoots biochar, Farm yard manure and NPK fertilizer on soil properties under tree mulberry garden

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Abstract
A field experiment was conducted during 2022, at Krishi Vigyan Kendra, Hassan, to know the effect of biochar and Farm Yard Manure (FYM) on soil properties. The experiment was planned in Randomized Complete Block Design (RCBD) with 10 treatments T_1: Absolute Control (without biochar and FYM), T_2: 100 per cent NPK, T_3: FYM @ 20 t $ha^{-1}y^{-1}$, T_4: 100 per cent NPK + FYM@ 20 t ha^{-1} (Package of practice), T_5: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$, T_6: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$, T_7: 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$ and T_8: 75 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$, T_9: 75 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$, T_{10}: 75 per cent NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t $ha^{-1}y^{-1}$replicated trice. The result revealed that combined application of 100 per cent recommended NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$ to soil significantly increased the Maximum water holding capacity (49.34 %), as compared to initial soil properties of experimental site. Significantly increased the soil pH (initial acidic (5.89) to neutral at harvest (6.87), Electrical Conductivity (EC) (0.23 dS m^{-1}), available nitrogen (361.17 kg ha^{-1}), available phosphorus (52.23 kg ha^{-1}), available potassium (299.39 kg ha^{-1}), exchangeable Ca [4.53 c mol (p^+) kg^{-1}] and Mg [2.49 c mol (p^+) kg^{-1}] available sulphur (15.89 mg kg^{-1}) and Diethylene triaminepenta acetic acid (DTPA) extractable micronutrients (Fe, Zn, Mn and Cu)compared to absolute control and package of practice treatments.

Keywords: Mulberry shoots biochar, soil pH, exchangeable calcium, available phosphorus

1. Introduction
Mulberry is one of the most important commercial crop grown extensively as a food plant for silkworm. It is a perennial and high biomass producing plant. The mulberry leaf quality plays a vital role in healthy growth of silkworm and the economic traits such as larval, cocoon and grainage parameters which are influenced largely by the nutritional status of the leaves fed to silkworm (Krishnaswami *et al*., 1971) [14]. When foliage has been used as food for silkworm, shoots is left wasted. These shoots often take a long time to decompose in soil. Keeping in this view mulberry shoots can be used as a feedstock for biochar production.
Biochar is a carbon-rich substance, produced by thermal decomposition of organic compounds at a relatively higher temperature (<700 °C) under limited supply of oxygen called pyrolysis. It contains more than 60 per cent carbon and is rich in various nutrients essential for crop growth. Retuning biochar to the field can quickly improve soil carbon storage and improve crop yields. Biochar has a great, stable, and a long term potential in carbon sequestration.
In recent years, biochar has emerged as an organic amendment with mineral nutrient elements and hold a promise to improve the soil quality and yield of crops. The biochar is found to have a positive impact on soil fertility, resulting in an increase in crop yield without causing a hazard to soil and water environment.
Biochar serves as a catalyst that enhances plant uptake of nutrients and water. Compared to other soil amendments, the high surface area and porosity of biochar makes it to adsorb or retain nutrients and hold moisture and in addition to this labile fraction of C in biochar provides C and energy to heterotrophic beneficial microorganisms to flourish and the ash fraction may supply some of the mineral nutrient requirements for crops (Glaser *et al*. 2002, and Warnock *et al*. 2007) [12, 27].
Addition of biochar to soils has attracted widespread attention as a method to sequester carbon in the soil. Increased soil carbon sequestration can improve soil quality because of the vital

role that carbon plays in chemical, biological and physical soil processes and many interfacial interactions. Biochar application to soil may thus improve the physical properties of soil because of retardation of native stable organic matter decomposition. It persists for a longer time in soil. Therefore, the studies on effects of biochar application on soil properties especially in mulberry garden and its potentiality as a nutrient source are very scanty and it deserves detailed investigation

2. Materials and Methods

A field experimentwas conducted during 2022, at the Krishi Vigyan Kendra, Kandali, Hassan. The experimental site is geographically located in Southern Transition Zone (Zone-7) of Karnataka and lies between12º 58ˈ57ˮ North latitude, 76º 2ˈ32ˮ East longitude at an altitude of 940 m above the mean sea level and it receives an average rainfall of 839 mm annually.

The soil of experimental plot was sandy loam in texture and prior to the laying out of the experiment, the soil samples were collected randomly drawn from 0 to 30 cm depth. The samples were mixed thoroughly and made into one composite sample. The composite sample of around 500 g was taken, air dried and grounded it and then passed through a 2 mm sieve and analysed for physical and chemical properties as per the standard procedures. The results of such soil analysis are presented in (Table 2,3,4)

Experiment details

Crop	Tree mulberry
Variety	Victory-1
Spacing	10 x 10 feet
Design	RCBD
No. of treatment	10
No. of replications	3
RDF	350:140:140kg NPK $ha^{-1}y^{-1}$

RDF: Recommended dose of fertilizer

Treatment details

Treatments	Description
T_1	Absolute Control
T_2	100% NPK
T_3	FYM @ 20 t $ha^{-1}y^{-1}$
T_4	100% NPK + FYM@ 20 t ha^{-1} (Package of practice)
T_5	100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$
T_6	100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$
T_7	100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$
T_8	75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$
T_9	75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$
T_{10}	75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t $ha^{-1}y^{-1}$

Note

1. FYM and mulberry shoots biochar were applied as basal application on the day of pruning.
2. Split quantity of NPK fertilizers was applied 15 days after pruning.
3. All other practices of mulberry cultivation were followed as per standard package of practices (Dandin and Giridhar 2014) [9]

To study the effect of different levels of biochar and FYM on physical, chemical properties and nutrient release pattern in soil. Soil samples were analyzed for bulk density,MWHC, pH, EC, primary nutrients (nitrogen, phosphorus and potash), secondary nutrients (calcium, magnesium and sulphur) and micronutrient zinc, iron, manganese and copper by adopting standard procedures. Properties of biochar used in experiment were given in Table 1.

2.1 Statistical Analysis

The data collected from the experimental mulberry garden was analysed statistically by using one-way RCBD for testing of significance by Fisher's method of analysis of variance (Snedecor and Cochran, 1979) [23]. The level of significance used in F test was P=0.05 for RCBD. Critical difference (CD) values were computed where F test was found significant.

Table 1: Physical and chemical properties of biochar

Parameters	Value
Bulk density (Mg m^{-3})	0.34
MWHC (%)	95.05
pH (1:10)	8.37
EC (dS m^{-1}) (1:10)	0.47
Total Carbon (%)	72.18
Nitrogen (%)	0.83
Phosphorous (%)	0.35
Potassium (%)	0.98
Calcium (%)	0.68
Magnesium (%)	0.43
Sulphur (mg kg^{-1})	0.15
Iron (mg kg^{-1})	477.72
Manganese (mg kg^{-1})	98.02
Copper (mg kg^{-1})	29.09
Zinc (mg kg^{-1})	38.68

3. Results and Discussion

3.1 Effect of levels of biochar on soil physical properties under mulberry garden

Effect of mulberry shoots biochar, FYM and fertilizer on soil physico-chemical properties.The effect of different levels of mulberry shoots biochar on soil physical properties (bulk density and maximum water holding capacity) and chemical properties (pH, Electrical conductivity and Organic carbon) were analysed and recorded before and after the experiment (Table 2). Among the treatments, the combined application of mulberry shoots biochar, FYM and RDF has recorded lower bulk density (1.30 Mg m^{-3}), and higher maximum water holding capacity (49.34 %), over the rest of the treatments. This could be due to application of organic carbon in the form of FYM and mulberry shoots biochar. Biochar and FYM addition to soil decreased the bulk density of the soil and increased the total porosity and it increase available water content and water holding capacity of soil by enhancing soil porosity and aggregate formation in sandy or loamy soil. FYM and mulberry shoots biochar act as cementing materials in forming stable soil aggregates. It has been suggested that the porous structure of biochar can influence its impact on soil porosity, bulk density, water holding capacity and adsorption capacity. Moreover, biochar particles are known for having more porosity to retain water due to their spherical shape and deformability (Atkinson *et al.*, 2010 and Downie *et al.*, 2009) [3, 11].

3.2 Effect of levels of biochar on soil chemical properties and nutrient status at harvest of tree mulberry leaves

The results on the effect of levels of mulberry shoots biochar with FYM on chemical properties like pH, electrical conductivity (EC), soil primary, secondary and micronutrients after harvest of tree mulberry is presented in Tables 2 to 4.

3.2.1 Soil pH, Electrical Conductivity (EC) and Organic carbon(OC)

At harvest of tree mulberry, the treatments which received increased levels of mulberry shoots biochar with FYM and RDF combination increased the soil pH over absolute control and package of practice. However, significantly higher soil pH value of 6.87 were recorded in the treatment, T_7 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$) and which was on par with treatments except T_4 (6.28), T_3 (6.09), T_2 (6.04) and T_1 (5.94) treatments. The observed changes in pH of soil applied with mulberry shoots biochar could be ascribed to the release of alkaline compounds from biochar, which neutralized the soil acidity and thus increased the soil

Table 2: Effect of mulberry shoots biochar application on Bulk Density (Mg m^{-3}), Maximum Water Holding Capacity (%) pH, EC and Organic carbon content of soil after harvest of tree mulberry leaves

Treatments	Bulk Density (Mg m^{-3})	Maximum Water Holding Capacity (%)	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (%)
Initial	1.35	35.38	5.89	0.12	0.53
T_1: Absolute Control	1.35	36.97	5.94	0.13	0.54
T_2: 100% NPK	1.35	38.43	6.04	0.14	0.54
T_3: FYM @ 20 t $ha^{-1}y^{-1}$	1.34	43.84	6.09	0.13	0.55
T_4: 100% NPK + FYM@ 20 t ha^{-1} (Package of practice)	1.34	44.40	6.28	0.16	0.57
T_5: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$	1.33	45.79	6.62	0.20	0.58
T_6: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$	1.33	47.01	6.69	0.22	0.60
T_7: 100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$	1.30	49.34	6.87	0.23	0.62
T_8: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t $ha^{-1}y^{-1}$	1.33	46.13	6.34	0.18	0.57
T_9: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$	1.32	43.06	6.45	0.19	0.58
T_{10}: 75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t $ha^{-1}y^{-1}$	1.30	49.05	6.42	0.19	0.60
F- Test	NS	*	*	*	NS
S. Em ±	0.04	0.95	0.16	0.00	0.01
CD @ 5 %		2.85	0.48	0.01	

* - significant at 5%, NS- Non significant

pH to some extent. During pyrolysis, cations (primarily K, Ca, Si and Mg) present in the feedstock formed metal oxides and once applied to soil, these oxides can react with H^+ and monomeric Al species and thus alleviate soil pH. As mulberry shoots biochar contain significant quantity of Ca, it can replace the monomeric Al species from soil exchange complex in acidic soil. Accompanying this reaction, there could be increase in soil solution pH caused by the depletion of the readily hydrolysable monomeric Al and the formation of the more neutral $[Al(OH)_3]^0$ species (Novak *et al.*, 2009) [19]. The findings of present study is in line with several authors viz., Abewa *et al.* (2014) [1]; Chintala *et al.* (2014) [8]; Hass *et al.* (2012) [13]; and Arunkumar *et al.* (2020) [2] who recorded increase in soil pH by applying different kinds of biochar to soil. Application of wood bark biochar at 37 t ha-1 increased the pH by 1.0 to 1.5 units (Yamato *et al.*, 2006) [28].

Application of increased levels of mulberry shoots biochar, FYM and RDF combination increased the EC of soil after harvest of tree mulberry leaves over absolute control (T_1) (Table 2). the higher EC value of soil recorded to be 0.23 dS m^{-1} in the treatment which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$ (T_7) at harvesting stage and minimum value (0.13dS m^{-1}) of EC was in the absolute control treatment (T_1) at harvest of mulberry leaves. This may be due to the presence of salt content and exchangeable cations in the mulberry shoots biochar which can increase the EC of treated plots compared to untreated plot. attributed the increase in EC of soil due to application of biochar are generally dominated by carbonates of alkali, amounts of silica, phosphates, and small amounts of organic and inorganic N. Similar results were also reported by Raison (1979) [21]. Significant increase in EC with varied levels of biochar application was often reported in the literature by Chintala *et al.* (2014) [8] and Arunkumar *et al.* (2020) [2]. However, increase in organic carbon of soil was found to be non-significant at harvesting of tree mulberry. However, the higher organic carbon value of soil recorded to be 0.62 per cent in the treatment which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$(T_7) at harvest of tree mulberry leaves.

3.2.2 Available primary nutrients (NPK) status in soil

The results pertaining to the effect of levels of mulberry shoots biochar and FYM and RDF combination on available N, P and K status of soil after harvest of tree mulberry leaves were presented in Table 3. A significant increase and higher available nitrogen status in soil was noticed after harvest of tree mulberry leaves due to combined application of mulberry shoots biochar and FYM at different levels with RDF over the absolute control, T_1 (307.71 kg ha^{-1}). However, among the treatments, the treatment T_7 with100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t $ha^{-1}y^{-1}$recorded significantly higher available N (361.17 kg ha^{-1}) status followed by T_6 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t $ha^{-1}y^{-1}$) which registered 359.35 kg ha^{-1} in soil at. The available nitrogen status of soil increased with the increased levels of mulberry shoots biochar, FYM and NPK fertilizer applied in combination compared to package of practice and absolute control. This is might be due to the fact that addition of mulberry shoots biochar and FYM and NPK fertilizer in combination contributed available nitrogen to the soil due mineralization of FYM and biochar. The availability and rate of mineralization of organic N found in biochar application to soil provides an indication of the ability of biochar as a slow release N fertilizer (Chan and Xu, 2009 and Steiner *et al.*, 2008) [5, 24]. Biochar application can reduce nutrient leaching from soil with resulting increase in fertilizer use efficiency (Lehman *et al*., 2009 and Novak *et al.*, 2009 Arunkumar *et* *al.*, 2020) [11, 17, 19, 2]. Increased retention of N with biochar addition was also observed earlier (Novak *et al.*, 2009) [19].

A significant increase in available P_2O_5 status of soil was noticed after harvest of tree mulberry leaves due to the combined addition of increased levels of biochar and FYM with RDF over package of practice and absolute control treatments (Table 3). The treatment which received 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1} (T_7) resulted in significant increase in the available P_2O_5 (52.23 kg ha^{-1}) followed 100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}(T_6) which recorded 50.08 kg ha^{-1} of available P_2O_5 in soil compared to all other treatments. However, the lowest available P_2O_5 content of 35.85 kg ha^{-1} was recorded in absolute control (T1) at harvest of tree mulberry. The phosphorous status in soil increased with the increased levels of mulberry shoots biochar at harvest of tree mulberry leaves. This may be due to the high concentrations of available P found in the biochar. Van Zwieten *et al.* (2010) [25], Chan *et al.* (2008) [6] and Arunkumar *et al.* (2020) [2] also reported the increase in available phosphorus in soil after the application of biochar. The possible mechanism for increased P_2O_5 availability with biochar application in soil can be attributed to presence of soluble and exchangeable phosphate in biochar, modifier of soil pH and ameliorator of P complexing metals (Al^{3+}, Fe^{3+}), promoter of microbial activity and hastening P mineralization. Such increase in available P_2O_5 content with biochar addition was also reported by Parvage *et al.* (2013) [20] and Hass *et al.* (2012) [13]. Increase in soil pH may also reduce Al and Fe activity which could also contribute to higher soil P availability.

Like available nitrogen status, the available K_2O status in soil significantly increased in all the treatments due to the combined addition of levels of biochar and FYM and NPK fertilizer after harvest of tree mulberry leaves over absolute control (T_1) and package of practice (T_4) (Table 3). Further, at given levels of FYM, with increased levels of biochar application, a significant increase in available K status in soil was observed over individual application FYM and RDF. However, maximum to the extent of 299.39 kg ha^{-1} available K content in soil was noticed in treatment T_7 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}) followed by T_6 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}) which registered 295.04 kg ha^{-1} available K at harvest stage. The lowest available K of 270.91 kg ha^{-1} was noticed in absolute control at harvest stage of tree mulberry leaves. The increased levels of mulberry shoots biochar increased the potassium status in soil after harvest of tree mulberry leaves which may be due to the high concentration of K found in the biochar (Chan *et al.*, 2007) [7]. The biochar contained high ash and itself has more amount of potassium content compared to other major nutrients, so by the application of ash rich biochar to soils increased the potassium content significantly. Increased K availability by biochar application has also been reported by (Major *et al.*, 2010) [18] which might be from the considerable amounts of K that were added along with the biochar from which it is readily leached.

Table 3: Effect of mulberry shoots biochar on primary and secondary nutrients content of soil after the harvest of tree mulberry leaves

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Calcium [c mol (p$^+$) kg^{-1}]	Magnesium [c mol (p$^+$) kg^{-1}]	Sulphur (mg kg^{-1})
Initial	306.20	35.49	269.01	2.52	1.13	11.42
T_1: Absolute Control	307.71	35.85	270.91	2.99	1.44	12.21
T_2: 100% NPK	340.01	36.54	272.83	3.21	1.49	12.78
T_3: FYM @ 20 t ha^{-1}y^{-1}	340.42	37.27	274.18	3.29	1.67	12.89
T_4: 100% NPK + FYM@ 20 t ha^{-1} (Package of practice)	345.81	39.18	277.58	3.43	1.73	13.59
T_5: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	356.32	47.88	288.35	4.05	2.27	14.68
T_6: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	359.35	50.08	295.04	4.38	2.37	14.99
T_7: 100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}	361.17	52.23	299.39	4.53	2.49	15.89
T_8: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	348.14	40.62	279.75	3.56	1.95	13.52
T_9: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	351.49	45.07	283.28	3.67	2.07	13.82
T_{10}: 75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t ha^{-1}y^{-1}	353.37	47.65	286.27	3.82	2.11	14.21
F- Test	*	*	*	*	*	*
S. Em ±	6.38	1.04	5.09	0.06	0.03	0.33
CD @ 5 %	18.96	3.09	15.14	0.20	0.11	0.98

* - significant at 5%

3.2.3 Secondary nutrient (Ca, Mg and S) status in soil

The results obtained in relation to the effect of levels of mulberry shoots biochar, FYM and RDF combination on exchangeable and available secondary nutrients status in soil after harvest of tree mulberry leaves are presented in Table 3. Exchangeable bases such as Ca and Mg content in soil varied significantly with application of varied levels of mulberry shoots biochar at harvest stage due its high cation exchange capacity. The increased levels of biochar increased the calcium and magnesium content in harvested stage which may be due to the higher concentration of Ca, Mg and exchangeable bases in biochar. This might be due to high porosity and surface/volume ratio and can improved Ca and Mg availability (Laird *et al.*, 2010) [15]. Increase in exchangeable bases in soil at different intervals can be attributed to release of basic cations from mulberry shoots biochar. During pyrolysis, biomass acids are converted into bio- oil and alkalinity is inherited by solid biochar Chan *et al.* (2008) [6]. Most of the Ca, Mg, K, P, and plant micronutrients in feedstock are partitioned into the biochar ash fraction during pyrolysis. Ash in biochar rapidly releases free bases such as Ca, Mg and K to the soil solution thereby not only increases soil pH but also exchangeable bases. Such observations were also noticed by Lehmann *et al.* (2003) [16] and Chan *et al.* (2008) [6].

With regard to available S status in soil, with increased in levels of mulberry shoots biochar with FYM and RDF available S status in soil increased significantly after harvest of tree mulberry leaves over absolute control and package of practice (Table 3). highest value of available S (15.89 mg kg^{-1}) in soil recorded by treatment, T_7 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}) followed by T_6 (100 per cent NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}) which recorded 14.99 mg kg^{-1}. Lowest available S 12.21 kg ha^{-1} was noticed in T_1 treatment. Sulphur content in soil varied significantly with application of different levels of mulberry shoots biochar after harvest of tree mulberry leaves. This may be due the contribution of available sulphur to soil after the mineralization of organic sulphur in biochar and also due to addition of zinc sulphate and application of FYM. The results suggest that biochar also improves the bioavailability of sulphur; which mainly depends on mineralization of organic forms of sulphur to cycle through soils (Deluca *et al.*, 2015) [10].

3.2.4 DTPA extractable micronutrients status in soil

The data pertaining to the DTPA extractable micronutrients like iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) status in soil after harvest of tree mulberry leaves as influenced by mulberry shoots biochar are presented in Table 4. It was noticed that micronutrient status of soil increased with increased levels of biochar, FYM and RDF combination over absolute control and package of practice treatments. Higher status of micronutrient status in soil was recorded after harvest of tree mulberry leaves. There lease of micronutrients during decomposition of organic manures. Increase in the content of micronutrients at harvest of crop might be due to higher availability of the plant nutrients from the soil nutrient reservoir and additional quantity of nutrients supplied through farm yard manure (Sharma and Dixit, 1987). The significant increase in copper content of soil by application of biochar at harvest could be due to increase the soluble organic carbon; thereby resulting in the mobilization of Cu. Cu is strongly chelated by organic carbon and is less subjected to adsorption process. Beesley and Marmiroli (2011) [4] also reported dependence of Cu content on soluble C and pH. The variation in micronutrient content in soil with the application of mulberry shoots biochar can be attributed to its physical and chemical properties. Biochar by virtue of its high surface area, high metal affinity, higher nutrient retention capacity, presence of acidic and basic functional groups and ability to alkalize soil might result in immobilization and precipitation of micronutrients in soil. Such of these mechanisms of metal immobilization due to biochar application were also reported by Novak *et al.* (2009) [19] and Vithanage *et al.* (2014) [26]

Table 4: Effect of mulberry shoots biochar application on micronutrients (Fe, Zn, Mn and Cu) (mg kg^{-1}) in soil after the harvest of tree mulberry leaves

Treatments	Iron (mg kg^{-1})	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})	Copper (mg kg^{-1})
Initial	10.13	0.37	5.04	0.59
T_1: Absolute Control	10.42	0.41	5.22	0.68
T_2: 100% NPK	10.71	0.45	5.62	0.72
T_3: FYM @ 20 t ha^{-1}y^{-1}	11.14	0.48	5.68	0.76
T_4: 100% NPK + FYM@ 20 t ha^{-1} (Package of practice)	11.44	0.50	5.74	0.80
T_5: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	12.02	0.54	5.97	0.87
T_6: 100% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	12.32	0.55	6.08	0.89
T_7: 100%NPK+ FYM@ 10 t ha^{-1} + Biochar @ 15 t ha^{-1}y^{-1}	12.50	0.58	6.42	0.90
T_8: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 5 t ha^{-1}y^{-1}	11.26	0.50	5.47	0.82
T_9: 75% NPK+ FYM@ 10 t ha^{-1} + Biochar @ 10 t ha^{-1}y^{-1}	11.62	0.52	5.66	0.83
T_{10}: 75% NPK+ FYM@ 10 t ha^{-1} +Biochar @ 15 t ha^{-1}y^{-1}	11.93	0.53	5.92	0.85
F- Test	*	*	*	*
S. Em ±	0.33	0.01	0.18	0.02
CD @ 5 %	1.00	0.05	0.53	0.08

* - significant at 5%

Overall, soil nutrients availability was increased in the treatments received mulberry shoots biochar, FYM and RDF combination as compared to package of practice and absolute control. The availability of nutrients in the biochar added soil may be related to the large surface area of biochar material providing adsorption sites. Moreover, the increase in the water. Holding capacity of biochar added soils may improve nutrient retention in the topsoil. Attachment of organic matter or minerals with sorbed nutrients (aggregation) to biochar may further increase nutrient retention. Several studies demonstrated that processing temperatures

4. Conclusion

Mulberry shoots biochar was found to be a rich source of carbon (72.18 %) and nutrients (N, K, Ca, Mg) with alkaline pH, medium EC, lower bulk density and higher maximum water holding capacity which helps in enhanced the soil properties. From the field investigation the combined application of biochar and FYM with RDF, resulted the most favourable physical and chemical properties of soil compared to package of practice. Since, FYM is a good source of microorganisms and hastens the better mineralization rate and increased the efficiency of biochar in soil. Based on the findings in this study, chemical fertilizer application to soils could be associated with biochar and FYM, through which multi-benefits (e.g., soil amendment, nutrient sources, environment protection, C sequestration) could be obtained simultaneously.

5. References

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